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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | | | added to the bracketed list based on NUREG-1368, Table 3.3 (page 3-22) recommendation. The "effects of coolant chemistry" noted in NUREG-1368, Table 3.3 (page 3-22) are considered to be covered by the revised SFR-DC. Service degradation, creep, fatigue, and stress rupture can be a particular concern for sodium reactors and fast neutron fluence. |
| 32 | *Inspection of reactor* ***[coolant pressure]*** *boundary.*<br>Components which are part of the reactor **[coolant pressure]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of reactor* ***[primary coolant ~~pressure~~]*** *boundary.*<br>Components which are part of the reactor **[primary coolant ~~pressure~~]** boundary shall be designed to permit (1) periodic inspection and 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" is relabeled within the brackets as "reactor primary coolant boundary" to reflect that the SFR reactor primary system operates at low-pressure. Thus, the coolant boundary design requirements differ from the traditional LWR coolant pressure boundary requirements. The effects of low pressure design are acknowledged in NUREG-1368 (page 3-28) (ML063410561) under discussion of GDC 4 and on (page 3-30) under GDC 14. The use of the term "primary" implies the GDC is applicable to the primary cooling system, not the intermediate cooling system. (See Section 6.3.1 of this report for a description of the SFR cooling systems.)<br><br>Section 3.2.4.5 of NUREG-1368, (page 3-57) discussed the need for an additional GDC focused on the intermediate cooling system design requirements. The design requirements related to the intermediate loop are addressed in new SFR-DC 70. |
| 33 | *Reactor* ***[coolant]*** *inventory maintenance.*<br>A system to maintain reactor **[coolant]** inventory for protection against small breaks in the reactor **[coolant pressure]** boundary shall be provided as necessary to assure that specified acceptable fuel design limits are not exceeded as a result of reactor **[coolant]** inventory loss due to leakage from the reactor **[coolant pressure]** boundary and rupture of small piping or other small components which are part of the boundary. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor* ***[primary coolant]*** *inventory maintenance.*<br>A system to maintain reactor **[coolant]** inventory for protection against small breaks in the reactor **[primary coolant ~~pressure~~]** boundary shall be provided as necessary to assure that specified acceptable fuel design limits are not exceeded as a result of reactor **[primary coolant]** inventory loss due to leakage from the reactor **[primary coolant ~~pressure~~]** boundary and | "Reactor coolant pressure boundary" is relabeled within the brackets as "reactor primary coolant boundary" to reflect that the SFR reactor primary system operates at low-pressure. Thus, the coolant boundary design requirements differ from the traditional LWR coolant pressure boundary requirements. The effects of low pressure design are acknowledged in NUREG-1368 (page 3-28) (ML063410561) under discussion of GDC 4 and on (page 3-30) under GDC 14. The use of |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | | rupture of small piping or other small components which are part of the boundary. | the term "primary" implies the GDC is applicable to the primary cooling system, not the intermediate cooling system. (See Section 6.3.1 of this report for a description of the SFR cooling systems.)<br><br>Section 3.2.4.5 of NUREG-1368, (page 3-57) discussed the need for an additional GDC focused on the intermediate cooling system design requirements. The design requirements related to the intermediate loop are addressed in new SFR-DC 70.<br><br>Both pool- and loop-type SFR designs limit loss of primary coolant so that an inventory adequate to perform the safety function of the residual heat removal system is maintained under operating, maintenance, testing, and postulated accident conditions. |
| 34 | *Residual heat removal.*<br>A system to remove residual heat shall be provided. 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 fuel design limits and the design conditions of the reactor **[coolant pressure]** boundary are not exceeded under all plant shutdown conditions following normal operation, including anticipated operational occurrences, and to provide continuous effective core cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | ARDC with additional SFR-specific clarification provided:<br><br>*Residual heat removal.*<br>A system to remove residual heat shall be provided. 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 fuel design limits and the design conditions of the reactor **[primary coolant ~~pressure~~]** boundary are not exceeded under all plant shutdown conditions following normal operation, including anticipated operational occurrences, and to provide continuous effective core cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | "Reactor coolant pressure boundary" is relabeled within the brackets as "reactor primary coolant boundary" to reflect that the SFR reactor primary system operates at low-pressure. Thus, the coolant boundary design requirements differ from the traditional LWR coolant pressure boundary requirements. The effects of low pressure design are acknowledged in NUREG-1368 (page 3-28) (ML063410561) under discussion of GDC 4 and on (page 3-30) under GDC 14. The use of the term "primary" implies the GDC is applicable to the primary cooling system, not the intermediate cooling system. (See Section 6.3.1 of this report for a description of the SFR cooling systems.)<br><br>Section 3.2.4.5 of NUREG-1368, (page 3-57) discussed the need for an additional GDC focused on the intermediate cooling system design requirements. The design requirements related to the intermediate loop are addressed in new SFR-DC 70. |

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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | | | The SFR designs reviewed satisfied NRC staff concerns in NUREG-1368 (page 3-41) regarding residual heat removal system heat transfer fluid compatibility and pressure differential with the primary coolant for designs where they are separated by a single passive barrier. |
| 35 | Advanced Reactor Design Criterion for core cooling under accident conditions is contained in ARDC-34. | ARDC with no further SFR-specific clarification provided. | |
| 36 | *Inspection of residual heat removal system.*<br>The residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[spray rings in the reactor pressure vessel, water injection nozzles, and piping]**, to assure the integrity and capability of the system. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of residual heat removal system.*<br>The residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[~~spray rings in the reactor pressure vessel, water injection nozzles,~~heat exchangers and piping]**, to assure the integrity and capability of the system. | The examples are LWR specific and are replaced with more design-specific examples |
| 37 | *Testing of residual heat removal system.*<br>The residual heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural 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. | ARDC with no further SFR-specific clarification provided. | |
| 38 | *Containment heat removal.*<br>A system to remove heat from the reactor containment shall be provided as necessary to maintain the containment pressure and temperature within acceptable limits following postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, | ARDC with no further SFR-specific clarification provided. | |

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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | isolation, and containment capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | | |
| 39 | *Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[the torus, sumps, spray nozzles, and piping]** to assure the integrity and capability of the system. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[~~the torus, sumps, spray nozzles, and~~ piping]** to assure the integrity and capability of the system. | The LWR-specific examples are removed. |
| 40 | *Testing of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural 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 operation of associated systems. | ARDC with no further SFR-specific clarification provided. | |
| 41 | *Containment atmosphere cleanup.*<br>Systems to control fission products, **[hydrogen, oxygen,]** and other substances which 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 **[hydrogen or oxygen]** and other substances in the containment atmosphere following postulated accidents to assure 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 assure that its safety function can be accomplished, assuming a single | ARDC with additional SFR-specific clarification provided:<br><br>*Containment atmosphere cleanup.*<br>Systems to control fission products, **[~~hydrogen, oxygen~~reaction products,]** and other substances which 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 **[~~hydrogen or oxygen~~reaction products]** and other substances in the containment atmosphere following postulated accidents to assure that containment integrity is maintained.<br><br>Each system shall have suitable redundancy in components and features, and suitable | The examples are LWR specific and are replaced with more design-specific examples. Means to detect sodium leakage and to limit and control the extent of sodium reactions are addressed in new SFR-DC 73 |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | failure. | interconnections, leak detection, isolation, and containment capabilities to assure that its safety function can be accomplished, assuming a single failure. | |
| 42 | *Inspection of containment atmosphere cleanup systems.* The containment atmosphere cleanup systems shall be designed to permit appropriate periodic inspection of important components, such as filter frames, ducts, and piping to assure the integrity and capability of the systems. | ARDC with no further SFR-specific clarification provided. | |
| 43 | *Testing of containment atmosphere cleanup systems.* The containment atmosphere cleanup systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural integrity of its 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 sequence that brings the systems into operation, including the operation of associated systems. | ARDC with no further SFR-specific clarification provided. | |
| 44 | *Structural and equipment cooling.* In addition to the heat rejection capability of the 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 assure that each system safety function can be accomplished, assuming a single failure. | ARDC with no further SFR-specific clarification provided. | |
| 45 | *Inspection of structural and equipment cooling systems.* The structural and equipment cooling systems shall be designed to permit appropriate periodic | ARDC with no further SFR-specific clarification provided. | |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | inspection of important components, such as heat exchangers and piping, to assure the integrity and capability of the systems. | | |
| 46 | *Testing of structural and equipment cooling systems.*<br>The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural 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. | ARDC with no further SFR-specific clarification provided. | |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| 50 | *Containment design basis.*<br>The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as **[energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning]**, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | ARDC with additional SFR-specific clarification provided:<br><br>*Containment design basis.*<br>The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as **[fission products, potential spray or aerosol formation, and potential exothermic chemical reaction~~energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning~~]**, (2) the limited experience and | All SFR designs that were reviewed employed a containment structure.<br><br>In NUREG-1368, Table 3.3 (page 3-24) (ML063410561), NRC staff recommended replacing reference to LOCA with "postulated accident." NRC staff further recommended (NUREG-1368, page 3-50) removing the reference to 10 CFR 50.44 regarding containment combustible gas control in BWRs and PWRs. These changes are proposed as part of ARDC~~-~~ 50. In NUREG-1368 (page 3-50), the NRC staff also recommended replacing metal-water and other chemical reactions from a degraded ECCS with "fission products, potential spray or aerosol formation, and potential exothermic chemical reactions" at the end of Item 1 of GDC 50. Therefore, the contents of the brackets in ARDC 50 were replaced. |

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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | | experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | |
| 51 | *Fracture prevention of containment pressure boundary.* The boundary of the reactor containment structure shall be designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | ARDC with additional SFR-specific clarification provided:<br><br>*Fracture prevention of containment ~~pressure~~ boundary.* The boundary of the reactor containment structure shall be designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | SFR containment is a boundary/barrier to release of radioactivity and not a pressure boundary. Deleting the word "pressure" in the SFR-DC title provides clarity as applied to the SFR designs reviewed. |
| 52 | *Capability for containment leakage rate testing.* The reactor containment structure and other equipment which may be subjected to containment test conditions shall be designed so that periodic integrated leakage rate testing can be conducted at containment design pressure. | ARDC with no further SFR-specific clarification provided. | |
| 53 | *Provisions for containment testing and inspection.* The reactor containment structure shall be designed to permit (1) appropriate periodic inspection of all important areas, such as penetrations, (2) an appropriate surveillance program, and (3) periodic testing at containment design pressure of the leaktightness of penetrations which have resilient seals and expansion bellows. | ARDC with no further SFR-specific clarification provided. | |
| 54 | *Piping systems penetrating containment.* Piping systems penetrating the primary reactor containment structure shall be provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems. Such piping | ARDC with additional SFR-specific clarification provided:<br><br>*Piping systems penetrating containment.* Piping systems penetrating the primary reactor containment structure shall be provided with leak detection, isolation, and containment capabilities | Not all penetrations will provide a release path to the atmosphere. Piping that may be of interest in the case of an SFR design is for the intermediate heat transport system (IHTS) and the passive residual heat removal system. Based on stakeholder input, a designer may be able to satisfactorily demonstrate that |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | having redundancy, reliability, and performance capabilities necessary to perform the containment safety function and which reflect the importance to safety of preventing radioactivity releases from containment through ~~isolating~~ these piping systems. When isolation valves are required, ~~Such~~ piping systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | containment isolation valves are not required for an SFR design. This rewording for the SFR-DC provides a designer the opportunity to present the safety case without containment isolation valves and associated need for testing. Otherwise, NUREG-1368 (ML063410561) (page 3-51) indicated that GDC 54 was applicable as written.<br><br>ANSI/ANS-54.1-1989 recommended revising the phrase "…containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems." to "…containment capabilities as required to perform the containment safety function." |
| 55 | *Reactor **[coolant pressure]** boundary penetrating containment.*<br>Each line that is part of the reactor **[coolant pressure]** boundary and that penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor **[primary coolant ~~pressure~~]** boundary penetrating containment.*<br>Each line that is part of the reactor **[primary coolant ~~pressure~~]** boundary and that penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment. | "Reactor coolant pressure boundary" is relabeled within the brackets as "reactor primary coolant boundary" to reflect that the SFR reactor primary system operates at low-pressure. Thus, the coolant boundary design requirements differ from the traditional LWR coolant pressure boundary requirements. The effects of low pressure design are acknowledged in NUREG-1368 (page 3-28) (ML063410561) under discussion of GDC 4 and on (page 3-30) under GDC 14. The use of the term "primary" implies the GDC is applicable to the primary cooling system, not the intermediate cooling system. (See Section 6.3.1 of this report for a description of the SFR cooling systems.)<br><br>Section 3.2.4.5 of NUREG-1368, (page 3-57) discussed the need for an additional GDC focused on the intermediate cooling system design requirements. The design requirements related to the intermediate loop are addressed in new SFR-DC 70.<br><br>The cover gas boundary is included as part of the reactor primary coolant boundary (referred |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | to as RCPB by PRISM) per NUREG-1368 (page 3-38). |
| 56 | *Primary containment isolation.*<br>Each line that connects directly to the containment atmosphere and penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the | ARDC with no further SFR-specific clarification provided. | |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety. | | |
| 57 | *Closed system isolation valves.*<br>Each line that penetrates the primary reactor containment structure and is neither part of the reactor **[coolant pressure]** boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | ARDC with additional SFR-specific clarification provided:<br><br>*Closed system isolation valves.*<br>Each line that penetrates the primary reactor containment structure and is neither part of the reactor **[primary coolant ~~pressure~~]** boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve unless it can be demonstrated that the containment safety function can be met without an isolation valve and assuming failure of a single active component. The isolation valve, if ~~which shall~~required, shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | "Reactor coolant pressure boundary" is relabeled within the brackets as "reactor primary coolant boundary" to reflect that the SFR reactor primary system operates at low-pressure. Thus, the coolant boundary design requirements differ from the traditional LWR coolant pressure boundary requirements. The effects of low pressure design are acknowledged in NUREG-1368 (page 3-28) (ML063410561) under discussion of GDC 4 and on (page 3-30) under GDC 14. The use of the term "primary" implies the GDC is applicable to the primary cooling system, not the intermediate cooling system. (See Section 6.3.1 of this report for a description of the SFR cooling systems.)<br><br>Section 3.2.4.5 of NUREG-1368, (page 3-57) discussed the need for an additional GDC focused on the intermediate cooling system design requirements. The design requirements related to the intermediate loop are addressed in new SFR-DC 70.<br><br>Not all penetrations will provide a release path to the atmosphere. Piping that may be of interest in the case of an SFR design is for the intermediate heat transport system (IHTS) and the residual heat removal system. A designer may be able to satisfactorily demonstrate that containment isolation valves are not required for an SFR design. This rewording for the SFR-DC provides a designer the opportunity to present the safety case without containment isolation valves. |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| | | | 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). |

| VI. Fuel and Radioactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| 60 | *Control of releases of radioactive materials to the environment.*<br>The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment. | ARDC with no further SFR-specific clarification provided. | |
| 61 | *Fuel storage and handling and radioactivity control.*<br>The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure 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 components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, 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 (5) to prevent significant reduction in fuel storage cooling under accident conditions. | ARDC with no further SFR-specific clarification provided. | |

| VI. Fuel and Radioactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| 62 | *Prevention of criticality in fuel storage and handling.*<br>Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations. | ARDC with no further SFR-specific clarification provided. | |
| 63 | *Monitoring fuel and waste storage.*<br>Appropriate systems shall be provided in fuel storage and radioactive waste systems and associated handling areas (1) to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and (2) to initiate appropriate safety actions. | ARDC with no further SFR-specific clarification provided. | |
| 64 | *Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the **[reactor containment]** atmosphere, **[spaces containing components for recirculation of loss-of-coolant accident fluids,]** effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | ARDC with additional SFR-specific clarification provided:<br><br>*Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the **[reactor containment]** atmosphere, **[spaces containing components for ~~recirculation of loss-of-coolant accident fluids~~ primary system sodium and cover gas cleanup and processing,]** effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | The phrase "**reactor containment**" in the first set of brackets in ARDC 64 is retained.<br><br>In NUREG-1368, Table 3.3 (page 3-25) (ML063410561) NRC staff recommended deleting the GDC-64 phrase "spaces containing components for recirculation of loss-of-coolant accident fluids." Otherwise, the NRC staff noted that criterion requirements are independent of the design of SFRs (page 3-55).<br><br>However, rather than delete the second bracketed phrase from ARDC 64, "**spaces containing components for recirculation of loss-of-coolant accident fluids,**" the bracketed text was modified to identify other SFR plant areas that should also be included to maintain consideration of all potential discharge paths and areas subject to monitoring. Therefore, primary system sodium and cover gas cleanup systems that may be outside containment and effluent processing systems are considered in place of the current text in the second set of brackets in ARDC 64. |

| VII. Additional SFR-DC | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| 70 | N/A | *Intermediate coolant systems.*<br>If an intermediate coolant system is provided, the intermediate coolant shall be compatible with sodium if it is separated from the reactor primary coolant by a single passive barrier. Where a single barrier separates the reactor primary coolant from the intermediate coolant, a pressure differential shall be maintained such that any leakage would flow from the intermediate coolant system to the reactor primary coolant system unless other provisions can be shown to be acceptable. The intermediate coolant boundary shall be designed to permit inspection and surveillance in areas where leakage can affect the safety functions of systems, structures and components. | NUREG-1368 (page 3-57) (ML063410561) Section 3.2.4.5 suggested the need for a separate criterion for the intermediate coolant system. Also separate criteria were included in NUREG-0968 (ML082381008) (Criterion 31–Design of Intermediate Cooling System and Criterion 33–Inspection of Intermediate Cooling System). |
| 71 | N/A | *Reactor coolant & cover gas purity control.*<br>Systems shall be provided as necessary to maintain primary coolant purity and cover gas purity within specified design limits. These limits shall be based on consideration of (1) chemical attack, (2) fouling and plugging of passages, and (3) radioisotope concentrations. | NUREG-1368 (page 3-57) (ML063410561) Section 3.2.4.6 suggested the need for a separate criterion for sodium and cover gas purity control. Also a separate criterion was included in NUREG-0968 (ML082381008) (Criterion 34–Reactor and intermediate coolant and cover gas purity control). |
| 72 | N/A | *Sodium heating systems.*<br>Heating systems shall be provided as necessary for systems and components important to safety, which contain or could be required to contain sodium. These heating systems and their controls shall be appropriately designed to assure that the temperature distribution and rate of change of temperature in systems and components containing sodium are maintained within design limits assuming a single failure. | NUREG-1368 (page 3-56) (ML063410561) Section 3.2.4.2 suggested the need for a separate criterion for sodium heating system. Also, a separate criterion was included in NUREG-0968 (ML082381008) (Criterion–7 Sodium Heating Systems). |
| 73 | N/A | *Sodium leakage detection and reaction prevention and mitigation.*<br>Means to detect sodium leakage and to limit and control the extent of sodium-air and sodium-concrete reactions shall be provided as necessary to assure that the safety functions of structures, systems and components important to safety are maintained. Special features such as inerted enclosures or guard vessels shall be provided as appropriate for systems containing reactor primary sodium coolant. | NUREG-1368 (page 3-56) (ML063410561) Section 3.2.4.1 suggested the need for a separate criterion for protection against sodium reactions. Also, a separate criterion was included in NUREG-0968 (ML082381008) (Criterion–4 Protection against Sodium and NaK reactions). |

| VII. Additional SFR-DC | | | |
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| Criterion | Proposed ARDC Language | Proposed SFR-DC Language | Rationale for Modification |
| 74 | N/A | *Sodium/water reaction prevention/mitigation.* Structures, systems, and components important to safety containing sodium shall be designed and located to limit the consequences of chemical reactions between sodium and water on the safety functions of any systems, structures, and components. Means shall be provided as appropriate to limit possible contacts between sodium and water.<br><br>If necessary to prevent loss of any plant safety function, the sodium-steam generator system shall be designed to detect and contain sodium-water reactions and limit the effects of the energy and reaction products released by such reactions. | NUREG-1368 (page 3-56) (ML063410561) Section 3.2.4.1 suggested the need for a separate criterion for protection against sodium reactions. Also, a separate criterion was included in NUREG-0968 (ML082381008) (Criterion–4 Protection against Sodium and NaK reactions). |

## 9.3 Proposed Modular High Temperature Gas-Cooled Reactor Design Criteria

| I. Overall Requirements | | | |
|---|---|---|---|
| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 1 | *Quality standards and records.*<br>Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit. | ARDC with no further modular HTGR-specific clarification provided. | |
| 2 | *Design bases for protection against natural phenomena.*<br>Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and | ARDC with no further modular HTGR-specific clarification provided. | |

| I. Overall Requirements | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | (3) the importance of the safety functions to be performed. | | |
| 3 | *Fire protection.*<br>Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit**[, particularly in locations such as the containment and control room]**. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Fire protection.*<br>Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, **[particularly in locations ~~such as the containment~~with safety related equipment and the control room]**. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. | This criterion establishes functional requirements that provide assurance that SSCs important to safety can perform their safety functions during fire events. It can be applied to modular HTGRs with minor modification.<br><br>Revisions address the reference to containment. The reactor building utilized by the modular HTGR design does not have the same functions as an LWR containment structure. In place of reference to the containment, reference is made instead to locations with safety related equipment. |
| 4 | *Environmental and dynamic effects design bases.*<br>Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low | ARDC with no further modular HTGR-specific clarification provided. | |

| I. Overall Requirements | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | under conditions consistent with the design basis for the piping. | | |
| 5 | *Sharing of structures, systems, and components.* Structures, systems, and components important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Sharing of structures, systems, and components.* Structures, systems, and components important to safety shall not be shared among reactor modules or reactor module groups ~~nuclear power units~~ unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one reactor module or reactor module group~~unit~~, an orderly shutdown and cooldown of the remaining reactor modules or reactor module groups~~units~~. | This criterion establishes functional requirements that provide assurance that SSCs can perform their safety functions independent of any other nuclear power units they may service.<br><br>It is expected that modular HTGR designs will include multi-module plant configurations that will need to consider these requirements. The criterion can be applied to modular HTGRs with minor modification. The language used is specific to the modular HTGR design to capture the importance of not sharing SSCs among modules or among module groups if the sharing could lead to a loss of safety function at one of the other shared modules/groups. |

| II. Multiple Barriers | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 10 | *Reactor design.* The reactor core and associated **[coolant]**, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor design.* The reactor ~~core~~ system and associated **[~~coolant~~heat removal]**, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable ~~fuel~~ core radionuclide release design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. | It is the entire reactor system, which includes the core and other components, and the other systems listed that assure that limits are not exceeded.<br><br>The revised criterion recognizes that the role of the helium in modular HTGR safety is different from that of a traditional "reactor core coolant" and that residual heat removal is not dependent on forced helium circulation. The core design ensures a passive residual heat removal capability (INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug. 2011, ML11251A169, pg. 17).<br><br>NGNP determined that an alternative to the LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on |

## II. Multiple Barriers

| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
|---|---|---|---|
| | | | 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific. |
| 11 | *Reactor inherent protection.*<br>The reactor core and associated systems that contribute to reactivity feedback shall be designed so that in the power operating range the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity. | ARDC with no further modular HTGR-specific clarification provided. | |
| 12 | *Suppression of reactor power oscillations.*<br>The reactor core and associated **[coolant]**, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Suppression of reactor power oscillations.*<br>The reactor core and associated ~~**[coolant]**, ~~control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable ~~fuel~~ core radionuclide release design limits are not possible or can be reliably and readily detected and suppressed. | This criterion is applicable to the modular HTGR core and associated systems but the primary circuit uses helium, which does not influence power oscillations due to its neutronic transparency (INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug. 2011, ML11251A169, pg. 8). Reference to "coolant" is not germane to this modular HTGR criterion.<br><br>NGNP determined that an alternative to the LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific. |
| 13 | *Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, **[the reactor coolant pressure boundary, and the containment and its associated systems]**. Appropriate controls | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process and~~,~~ the integrity of the ~~reactor core, **[the reactor coolant**~~ | Modified the criterion to reflect use of the modular HTGR functional containment, which is summarized in a set of slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting summary (ML12219A205). NRC staff feedback on functional containment is documented in "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1- ML14174A774, section 3, and enclosure 2 - ML14174A845, section 3.11). |

| II. Multiple Barriers | | | |
|---|---|---|---|
| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | shall be provided to maintain these variables and systems within prescribed operating ranges. | ~~**pressure boundary, and the containment and its associated systems]**~~functional containment. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges. | |
| 14 | *Reactor **[coolant pressure]** boundary.*<br>The reactor **[coolant pressure]** boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor **[~~coolant~~helium pressure]** boundary.*<br>The reactor **[~~coolant~~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,~~ and~~ of gross rupture, and of unacceptable ingress of air, secondary coolant, or other fluids. | The reactor HPB role and function are described in Sec 5.4 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug. 2011, ML11251A169. The reactor helium pressure boundary is one of the multiple functional containment radionuclide release barriers in a configuration summarized in a set of slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting summary (ML12219A205). According to working definitions developed by NGNP, the reactor HPB contains (but is not synonymous with) the primary circuit and should not be defined purely in terms of "helium wetted surfaces."<br><br>Criterion 14 focuses on reactor HPB design against substantial failure while Criterion 15 emphasizes not exceeding reactor HPB design margins during normal operation, including AOOs. Criterion 14 was revised to recognize that the reactor HPB must be constructed to resist rupture, which would trigger associated radionuclide release mechanisms, and to inhibit ingress of air, secondary coolant, and other contaminant fluids, which could in turn, oxidize the graphite core (INL/EXT-10-17997, "NGNP Mechanistic Source Terms White Paper, July 2010, ML102040260). |
| 15 | *Reactor **[coolant]** system design.*<br>The reactor **[coolant]** system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor **[coolant pressure]** boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor **[~~coolant~~helium pressure boundary]** ~~system~~ design.*<br>The reactor ~~**[coolant]**~~ system, vessel system, heat removal systems, and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of | The reactor HPB role and function are described in Sec 5.4 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug. 2011, ML11251A169. The reactor helium pressure boundary is one of the multiple functional containment radionuclide release barriers in a configuration summarized in a set of slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting |

| II. Multiple Barriers | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | | the reactor [~~coolant~~**helium pressure]** boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. | summary (ML12219A205). NRC staff acknowledged the role played by the HPB in functional containment decisions in ML14174A845, Section 3.12.4. According to working definitions developed by NGNP, the reactor HPB contains (but is not synonymous with) the primary circuit and should not be defined purely in terms such as of "helium wetted surfaces."<br><br>Criterion 15 focuses on not exceeding reactor HPB design margins during normal operations, including AOOs. Criterion 15 was modified to note that the reactor system, vessel system, and heat removal systems are the systems that are designed with margins to ensure that the reactor HPB integrity is maintained rather than the "reactor coolant system". |
| 16 | *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 effectively 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. | ARDC with no further modular HTGR-specific clarification provided. | |
| 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 assure that (1) specified acceptable fuel design limits and design conditions of the reactor **[coolant 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. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Electric power systems.*<br>~~Electric~~ Onsite 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 assure that (1) specified acceptable ~~fuel~~ core radionuclide release design limits and design conditions of the reactor **[~~coolant~~ helium pressure]** boundary are not exceeded as a result of anticipated operational | The criterion was revised to align electric power systems with the modular HTGR safety design approach. Inputs considered in this change include;<br><br>a) The passive safety design of modular HTGRs does not rely on offsite or onsite AC power for any safety-related function during any postulated accident scenario (INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug. 2011, ML11251A169, pg. 9). DC power is required for some systems and is provided by safety related onsite equipment. |

| II. Multiple Barriers | | | |
|---|---|---|---|
| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. | 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~~ as required during postulated accidents. | b) Reference to application of the single failure criterion was updated to reflect the NRC staff's assessment of NGNP proposals in this area, as noted on July 17, 2014 in "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1- ML14174A774, section 1).<br><br>NGNP also determined that an alternative to the LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel; NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific. |
| 18 | *Inspection and testing of electric power systems.* 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. | ARDC with no further modular HTGR-specific clarification provided. | |
| 19 | *Control room.* A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions. Adequate radiation protection shall be provided to permit access and occupancy of | ARDC with no further modular HTGR-specific clarification provided. | |

| II. Multiple Barriers | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent (TEDE), for the duration of the accident.<br><br>Adequate habitability measures shall be provided to permit access and occupancy of the control room during normal operations and under accident conditions.<br><br>Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures. | | |

| III. Reactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 20 | *Protection system functions.*<br>The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Protection system functions.*<br>The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable ~~fuel~~ core radionuclide release design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety. | NGNP determined an alternative to LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific. |
| 21 | *Protection system reliability and testability.*<br>The protection system shall be designed for high functional reliability and inservice testability commensurate with the safety functions to be performed. Redundancy and independence designed into the protection system shall be sufficient to assure that (1) no single failure results in loss of the protection | ARDC with no further modular HTGR-specific clarification provided. | |

| III. Reactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | function and (2) removal from service of any component or channel does not result in loss of the required minimum redundancy unless the acceptable reliability of operation of the protection system can be otherwise demonstrated. The protection system shall be designed to permit periodic testing of its functioning when the reactor is in operation, including a capability to test channels independently to determine failures and losses of redundancy that may have occurred. | | |
| 22 | *Protection system independence.* The protection system shall be designed to assure that the effects of natural phenomena, and of normal operating, maintenance, testing, and postulated accident conditions on redundant channels do not result in loss of the protection function, or shall be demonstrated to be acceptable on some other defined basis. Design techniques, such as functional diversity or diversity in component design and principles of operation, shall be used to the extent practical to prevent loss of the protection function. | ARDC with no further modular HTGR-specific clarification provided. | |
| 23 | *Protection system failure modes.* The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis if conditions such as disconnection of the system, loss of energy (e.g., **[electric power, instrument air]**), or postulated adverse environments (e.g., **[extreme heat or cold, fire, pressure, steam, water, and radiation]**) are experienced. | ARDC with no further modular HTGR-specific clarification provided. | |
| 24 | *Separation of protection and control systems.* The protection system shall be separated from control systems to the extent that failure of any single control system component or channel, or failure or removal from service of any single protection system component or channel which is common to the control and protection systems leaves intact a system satisfying all | ARDC with no further modular HTGR-specific clarification provided. | |

| III. Reactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | reliability, redundancy, and independence requirements of the protection system. Interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired. | | |
| 25 | *Protection system requirements for reactivity control malfunctions.*<br>The protection system shall be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection or dropout) of control rods. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Protection system requirements for reactivity control malfunctions.*<br>The protection system shall be designed to assure that specified acceptable ~~fuel~~core radionuclide release design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection~~ or dropout~~) of control rods. | NGNP determined an alternative to LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific.<br><br>The reference to rod dropout is boiling water reactor-specific; it does not apply to modular HTGR designs, all of which are designed for top down insertion of control rods. |
| 26 | *Reactivity control system redundancy and capability.*<br>**[Two]** independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. A second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes **[(including xenon burnout)]** to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactivity control system redundancy and capability.*<br>~~**[Two]** i~~Independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable ~~fuel~~core radionuclide release design limits are not exceeded. A second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes **[(including xenon burnout)]** to assure acceptable ~~fuel~~core radionuclide release design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. | Wording adjustments were made to provide flexibility to account for a range of design options to meet the criterion safety goal, potentially using more than two independent reactivity control systems (see MHTGR PSID, Section 4.2).<br><br>NGNP determined an alternative to LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific. |

| III. Reactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 27 | *Combined reactivity control systems capability.*<br>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. | ARDC with no further modular HTGR-specific clarification provided. | |
| 28 | *Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor **[coolant 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. These postulated reactivity accidents shall include consideration of **[rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold water addition]**. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor **[~~coolant~~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. These postulated reactivity accidents shall include consideration of **[rod ejection (unless prevented by positive means), ~~rod dropout, steam line rupture,~~ changes in reactor ~~coolant~~ temperature ~~and pressure~~, and ~~cold water addition~~moisture ingress]**. | The concept of limiting the potential rate and amount of reactivity increases applies to modular HTGRs, but minor revisions were made to address the reactor helium pressure boundary and the inapplicability of rod dropout for modular HTGRs.<br><br>The list of reactivity accidents was modified to address reactor temperature changes resulting from a number of possible initiating events that could affect reactivity, including moisture ingress (see Sections 15.7 – 15.10 of MHTGR PSID). Cold-water addition does not apply to the modular HTGR. |
| 29 | *Protection against anticipated operational occurrences.*<br>The protection and reactivity control systems shall be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences. | ARDC with no further modular HTGR-specific clarification provided. | |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 30 | *Quality of reactor* ***[coolant pressure]*** *boundary.*<br>Components which are part of the reactor **[coolant pressure]** boundary shall be designed, fabricated, erected, and tested to the | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Quality of reactor* ***[~~coolant~~helium pressure]*** *boundary.*<br>Components which are part of the reactor | The reactor HPB is the one of multiple modular HTGR fission product release barriers; the release barrier configuration is summarized in slides presented to NRC during a July 2012 public meeting (ML12223A146) with associated |

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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor **[coolant]** leakage. | **[~~coolant~~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 **[~~coolant~~helium]** leakage. | NRC meeting summary (ML12219A205).<br><br>System factors discussed in section 2.3.3 of INL/EXT-10-17997, "NGNP Mechanistic Source Terms White Paper, July 2010, ML102040260, note the HPB integrity is relevant to this criterion due to its role in functional containment and its contribution in controlling graphite chemical attack via contaminant ingress. The adapted criterion addresses the need for high quality HPB component fabrication. |
| 31 | *Fracture prevention of reactor **[coolant pressure]** boundary.*<br>The reactor **[coolant pressure]** boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures **[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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Fracture prevention of reactor **[~~coolant~~helium pressure]** boundary.*<br>The reactor **[~~coolant~~helium pressure]** boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures **[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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. | The reactor HPB has a different function as compared to the LWR reactor coolant pressure boundary. The reactor HPB role in the functional containment and in the control of core chemical attack from contaminant ingress is noted in the Criterion 30 rationale; radionuclide release mechanisms in event of reactor HPB failure are discussed in Section 5.4 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug 2011, ML11251A169.<br><br>This criterion contributes to assuring that modular HTGR functional containment will meet 10CFR50.34 (10 CFR 52.79) requirements at the plant's exclusion area boundary (EAB) with margin without consideration of retention by reactor building. This key functional containment performance attribute was presented to the ACRS by NGNP on 1/17/13 (ML13044A656), and acknowledged by NRC staff on July 17, 2014 in "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1- ML14174A774, section 3, and enclosure 2 - ML14174A845, section 3.11). Criterion was modified to reference the reactor HPB. |
| 32 | *Inspection of reactor **[coolant pressure]** boundary.*<br>Components which are part of the reactor **[coolant pressure]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Inspection of reactor **[~~coolant~~helium pressure]** boundary.*<br>Components which are part of the reactor | Criterion was modified to recognize that modular HTGRs have a reactor HPB rather than RCPB. The reactor HPB contributes to functional containment as summarized in slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting |

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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | **[~~coolant~~helium pressure]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural ~~and leaktight~~ integrity, and (2) an appropriate material surveillance program for the reactor vessel. | summary (ML12219A205).<br><br>Section 5.4 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug 2011, ML11251A169, summarizes the radionuclide release mechanisms in the event of reactor HPB failure.<br><br>This criterion contributes to assuring that the modular HTGR functional containment will meet 10CFR50.34 (10 CFR 52.79) requirements at the plant's exclusion area boundary (EAB) with margin for postulated accidents without consideration of retention by reactor building. This key functional containment performance attribute was presented to the ACRS by NGNP on 1/17/13 (ML13044A656), and was acknowledged by the NRC staff on July 17, 2014 in "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1-ML14174A774, section 3 and enclosure 2 - ML14174A845, section 3.11).<br><br>The reactor HPB requires appropriate inspection and surveillance but may not require "leaktight" integrity; issues related to verifying the reactor HPB leakage are presumed addressed by assessing "structural integrity." |
| 33 | *Reactor **[coolant]** inventory maintenance.*<br><br>A system to maintain reactor **[coolant]** inventory for protection against small breaks in the reactor **[coolant pressure]** boundary shall be provided as necessary to assure that specified acceptable fuel design limits are not exceeded as a result of reactor **[coolant]** inventory loss due to leakage from the reactor **[coolant pressure]** boundary and rupture of small piping or other small components which are part of the boundary. | Not applicable to modular HTGR. | Although modular HTGRs have helium makeup and cleanup systems, they are not relied upon during postulated accidents. Coolant makeup for protection against small LWR leaks has no modular HTGR counterpart (See Section 6.1, INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug 2011, ML11251A169).<br><br>Modular HTGR specified acceptable core radionuclide release design limits are not assured by the system addressed by this ARDC; adequate core cooling is maintained even with a depressurized primary circuit. Criterion does not |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | | | apply to modular HTGRs. |
| 34 | *Residual heat removal.*<br>A system to remove residual heat shall be provided. 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 fuel design limits and the design conditions of the reactor **[coolant pressure]** boundary are not exceeded under all plant shutdown conditions following normal operation, including anticipated operational occurrences, and to provide continuous effective core cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*~~Residual~~ Passive residual heat removal.*<br>A passive system to remove residual heat shall be provided. 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 ~~fuel~~ core radionuclide release design limits ~~and the design conditions of the reactor~~ ~~**[coolant pressure]** boundary~~ are not exceeded ~~under all plant shutdown conditions following normal operation, including~~ during anticipated operational occurrences, and to provide continuous effective ~~core~~ cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished~~, assuming a single failure~~. | This criterion was revised to show that safety residual heat removal in modular HTGRs relies on a passive reactor cavity cooling system (RCCS) as the conduit to ultimate heat sink (See Section 2.3.4 of INL/EXT-10-17997, "NGNP Mechanistic Source Terms White Paper, July 2010, ML102040260, and page R 5-4-2 of "Preliminary Safety Information Document for the Standard MHTGR", HTGR-86-024, Sep 9, 1992, Amendment 13). "Passive" is added to clarify and emphasize its key role in the overall modular HTGR design and configuration.<br><br>NGNP determined an alternative to LWR-based SAFDL is needed which aligns with the modular HTGR safety basis and the role of coated particle fuel (see Section 7.2.2); NRC staff noted this issue before the ACRS on 4/9/2013 (ML13119A447). "Specified acceptable core radionuclide release design limits" designates the modular HTGR-specific regulatory limit. The quantitative value of the SARRDL will be design specific.<br><br>The modular HTGR RCCS protects the integrity of the reactor vessel when needed under postulated accident conditions. It is also relied upon for heat removal during some AOOs during which the SARRDL is not to be exceeded. Text of first paragraph was modified to communicate RCCS function.<br><br>Reference to application of the single failure criteria was updated to reflect the NRC staff's assessment of NGNP proposals in this area, as noted on July 17, 2014 in "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1- ML14174A774, section 1). It is expected that the single failure design criterion will be replaced with a probabilistic (reliability) criterion in modular HTGRs. |

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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 35 | Advanced Reactor Design Criterion for core cooling under accident conditions is contained in ARDC-34. | ARDC with no further modular HTGR-specific clarification provided. | |
| 36 | *Inspection of residual heat removal system.* The residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[spray rings in the reactor pressure vessel, water injection nozzles, and piping]**, to assure the integrity and capability of the system. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Inspection of passive residual heat removal system.* The passive residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[~~spray rings in the reactor pressure vessel, water injection nozzles, and piping~~design-specific equipment]**, to assure the integrity and capability of the system. | Criterion 36 is renamed and revised for inspection of the passive residual heat removal system required by Criterion 34.<br><br>Modular HTGRs do not have an emergency forced cooling system but use a passive reactor cavity cooling system (RCCS) (subject to Criterion 34) for residual heat removal to keep structures, systems and components within allowable limits. The Criterion 34 RCCS (active or passive mode under normal conditions, always passive under accident conditions) is subject to inspection under Criterion 36.<br><br>Section 2.3.4 of INL/EXT-10-17997, "NGNP Mechanistic Source Terms White Paper, July 2010, ML102040260, identifies the RCCS contribution to the modular HTGR safety basis. Pg. R 5-7-1 of "Preliminary Safety Information Document for the Standard MHTGR", HTGR-86-024, Sep 9, 1992, Amendment 13, states provisions for visual inspection will be required to assure RCCS integrity and structural support.<br><br>LWR-specific equipment (spray rings, water injection nozzles, and piping) inside the brackets will be replaced (later) with RCCS design-specific equipment, depending on which RCCS working fluid (air or water) is used in the design. |
| 37 | *Testing of residual heat removal system.* The residual heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural 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, | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Testing of passive residual heat removal system.* The passive residual heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural integrity of its components, (2) the operability and performance of the system components, and (3) the operability of the system as a whole and, if applicable, under conditions | Criterion 37 is renamed and revised for testing of the passive residual heat removal system required by modular HTGR-DC 34.<br><br>Section 2.3.4 of INL/EXT-10-17997, "NGNP Mechanistic Source Terms White Paper, July 2010, ML102040260, notes the passive RCCS (using either air or water as heat transfer fluid) contributes to the modular HTGR safety basis and is subject to component integrity testing. |

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| | including operation of associated systems and interfaces with an ultimate heat sink. | 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. | However, Section 6.1 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach", Aug 2011, ML11251A169, indicates that RCCS performance does not require "leaktight" conditions.<br><br>Some modular HTGR reactor cavity cooling system (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>Criterion was modified to reflect the passive nature of the modular HTGR RCCS and the need to verify ability to transition the RCCS from active mode (if present) to passive mode during postulated accidents. |
| 38 | *Containment heat removal.*<br>A system to remove heat from the reactor containment shall be provided as necessary to maintain the containment pressure and temperature within acceptable limits following postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | Not applicable to modular HTGR. | Modular HTGRs do not employ a containment structure. Modular HTGRs use multiple functional containment barriers that are summarized in a set of slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting summary (ML12219A205).<br><br>For the purpose of modular HTGR functional containment protection, heat removal is assured by Criterion 10 (Reactor design) and Criterion 15 (Reactor HPB design).<br><br>Containment heat removal under Criterion 38 is not applicable to modular HTGRs. |
| 39 | *Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[the torus, sumps, spray nozzles, and piping]** to assure the integrity and capability of the system. | Not applicable to modular HTGR. | Containment heat removal under Criterion 38 is not applicable to modular HTGRs, so Criterion 39 is also not applicable. |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 40 | *Testing of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural 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 operation of associated systems. | Not applicable to modular HTGR. | Containment heat removal under Criterion 38 is not applicable to modular HTGRs, so Criterion 40 is also not applicable. |
| 41 | *Containment atmosphere cleanup.*<br>Systems to control fission products, **[hydrogen, oxygen,]** and other substances which 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 **[hydrogen or oxygen]** and other substances in the containment atmosphere following postulated accidents to assure 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 assure that its safety function can be accomplished, assuming a single failure. | Not applicable to modular HTGR. | Modular HTGRs rely on all but one of their multiple functional containment barriers to meet 10CFR50.34 (10 CFR 52.79) dose criteria. The exception is the reactor building. The modular HTGR reactor building is vented and may not have exhaust filtration provisions. Explosive gas mixtures are not a source of hazard in the modular HTGR reactor building (see PSID for the Standard MHTGR, HTGR-86-024, pg R15-2-1). There is no corollary modular HTGR system for containment atmosphere cleanup.<br><br>Criterion 41 is not applicable to modular HTGRs. |
| 42 | *Inspection of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic inspection of important components, such as filter frames, ducts, and piping to assure the integrity and capability of the systems. | Not applicable to modular HTGR. | Containment atmosphere cleanup under Criterion 41 is not applicable to modular HTGRs, so Criterion 42 is also not applicable. |

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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 43 | *Testing of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural integrity of its 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 sequence that brings the systems into operation, including the operation of associated systems. | Not applicable to modular HTGR. | Containment atmosphere cleanup under Criterion 41 is not applicable to modular HTGRs, so Criterion 43 is also not applicable. |
| 44 | *Structural and equipment cooling.*<br>In addition to the heat rejection capability of the 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 assure that each system safety function can be accomplished, assuming a single failure. | Not applicable to modular HTGR. | The only safety related modular HTGR heat transfer system is the RCCS, which is addressed by Criterion 34. There is no modular HTGR system analogous to that addressed in Criterion 44 (See Section 6 of INL/EXT-11-22708, “Modular HTGR Safety Basis and Approach”, Aug 2011, ML11251A169).<br><br>Criterion 44 is not applicable to modular HTGRs. |
| 45 | *Inspection of structural and equipment cooling systems.*<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. | Not applicable to modular HTGR. | Cooling water under Criterion 44 is not applicable to modular HTGRs, so Criterion 45 is also not applicable. |
| 46 | *Testing of structural and equipment cooling systems.*<br>The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural integrity of their components, (2) the operability | Not applicable to modular HTGR. | Cooling water under Criterion 44 is not applicable to modular HTGRs, so Criterion 46 is also not applicable. |

| IV. Fluid Systems | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | 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. | | |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 50 | *Containment design basis.*<br>The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as **[energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning]**, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | Not applicable to modular HTGR. | Modular HTGRs do not have a "reactor containment structure", but instead rely on a multi-barrier functional containment configuration to control the release of radionuclides. That configuration is summarized in a set of slides presented to NRC in a July 2012 public meeting (ML12223A146) with associated NRC meeting summary (ML12219A205).<br><br>Design requirements for the individual constituents of the modular HTGR functional containment are addressed by proposed modular HTGR Design Criteria 10 (Reactor Design), 15 (Reactor Helium Pressure Boundary Design), 16 (Containment Design), 34 (Passive Residual Heat Removal), 70 (Reactor Vessel and Reactor System Structural Design Basis), and 71 (Reactor Building Design Basis).<br><br>Performance standards for the functional containment have been proposed by NGNP and were reviewed by the NRC staff as summarized in their July 17, 2014 report "NGNP – Assessment of Key Licensing Issues", ML14174A734 (enclosure 1- ML14174A774, section 3).<br><br>It is further noted that the modular HTGR functional containment will meet 10CFR50.34 (10 CFR 52.79) requirements at the plant's |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | | | exclusion area boundary (EAB) with margin without consideration of reactor building retention. This key functional containment performance attribute was presented to the ACRS by NGNP on 1/17/13 (ML13044A656), and was discussed by NRC staff as a part of the functional containment performance standard (Assessment Report ML14174A734 with enclosure 1- ML14174A774, section 3, and enclosure 2 - ML14174A845, section 3.3). |
| 51 | *Fracture prevention of containment pressure boundary.* The boundary of the reactor containment structure shall be designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | Not applicable to modular HTGR. | This criterion is associated with rapid fracture propagation of the LWR-based containment pressure boundary. The modular HTGR Reactor Building does not provide a corresponding pressure retention function, so this criterion does not apply. Requirements regarding the performance of the modular HTGR Reactor Building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for testing and inspection). |
| 52 | *Capability for containment leakage rate testing.* The reactor containment structure and other equipment which may be subjected to containment test conditions shall be designed so that periodic integrated leakage rate testing can be conducted at containment design pressure. | Not applicable to modular HTGR. | The modular HTGR Reactor Building does not provide a pressure retention function, and it is not relied upon to meet the offsite dose requirements of 10 CFR 50.34 (10 CFR 52.79). Therefore, this criterion does not apply. Requirements regarding the performance of the modular HTGR Reactor Building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for testing and inspection). |
| 53 | *Provisions for containment testing and inspection.* The reactor containment structure shall be designed to permit (1) appropriate periodic inspection of all important areas, such as penetrations, (2) an appropriate surveillance | Not applicable to modular HTGR. | Reactor Building testing and inspection is addressed by new Criterion 72. |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | program, and (3) periodic testing at containment design pressure of the leaktightness of penetrations which have resilient seals and expansion bellows. | | |
| 54 | *Piping systems penetrating containment.* Piping systems penetrating the primary reactor containment structure shall be provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems. Such piping systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | Not applicable to modular HTGR. | The modular HTGR Reactor Building does not provide a pressure retention function, and it is not relied upon to meet the offsite dose requirements of 10 CFR 50.34 (10 CFR 52.79). Therefore, this criterion regarding piping systems that may exist between the Reactor Building atmosphere and the outside environment does not apply. Requirements regarding the performance of the modular HTGR Reactor Building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for testing and inspection). |
| 55 | *Reactor **[coolant pressure]** boundary penetrating containment.* Each line that is part of the reactor **[coolant pressure]** boundary and that penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment. | Not applicable to modular HTGR. | Lines that form a portion of the reactor Helium Pressure Boundary do not penetrate the Reactor Building. Therefore, this criterion does not apply. |

| V. Reactor Containment | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | | |
| 56 | *Primary containment isolation.*<br>Each line that connects directly to the containment atmosphere and penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside | Not applicable to modular HTGR. | The modular HTGR Reactor Building does not provide a pressure retention function, and it is not relied upon to meet the offsite dose requirements of 10 CFR 50.34. Therefore, this criterion regarding isolation valves does not apply. Requirements regarding the performance of the modular HTGR Reactor Building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for testing and inspection). |

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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety. | | |
| 57 | *Closed system isolation valves.*<br>Each line that penetrates the primary reactor containment structure and is neither part of the reactor **[coolant pressure]** boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | Not applicable to modular HTGR. | The modular HTGR Reactor Building does not provide a pressure retention function, and it is not relied upon to meet the offsite dose requirements of 10 CFR 50.34. Therefore, this criterion regarding isolation valves does not apply. Requirements regarding the performance of the modular HTGR Reactor Building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for testing and inspection). |

| VI. Fuel and Radioactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 60 | *Control of releases of radioactive materials to the environment.*<br>The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment. | ARDC with no further modular HTGR-specific clarification provided. | |

| VI. Fuel and Radioactivity Control | | | |
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| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 61 | *Fuel storage and handling and radioactivity control.*<br>The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure 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 components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, 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 (5) to prevent significant reduction in fuel storage cooling under accident conditions. | ARDC with no further modular HTGR-specific clarification provided. | |
| 62 | *Prevention of criticality in fuel storage and handling.*<br>Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations. | ARDC with no further modular HTGR-specific clarification provided. | |
| 63 | *Monitoring fuel and waste storage.*<br>Appropriate systems shall be provided in fuel storage and radioactive waste systems and associated handling areas (1) to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and (2) to initiate appropriate safety actions. | ARDC with no further modular HTGR-specific clarification provided. | |
| 64 | *Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the **[reactor containment]** atmosphere, **[spaces containing components for recirculation of loss-of-coolant accident fluids,]** effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the **[reactor ~~containment~~building]** atmosphere, ~~**[spaces containing components for recirculation of loss-of-coolant accident fluids,]**~~ effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated | The underlying concept of monitoring radioactivity releases from the modular HTGR particle fuel to the reactor building, effluent discharge paths, and the plant environs applies. High radioactivity in the reactor building provides input to the plant protection system. In addition, the reactor building atmosphere is monitored for personnel protection. Recirculation of loss-of-coolant fluids (i.e., water) does not apply to the modular HTGR. |

| VI. Fuel and Radioactivity Control | | | |
|---|---|---|---|
| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| | | operational occurrences, and from postulated accidents. | The descriptions of the associated atmospheres and spaces that are required to be monitored are revised to reflect the modular HTGR's different design configuration and functional containment arrangement. |

| VII. Additional Modular HTGR-DC | | | |
|---|---|---|---|
| Criterion | Proposed ARDC Language | Proposed Modular HTGR-DC Language | Rationale for Modification |
| 70 | N/A | *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 modular HTGR design-specific GDC is necessary to assure reactor vessel and reactor system (reactor internals) integrity is preserved for passive heat removal and for insertion of neutron absorbers. |
| 71 | N/A | *Reactor building design basis.*<br>The design of the reactor building shall be such that during postulated accidents it structurally protects the geometry for passive removal of residual heat from the reactor core to the ultimate heat sink and provides a pathway for release of reactor helium from the building in the event of depressurization accidents. | The reactor building functions are to protect and maintain passive cooling geometry and to provide a pathway for the release of helium from the building in the case of a line break in the reactor helium pressure boundary. This newly established criterion assures that these safety functions are provided.<br><br>It is noted that the reactor building is not relied upon to meet the offsite dose requirements of 10 CFR 50.34 (10 CFR 52.79). |
| 72 | N/A | *Provisions for periodic reactor building inspection.*<br>The reactor building shall be designed to permit (1) appropriate periodic inspection of all important structural areas and the depressurization pathway, and (2) an appropriate surveillance program. | This newly established criterion regarding periodic inspection and surveillance provides assurance that the reactor building will perform its safety functions of protecting and maintaining the configuration needed for passive cooling and providing a discharge pathway for helium depressurization events. |

## 9.4 General Design Criteria - Advanced Reactor Design Criteria - SFR Design Criteria – mHTGR Design Criteria Comparison Table

The five-column table provided below presents the current GDC language (as it exists in 10 CFR 50, Appendix A) and the proposed language for ARDC, SFR-DC, and modular HTGR-DC in a format that allows for direct comparison of the related design criteria.

The left column contains GDC number and the second column contains the current GDC language. The second column also serves as a reference for comparison with the other columns. The third column from the left contains proposed ARDC language. If the proposed ARDC language for a given criterion is the same as the current GDC language, then the proposed ARDC language column states "Same as GDC." The final two columns contain the proposed SFR-DC and modular HTGR language. If the proposed SFR-DC language is the same as the ARDC, then the proposed SFR-DC language column states "ARDC with no further SFR-specific clarification provided." A similar statement is made in the modular HTGR column, where applicable.

Upon review of the table (from right to left), those design criteria that correspond to the current GDC language with no proposed changes can be quickly identified.

In addition, several ARDC contain brackets around certain phrases that may not apply to all advanced reactor designs. The corresponding design criteria may accept the ARDC bracketed text or propose a design-specific alternative, if appropriate. The bracketed text appears in bold for emphasis. Also, note that newly proposed text is inserted using blue font and deleted text is displayed with a redline/strikeout font style.

| **I. Overall Requirements** | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed Modular HTGR-DC Language |
| 1 | *Quality standards and records.*<br>Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 2 | *Design bases for protection against natural phenomena.*<br>Structures, systems, and components | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| I. Overall Requirements | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed Modular HTGR-DC Language |
| | important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed. | | | |
| 3 | *Fire protection.*<br>Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. | *Fire protection.*<br>Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit[**, particularly in locations such as the containment and control room**]. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Fire protection.*<br>Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, **[particularly in locations ~~such as the containment~~with safety related equipment and the control room]**. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. |
| 4 | *Environmental and dynamic effects design bases.*<br>Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately protected against | *Environmental and dynamic effects design bases.*<br>Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents~~, including loss of coolant accidents~~. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| **I. Overall Requirements** | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed Modular HTGR-DC Language |
| | dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping. | whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping. | | |
| 5 | *Sharing of structures, systems, and components.*<br>Structures, systems, and components important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Sharing of structures, systems, and components.*<br>Structures, systems, and components important to safety shall not be shared among reactor modules or reactor module groups ~~nuclear power units~~ unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one reactor module or reactor module group~~unit~~, an orderly shutdown and cooldown of the remaining reactor modules or reactor module groups~~units~~. |

| **II. Multiple Barriers** | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 10 | *Reactor design.*<br>The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. | *Reactor Design.*<br>The reactor core and associated **[coolant]**, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor design.*<br>The reactor ~~core~~ system and associated **[~~coolant~~heat removal]**, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable ~~fuel~~ core radionuclide release design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. |
| 11 | *Reactor inherent protection.*<br>The reactor core and associated coolant systems shall be designed so that in the power operating range the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity. | *Reactor inherent protection.*<br>The reactor core and associated ~~coolant~~ systems that contribute to reactivity feedback shall be designed so that in the power operating range the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity. | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| II. Multiple Barriers | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 12 | *Suppression of reactor power oscillations.*<br>The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed. | *Suppression of reactor power oscillations.*<br>The reactor core and associated **[coolant]**, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed. | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Suppression of reactor power oscillations.*<br>The reactor core and associated **~~[coolant],~~** control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable ~~fuel~~ core radionuclide release design limits are not possible or can be reliably and readily detected and suppressed. |
| 13 | *Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, the reactor coolant pressure boundary, and the containment and its associated systems. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges | *Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, **[the reactor coolant pressure boundary, and the containment and its associated systems]**. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges. | ARDC with additional SFR-specific clarification provided:<br><br>*Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, **[the reactor primary coolant~~pressure~~ boundary, and the containment and its associated systems]**. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Instrumentation and control.*<br>Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process and the integrity of the ~~reactor core,~~ **~~[the reactor coolant pressure boundary, and the containment and its associated systems]~~**functional containment. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges. |
| 14 | *Reactor coolant pressure boundary.*<br>The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. | *Reactor **[coolant pressure]** boundary.*<br>The reactor **[coolant pressure]** boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor **[primary coolant ~~pressure~~]** boundary.*<br>The reactor **[primary coolant ~~pressure~~]** boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor **[~~coolant~~helium pressure]** boundary.*<br>The reactor **[~~coolant~~ 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~~, and~~ of gross rupture and of unacceptable ingress of air, secondary coolant, or other fluids.. |
| 15 | *Reactor coolant system design.*<br>The reactor coolant system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor coolant pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. | *Reactor **[coolant]** system design.*<br>The reactor **[coolant]** system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor **[coolant pressure]** boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor **[primary coolant]** system design.*<br>The reactor **[primary coolant]** system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor **[primary coolant ~~pressure~~]** boundary are not exceeded during any condition of normal operation, including anticipated operational | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactor **[~~coolant~~helium pressure boundary]** ~~system~~ design.*<br>The reactor **~~[coolant]~~** system, vessel system, heat removal systems, and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor **[~~coolant~~helium pressure]** |

| II. Multiple Barriers | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | | | occurrences. | boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. |
| 16 | *Containment design.*<br>Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. | *Containment design.*<br>A r~~R~~eactor functional containment, ~~and associated systems~~ 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 ~~establish an essentially leak-tight barrier against the uncontrolled~~ 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. | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 17 | *Electric power systems.*<br>An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.<br><br>The onsite electric power supplies, including the batteries, and the onsite electric distribution system, shall have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure.<br><br>Electric power from the transmission network to the onsite electric distribution system shall be supplied by two physically independent circuits (not necessarily on separate rights of way) designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions. A switchyard common to both circuits is acceptable. Each of these circuits shall be designed to be available in sufficient time following a loss of all onsite alternating | *Electric power systems.*<br>~~An onsite e~~Electric power systems ~~and an offsite electric power system~~ shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for the ~~each~~ systems ~~(assuming the other system is not functioning)~~ shall be to provide sufficient capacity, ~~and~~ capability, and reliability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor **[coolant pressure]** boundary are not exceeded as a result of anticipated operational occurrences and (2) ~~the core is cooled and the containment integrity and other~~ vital functions that rely on electric power are maintained in the event of postulated accidents.<br><br>The onsite electric power systems~~supplies, including the batteries, and the onsite electric distribution system,~~ shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure.<br><br>~~Electric power from the transmission network to the onsite electric distribution system shall be supplied by two physically independent circuits (not necessarily on separate rights of way) designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions. A switchyard common to both circuits is acceptable. Each of these circuits shall be designed to be available in sufficient time following a loss of all onsite alternating current power supplies and the other offsite electric~~ | ARDC with additional SFR-specific clarification provided:<br><br>*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 assure that (1) specified acceptable fuel design limits and design conditions of the reactor **[primary coolant ~~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><br>The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Electric power systems.*<br>~~Electric~~ Onsite 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 assure that (1) specified acceptable ~~fuel~~ core radionuclide release design limits and design conditions of the reactor **[~~coolant~~ 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><br>The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions~~,~~ ~~assuming a single failure~~ as required during postulated accidents. |

| II. Multiple Barriers | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | current power supplies and the other offsite electric power circuit, to assure that specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded. One of these circuits shall be designed to be available within a few seconds following a loss-of-coolant accident to assure that core cooling, containment integrity, and other vital safety functions are maintained.<br><br>Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies. | ~~power circuit, to assure that specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded. One of these circuits shall be designed to be available within a few seconds following a loss-of-coolant accident to assure that core cooling, containment integrity, and other vital safety functions are maintained.~~<br><br>~~Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies.~~ | | |
| 18 | *Inspection and testing of electric power systems.*<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 the nuclear power unit, the offsite power system, and the onsite power system. | *Inspection and testing of electric power systems.*<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~~the nuclear power unit, the offsite power system, and the onsite power system~~ | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 19 | *Control room.*<br>A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions, including loss-of-coolant accidents. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident. Equipment at | *Control room.*<br>A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions~~, including loss-of-coolant accidents~~. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent (TEDE)~~ whole body, or its equivalent to any part of the body~~, for the duration of the accident. | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| II. Multiple Barriers | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.<br><br>Applicants for and holders of construction permits and operating licenses under this part who apply on or after January 10, 1997, applicants for design approvals or certifications under part 52 of this chapter who apply on or after January 10, 1997, applicants for and holders of combined licenses or manufacturing licenses under part 52 of this chapter who do not reference a standard design approval or certification, or holders of operating licenses using an alternative source term under § 50.67, shall meet the requirements of this criterion, except that with regard to control room access and occupancy, adequate radiation protection shall be provided to ensure that radiation exposures shall not exceed 0.05 Sv (5 rem) total effective dose equivalent (TEDE) as defined in § 50.2 for the duration of the accident. | Adequate habitability measures shall be provided to permit access and occupancy of the control room during normal operations and under accident conditions.<br><br>Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.<br><br>~~Applicants for and holders of construction permits and operating licenses under this part who apply on or after January 10, 1997, applicants for design approvals or certifications under part 52 of this chapter who apply on or after January 10, 1997, applicants for and holders of combined licenses or manufacturing licenses under part 52 of this chapter who do not reference a standard design approval or certification, or holders of operating licenses using an alternative source term under § 50.67, shall meet the requirements of this criterion, except that with regard to control room access and occupancy, adequate radiation protection shall be provided to ensure that radiation exposures shall not exceed 0.05 Sv (5 rem) total effective dose equivalent (TEDE) as defined in § 50.2 for the duration of the accident.~~ | | |

| III. Reactivity Control | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 20 | *Protection system functions.*<br>The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Protection system functions.*<br>The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable ~~fuel~~ core radionuclide release design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety. |

| III. Reactivity Control | | | | |
|---|---|---|---|---|
| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 21 | *Protection system reliability and testability.* The protection system shall be designed for high functional reliability and inservice testability commensurate with the safety functions to be performed. Redundancy and independence designed into the protection system shall be sufficient to assure that (1) no single failure results in loss of the protection function and (2) removal from service of any component or channel does not result in loss of the required minimum redundancy unless the acceptable reliability of operation of the protection system can be otherwise demonstrated. The protection system shall be designed to permit periodic testing of its functioning when the reactor is in operation, including a capability to test channels independently to determine failures and losses of redundancy that may have occurred. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 22 | *Protection system independence.* The protection system shall be designed to assure that the effects of natural phenomena, and of normal operating, maintenance, testing, and postulated accident conditions on redundant channels do not result in loss of the protection function, or shall be demonstrated to be acceptable on some other defined basis. Design techniques, such as functional diversity or diversity in component design and principles of operation, shall be used to the extent practical to prevent loss of the protection function. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 23 | *Protection system failure modes.* The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis if conditions such as disconnection of the system, loss of energy (e.g., electric power, instrument air), or postulated adverse environments (e.g., extreme heat or cold, fire, pressure, steam, water, and radiation) are experienced. | *Protection system failure modes.* The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis if conditions such as disconnection of the system, loss of energy (e.g., **[electric power, instrument air]**), or postulated adverse environments (e.g., **[extreme heat or cold, fire, pressure, steam, water, and radiation]**) are experienced. | ARDC with additional SFR-specific clarification provided:<br><br>*Protection system failure modes.* The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis if conditions such as disconnection of the system, loss of energy (e.g., **[electric power, instrument air]**), or postulated adverse environments (e.g., **[extreme heat or cold, fire, sodium and sodium reaction products, ~~pressure, steam, water,~~ and radiation]**) are experienced. | ARDC with no further modular HTGR-specific clarification provided. |
| 24 | *Separation of protection and control systems.* The protection system shall be separated from control systems to the extent that failure of any single control system component or channel, or failure or removal from service of any single protection system component or channel which is common to the control and protection | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| III. Reactivity Control | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | systems leaves intact a system satisfying all reliability, redundancy, and independence requirements of the protection system. Interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired. | | | |
| 25 | *Protection system requirements for reactivity control malfunctions.*<br>The protection system shall be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection or dropout) of control rods. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Protection system requirements for reactivity control malfunctions.*<br>The protection system shall be designed to assure that specified acceptable ~~fuel~~core radionuclide release design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection ~~or dropout~~) of control rods. |
| 26 | *Reactivity control system redundancy and capability.*<br>Two independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. | *Reactivity control system redundancy and capability.*<br>**[Two]** independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. ~~The~~ A second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes **[(including xenon burnout)]** to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactivity control system redundancy and capability.*<br>**[Two]** independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. A second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes ~~**[(including xenon burnout)]**~~ to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactivity control system redundancy and capability.*<br>~~**[Two]** i~~Independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable ~~fuel~~core radionuclide release design limits are not exceeded. A second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes **[(including xenon burnout)]** to assure acceptable ~~fuel~~core radionuclide release design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions. |
| 27 | *Combined reactivity control systems capability.*<br>The reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes to assure that under postulated accident conditions and with appropriate margin for stuck rods the capability | *Combined reactivity control systems capability.*<br>The reactivity control systems shall be designed to have a combined capability~~, in conjunction with poison addition by the emergency core cooling system,~~ 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 | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| III. Reactivity Control | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | to cool the core is maintained. | maintained. | | |
| 28 | *Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor coolant pressure boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor pressure vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents shall include consideration of rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold water addition. | *Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor **[coolant pressure]** boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor ~~pressure~~ vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents shall include consideration of **[rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold water addition]**. | ARDC with additional SFR-specific clarification provided:<br><br>*Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor **[primary coolant ~~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. These postulated reactivity accidents shall include consideration of **[~~rod ejection (unless prevented by positive means), rod dropout, steam line rupture,~~ changes in reactor coolant temperature and ~~pressure, and cold water addition~~changes in power/flow rates]**. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Reactivity limits.*<br>The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor **[~~coolant~~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. These postulated reactivity accidents shall include consideration of **[rod ejection (unless prevented by positive means), ~~rod dropout, steam line rupture,~~ changes in reactor ~~coolant~~ temperature ~~and pressure~~, and ~~cold water addition~~moisture ingress]**. |
| 29 | *Protection against anticipated operational occurrences.*<br>The protection and reactivity control systems shall be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |

| IV. Fluid Systems | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 30 | *Quality of reactor coolant pressure boundary.*<br>Components which are part of the reactor coolant 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 coolant leakage. | *Quality of reactor **[coolant pressure]** boundary.*<br>Components which are part of the reactor **[coolant 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 **[coolant]** leakage. | ARDC with additional SFR-specific clarification provided:<br><br>*Quality of reactor **[primary coolant ~~pressure~~]** boundary.*<br>Components which are part of the reactor **[primary coolant ~~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 **[coolant]** leakage. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Quality of reactor **[~~coolant~~helium pressure]** boundary.*<br>Components which are part of the reactor **[~~coolant~~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 **[~~coolant~~helium]** leakage. |
| 31 | *Fracture prevention of reactor coolant pressure boundary.*<br>The reactor coolant pressure boundary shall be designed with sufficient margin to assure that when stressed under operating, | *Fracture prevention of reactor **[coolant pressure]** boundary.*<br>The reactor **[coolant pressure]** boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, | ARDC with additional SFR-specific clarification provided:<br><br>*Fracture prevention of reactor **[primary coolant ~~pressure~~]** boundary.* | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Fracture prevention of reactor **[~~coolant~~helium pressure]** boundary.* |

| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
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| | **IV. Fluid Systems** | | | |
| | 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 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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. | 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 **[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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. | The reactor **[primary coolant ~~pressure~~]** boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a 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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. | The reactor **[~~*oolant*~~*helium* pressure]** boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures **[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 on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws. |
| 32 | *Inspection of reactor coolant pressure boundary.*<br>Components which are part of the reactor coolant pressure boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor pressure vessel. | *Inspection of reactor* ***[coolant pressure]*** *boundary.*<br>Components which are part of the reactor **[coolant pressure]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor ~~pressure~~ vessel. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of reactor* ***[primary coolant ~~pressure~~]*** *boundary.*<br>Components which are part of the reactor **[primary coolant ~~pressure~~]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Inspection of reactor* ***[~~coolant~~helium pressure]*** *boundary.*<br>Components which are part of the reactor **[~~coolant~~helium pressure]** boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural ~~and leaktight~~ integrity, and (2) an appropriate material surveillance program for the reactor vessel. |
| 33 | *Reactor coolant makeup.*<br>A system to supply reactor coolant makeup for protection against small breaks in the reactor coolant pressure boundary shall be provided. The system safety function shall be to assure that specified acceptable fuel design limits are not exceeded as a result of reactor coolant loss due to leakage from the reactor coolant pressure boundary and rupture of small piping or other small components which are part of the boundary. The system shall be designed to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished using the piping, pumps, and valves used to maintain coolant inventory during normal reactor operation. | *Reactor* ***[coolant]*** ~~*makeup*~~*inventory maintenance.*<br>A system to ~~supply~~ maintain reactor **[coolant]** inventory ~~*makeup*~~for protection against small breaks in the reactor **[coolant pressure]** boundary shall be provided as necessary to ~~.~~ ~~The system safety function shall be to~~ assure that specified acceptable fuel design limits are not exceeded as a result of reactor **[coolant]** inventory loss due to leakage from the reactor **[coolant pressure]** boundary and rupture of small piping or other small components which are part of the boundary. ~~The system shall be designed to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished using the piping, pumps, and valves used to maintain coolant inventory during normal reactor operation.~~ | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor* ***[primary coolant]*** *inventory maintenance.*<br>A system to maintain reactor **[coolant]** inventory for protection against small breaks in the reactor **[*primary* coolant ~~pressure~~]** boundary shall be provided as necessary to assure that specified acceptable fuel design limits are not exceeded as a result of reactor inventory loss due to leakage from the reactor **[primary coolant ~~pressure~~]** boundary and ***primary*** of small piping or other small components which are part of the boundary. | Not applicable to modular HTGR. |
| 34 | *Residual heat removal.*<br>A system to remove residual heat shall be provided. The system safety function shall be | *Residual heat removal.*<br>A system to remove residual heat shall be provided. The system safety function shall be to | ARDC with additional SFR-specific clarification provided: | ARDC with additional modular HTGR-specific clarification provided: |

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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure. | 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 fuel design limits and the design conditions of the reactor **[coolant pressure]** boundary are not exceeded under all plant shutdown conditions following normal operation, including anticipated operational occurrences, and to provide continuous effective core cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that ~~for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available)~~ the system safety function can be accomplished, assuming a single failure. | *Residual heat removal.*<br>A system to remove residual heat shall be provided. 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 fuel design limits and the design conditions of the reactor **[primary coolant ~~pressure~~]** boundary are not exceeded under all plant shutdown conditions following normal operation, including anticipated operational occurrences, and to provide continuous effective core cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished, assuming a single failure. | *~~Residual~~ Passive residual heat removal.*<br>A passive system to remove residual heat shall be provided. 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 ~~fuel~~ core radionuclide release design limits ~~and the design conditions of the reactor **[coolant pressure]** boundary~~ are not exceeded ~~under all plant shutdown conditions following normal operation, including~~ during anticipated operational occurrences, and to provide continuous effective ~~core~~ cooling during postulated accidents.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that the system safety function can be accomplished~~, assuming a single failure~~. |
| 35 | *Emergency core cooling.*<br>A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure. | Advanced Reactor Design Criterion for core cooling under accident conditions is contained in ARDC-34. | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 36 | *Inspection of emergency core cooling system.*<br>The emergency core cooling system shall be designed to permit appropriate periodic inspection of important components, such as spray rings in the reactor pressure vessel, water injection nozzles, and piping, to assure the integrity and capability of the system. | *Inspection of ~~emergency core cooling~~residual heat removal system.*<br>The ~~emergency core cooling system~~ residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[spray rings in the reactor pressure vessel, water injection nozzles, and piping]**, to assure the integrity and capability of the system. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of residual heat removal system.*<br>The residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[~~spray rings in the reactor pressure vessel, water injection nozzles,~~heat exchangers and piping]**, to assure the integrity and capability of | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Inspection of passive residual heat removal system.*<br>The passive residual heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[~~spray rings in the reactor pressure vessel, water injection nozzles,~~** |

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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | | | the system. | ~~**and piping**~~**design-specific equipment]**, to assure the integrity and capability of the system. |
| 37 | *Testing of emergency core cooling system.*<br>The emergency core cooling system shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the active components of the system, and (3) the operability of the system as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system. | *Testing of residual heat removal~~emergency core cooling~~ system.*<br>The residual heat removal ~~emergency core cooling~~ system shall be designed to permit appropriate periodic ~~pressure and~~ functional testing to assure (1) the structural ~~and leaktight~~ integrity of its components, (2) the operability and performance of the ~~active~~ system components~~ of the system~~, and (3) the operability of the system as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the system into operation, including operation of associated systems and interfaces with an ultimate heat sink.~~ including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system~~ | ARDC with no further SFR-specific clarification provided. | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Testing of passive residual heat removal system.*<br>The passive residual heat removal system shall be designed to permit appropriate periodic functional testing to assure (1) the structural integrity of its components, (2) the operability and performance of the system components, and (3) 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 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. |
| 38 | *Containment heat removal.*<br>A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure. | *Containment heat removal.*<br>A system to remove heat from the reactor containment shall be provided as necessary~~.~~ ~~The system safety function shall be~~ to maintain ~~reduce rapidly, consistent with the functioning of other associated systems,~~ the containment pressure and temperature within acceptable limits following ~~following any loss-of-coolant~~ postulated accidents~~ and maintain them at acceptably low levels~~.<br><br>Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that ~~for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available)~~ the system safety function can be accomplished, assuming a single failure. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 39 | *Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as the torus, sumps, spray nozzles, and piping to assure the integrity and capability of the system. | *Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[the torus, sumps, spray nozzles, and piping]** to assure the integrity and capability of the system. | ARDC with additional SFR-specific clarification provided:<br><br>*Inspection of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic inspection of important components, such as **[**~~**the torus, sumps, spray nozzles, and**~~ **piping]** | Not applicable to modular HTGR. |

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| | | | to assure the integrity and capability of the system. | |
| 40 | *Testing of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the active components of the system, 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 operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system. | *Testing of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic ~~pressure and~~ functional testing to assure (1) the structural ~~and leaktight~~ integrity of its components, (2) the operability and performance of the ~~active~~ system components~~ of the system~~, and (3) the operability of the system as a whole, and under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation~~, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system~~, including operation of associated systems. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 41 | *Containment atmosphere cleanup.*<br>Systems to control fission products, hydrogen, oxygen, and other substances which 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 hydrogen or oxygen and other substances in the containment atmosphere following postulated accidents to assure 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 assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) its safety function can be accomplished, assuming a single failure. | *Containment atmosphere cleanup.*<br>Systems to control fission products, **[hydrogen, oxygen,]** and other substances which 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 **[hydrogen or oxygen]** and other substances in the containment atmosphere following postulated accidents to assure 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 assure that ~~for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available)~~ its safety function can be accomplished, assuming a single failure. | ARDC with additional SFR-specific clarification provided:<br><br>*Containment atmosphere cleanup.*<br>Systems to control fission products, **[~~hydrogen, oxygen~~reaction products,]** and other substances which 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 **[~~hydrogen or oxygen~~reaction products]** and other substances in the containment atmosphere following postulated accidents to assure 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 assure that its safety function can be accomplished, assuming a single failure. | Not applicable to modular HTGR. |
| 42 | *Inspection of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic inspection of important components, such as filter frames, ducts, and piping to assure the integrity and capability of the systems. | Same as GDC | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |

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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 43 | *Testing of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the active components of the systems such as fans, filters, dampers, pumps, and valves 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 operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of associated systems. | *Testing of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic ~~pressure and~~ functional testing to assure (1) the structural ~~and leaktight~~ integrity of its components, (2) the operability and performance of the ~~active~~ system components, ~~of the systems such as fans, filters, dampers, pumps, and valves~~ 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 ~~operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and~~ the operation of associated systems. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 44 | *Cooling water.*<br>A system to transfer heat from structures, systems, and components important to safety, to an ultimate heat sink shall be provided. The system safety function shall be 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 assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure. | *Structural and equipment cooling~~Cooling water~~.*<br>In addition to the heat rejection capability of the residual heat removal system, ~~A~~ systems to transfer heat from structures, systems, and components important to safety, to an ultimate heat sink shall be provided, as necessary~~. The system safety function shall be~~ 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 assure that ~~for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the~~ each system safety function can be accomplished, assuming a single failure. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 45 | *Inspection of cooling water system.*<br>The cooling water system 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 system. | *Inspection of structural and equipment cooling ~~water~~ systems.*<br>The ~~cooling water~~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. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 46 | *Testing of cooling water system.*<br>The cooling water system shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and the performance of the active components of the system, and (3) the | *Testing of structural and equipment cooling ~~water~~ systems.*<br>The structural and equipment cooling ~~water~~ systems shall be designed to permit appropriate periodic ~~pressure and~~ functional testing to assure (1) the structural ~~and leaktight~~ integrity of their ~~its~~ components, (2) the operability and the | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |

| IV. Fluid Systems | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | 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 for reactor shutdown and for loss-of-coolant accidents, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources. | performance of the ~~active~~ system components ~~of the system~~, 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~~s~~ the systems into operation for reactor shutdown and postulated accidents, including operation of associated systems ~~and for loss-of-coolant accidents, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources~~. | | |

| V. Reactor Containment | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 50 | *Containment design basis.* The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | *Containment design basis.* The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents~~any loss-of-coolant accident~~. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as **[energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning]**, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | ARDC with additional SFR-specific clarification provided:<br><br>*Containment design basis.* The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as **[fission products, potential spray or aerosol formation, and potential exothermic chemical reaction~~energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning~~]**, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters. | Not applicable to modular HTGR. |
| 51 | *Fracture prevention of containment pressure boundary.* The reactor containment boundary shall be designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its ferritic materials behave in a nonbrittle manner and (2) the probability of rapidly propagating | *Fracture prevention of containment pressure boundary.* The ~~reactor containment~~ boundary of the reactor containment structure shall be designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its ~~ferritic~~ materials behave in a nonbrittle manner and (2) the probability of | ARDC with additional SFR-specific clarification provided:<br><br>*Fracture prevention of containment ~~pressure~~ boundary.* The boundary of the reactor containment structure shall be designed with sufficient margin to assure that under operating, maintenance, | Not applicable to modular HTGR. |

| V. Reactor Containment | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary material during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | testing, and postulated accident conditions (1) its materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state, and transient stresses, and (3) size of flaws. | |
| 52 | *Capability for containment leakage rate testing.*<br>The reactor containment and other equipment which may be subjected to containment test conditions shall be designed so that periodic integrated leakage rate testing can be conducted at containment design pressure. | *Capability for containment leakage rate testing.*<br>The reactor containment structure and other equipment which may be subjected to containment test conditions shall be designed so that periodic integrated leakage rate testing can be conducted at containment design pressure. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 53 | *Provisions for containment testing and inspection.*<br>The reactor containment shall be designed to permit (1) appropriate periodic inspection of all important areas, such as penetrations, (2) an appropriate surveillance program, and (3) periodic testing at containment design pressure of the leaktightness of penetrations which have resilient seals and expansion bellows. | *Provisions for containment testing and inspection.*<br>The reactor containment structure shall be designed to permit (1) appropriate periodic inspection of all important areas, such as penetrations, (2) an appropriate surveillance program, and (3) periodic testing at containment design pressure of the leaktightness of penetrations which have resilient seals and expansion bellows. | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |
| 54 | *Piping systems penetrating containment.*<br>Piping systems penetrating primary reactor containment shall be provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems. Such piping systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | *Piping systems penetrating containment.*<br>Piping systems penetrating the primary reactor containment structure shall be provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems. Such piping systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | ARDC with additional SFR-specific clarification provided:<br><br>*Piping systems penetrating containment.*<br>Piping systems penetrating the primary reactor containment structure shall be provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities necessary to perform the containment safety function and which reflect the importance to safety of preventing radioactivity releases from containment through ~~isolating~~ these piping systems. When isolation valves are required, ~~Such~~ piping systems shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits. | Not applicable to modular HTGR. |
| 55 | *Reactor coolant pressure boundary penetrating containment.*<br>Each line that is part of the reactor coolant pressure boundary and that penetrates primary reactor containment shall be provided with containment isolation valves as follows, unless it can be demonstrated that the | *Reactor **[coolant pressure]** boundary penetrating containment.*<br>Each line that is part of the reactor **[coolant pressure]** boundary and that penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the | ARDC with additional SFR-specific clarification provided:<br><br>*Reactor **[primary coolant ~~pressure~~]** boundary penetrating containment.*<br>Each line that is part of the reactor **[primary coolant ~~pressure~~]** boundary and that | Not applicable to modular HTGR. |

| V. Reactor Containment | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.<br><br>Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to assure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for inservice inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs. | |
| 56 | *Primary containment isolation.*<br>Each line that connects directly to the containment atmosphere and penetrates primary reactor containment shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside | *Primary containment isolation.*<br>Each line that connects directly to the containment atmosphere and penetrates the primary reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis:<br>(1) One locked closed isolation valve inside and one locked closed isolation valve outside | ARDC with no further SFR-specific clarification provided. | Not applicable to modular HTGR. |

| V. Reactor Containment | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety. | containment; or<br>(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or<br>(3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or<br>(4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment.<br><br>Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety. | | |
| 57 | *Closed system isolation valves.*<br>Each line that penetrates primary reactor containment and is neither part of the reactor coolant pressure boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | *Closed system isolation valves.*<br>Each line that penetrates the primary reactor containment structure and is neither part of the reactor **[coolant pressure]** boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | ARDC with additional SFR-specific clarification provided:<br><br>*Closed system isolation valves.*<br>Each line that penetrates the primary reactor containment structure and is neither part of the reactor **[primary coolant ~~pressure~~]** boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve unless it can be demonstrated that the containment safety function can be met without an isolation valve and assuming failure of a single active component. The isolation valve, if ~~which shall~~required, shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve. | Not applicable to modular HTGR. |

| VI. Fuel and Radioactivity Control | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| 60 | *Control of releases of radioactive materials to the environment.*<br>The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 61 | *Fuel storage and handling and radioactivity control.*<br>The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure 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 components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, 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 (5) to prevent significant reduction in fuel storage coolant inventory under accident conditions. | *Fuel storage and handling and radioactivity control.*<br>The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure 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 components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, 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 (5) to prevent significant reduction in fuel storage ~~coolant inventory~~ cooling under accident conditions. | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 62 | *Prevention of criticality in fuel storage and handling.*<br>Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 63 | *Monitoring fuel and waste storage.*<br>Appropriate systems shall be provided in fuel storage and radioactive waste systems and associated handling areas (1) to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and (2) to initiate appropriate safety actions. | Same as GDC | ARDC with no further SFR-specific clarification provided. | ARDC with no further modular HTGR-specific clarification provided. |
| 64 | *Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for recirculation of | *Monitoring radioactivity releases.*<br>Means shall be provided for monitoring the **[reactor containment]** atmosphere, **[spaces containing components for recirculation of** | ARDC with additional SFR-specific clarification provided:<br><br>*Monitoring radioactivity releases.* | ARDC with additional modular HTGR-specific clarification provided:<br><br>*Monitoring radioactivity releases.* |

| VI. Fuel and Radioactivity Control | | | | |
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| Criterion | Current GDC Language | Proposed ARDC Language | Proposed SFR-DC Language | Proposed HTGR-DC Language |
| | loss-of-coolant accident fluids, effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | **loss-of-coolant accident fluids,]** effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | Means shall be provided for monitoring the **[reactor containment]** atmosphere, **[spaces containing components for** ~~**recirculation of loss-of-coolant accident fluids**~~ **primary system sodium and cover gas cleanup and processing,]** effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. | Means shall be provided for monitoring the **[reactor** ~~**containment**~~**building]** atmosphere, ~~**[spaces containing components for recirculation of loss-of-coolant accident fluids,]**~~ effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. |