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U.S. Nuclear Regulatory Commission
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Subject: Transmittal of Responses to Request for Additional Information on GA-EMS Fast Modular Reactor Principal Design Criteria Topical Report

General Atomics - Electromagnetic Systems (GA-EMS) is submitting to the Nuclear Regulatory Commission (NRC) the enclosed responses to the six requests for additional information on the Fast Modular Reactor (FMR) Principal Design Criteria Topical Report.

If the responses and modifications to the FMR Principal Design Criteria are acceptable, GA-EMS will revise the topical report to incorporate those modifications.

If you have any questions or need any additional information, please contact John Bolin by email at john.bolin@ga.com or by phone at 858-762-7576.

Sincerely,

John Bolin
Nuclear Technologies and Materials Division
General Atomics – Electromagnetic Systems

Enclosure: Responses to Request for Additional Information on GA-EMS FMR Principal Design Criteria Topical Report

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ENCLOSURE

RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION ON GA-EMS FMR PRINCIPAL DESIGN CRITERIA TOPICAL REPORT

RAI FMR-DC 12:

GAEMS TR FMR-DC 12 provides a criterion for the suppression of reactor power oscillations largely consistent with GDC 12. Relative to GDC 12, the only substantive change is to remove the word “coolant” from the design criterion. The rationale for this adaptation to the GDC provided in the TR is that the helium coolant in the FMR does not affect the core’s susceptibility to power oscillations. The staff agrees with this point and notes that it is consistent with the adaptations for MHTGR-DC 12. However, ARDC 12 adapted GDC 12 by adding the word “structures”, because “items such as reflectors, which could be considered either outside or not part of the reactor core, may affect susceptibility of the core to power oscillations.” This is particularly true for fast reactors like the FMR. Please explain why it is not necessary to address the role of structures in power oscillations for the FMR.

Response to RAI FMR-DC 12:

Agreed. The word “structures” will be added to FMR-DC 12 consistent with ARDC-12 since items not part of the reactor core may affect susceptibility of the core to power oscillations. This effect is expected to be much less significant in the FMR because of its ceramic core structure and minimal thermal expansion effects compared to other fast reactors with metallic core structures.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
12	*Suppression of reactor power oscillations.* The reactor core, associated structures, and associated control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.	The word “structures” was added because items such as reflectors, which could be considered either outside or not part of the reactor core, may affect susceptibility of the core to power oscillations. Helium in the FMR does not affect reactor core susceptibility to coolant-induced power oscillations; therefore, the word “coolant” was deleted.

RAI FMR-DC 34:

GA-EMS TR FMR-DC 34 provides a criterion for the design of the passive residual heat removal (PRHR) system. Overall, this criterion is very similar to MHTGR-DC 34 from RG 1.232, aside from the change to specified acceptable fuel design limits (SAFDLs) from specified acceptable system radionuclide release design limits (SARRDLs), which is consistent with other FMR-DC. However, compared to the design-specific PDC provided in RG 1.232, the words “[f]or normal operations and anticipated operational occurrences” are missing from the FMR-DC. Please provide a justification for removing this language.

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Response to RAI FMR-DC 34:

The missing words "(f)or normal operations and anticipated occurrences" will be placed at the beginning of the second sentence in FMR-DC 34 consistent with the PDC provided in RG 1.232. The rationale will also be modified to be consistent with MHTGR-DC 34. The PDC will be modified to reflect the broader scope of available residual heat removal systems.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
34	*~~Passive residual~~ Residual heat removal.* ~~A passive system~~ System(s) to remove residual heat shall be provided. For normal operations and anticipated operational occurrences, ~~The~~ 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 helium pressure boundary are not exceeded. During postulated accidents, the system safety function shall provide effective core cooling. Suitable redundancy in components and features and suitable interconnections, leak detection, and isolation capabilities shall be provided to ensure the system safety function can be accomplished, assuming a single failure.	~~The word "passive" was added, based on the FMR design.~~For normal operations, anticipated operational occurrences, and postulated accidents, active non-safety-related systems and passive safety-related systems are available to remove residual heat. "Ultimate heat sink" has been added ~~to explain that, if FMR-DC 44 is deemed not applicable to the design,~~because the residual heat removal systems ~~is then~~are required to provide the heat removal path to the ultimate heat sink rather than rely on an additional intermediary system. "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for MHTGRs and the FMR. The FMR-DC 34 incorporates the postulated accident residual heat removal requirements contained in GDC 35. Effective core cooling under postulated accident conditions is defined as maintaining fuel temperature limits below design values to help ensure the siting regulatory dose limits criteria at the exclusion area boundary (EAB) and low-population zone (LPZ) are not exceeded and the integrity of the core, the core structural components, and the reactor vessel is maintained under postulated accident conditions, thereby ensuring a geometry ~~is preserved which supports~~ required for ~~residual~~ passive heat removal. The GDC reference to electric power was removed. Refer to FMR-DC 17 concerning those systems that require electric power.

RAI FMR-DC 37:

GA-EMS TR FMR-DC 37 provides a criterion for testing of the PRHR system. Some of the language used in this PDC appears to be redundant. Specifically, the last two clauses from the FMR-DC 37 may cover overlapping systems:

- "including operation of associated systems and interfaces with an ultimate heat sink and the transition from the standby normal operation mode to the passive operation mode relied upon during postulated accidents"
- "including the operation of applicable portions of the protection system and the operation of the associated structural and equipment cooling water system."

Please clarify whether both clauses are needed.

Response to RAI FMR-DC 37:

The first clause referred to in this RAI will be rewritten to be the same as MHTGR-DC 37.

> "including associated systems, for AOO or postulated accident decay heat removal to the ultimate heat sink and, if applicable, and system(s) necessary to transition from active normal operation to passive mode."

The second clause referred to in this RAI is not applicable to FMR-DC 37 and will be deleted. The rationale will also be modified to be more consistent with the MHTGR-DC 37. The PDC will be modified to reflect the broader scope of available residual heat removal systems.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
37	*Testing of ~~passive~~ residual heat removal system.* The ~~passive~~ residual heat removal system(s) shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leak-tight 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, for AOO or postulated accident decay heat removal to the ~~and interfaces with an~~ ultimate heat sink and, if applicable, any system(s) necessary to ~~the~~ transition from ~~the standby~~active normal operation ~~mode~~ to ~~the~~ passive ~~operation~~ mode ~~relied upon during postulated accidents, including the operation of applicable portions of the protection system and the operation of the~~	Criterion 37 has been ~~renamed and~~ revised for testing the ~~passive~~ residual heat removal system(s) required by FMR-DC 34. For normal operations, anticipated operational occurrences, and postulated accidents, active non-safety-related systems and passive safety-related systems are available to remove residual heat. ~~Reference to the operation of applicable portions of the protection system, structural and equipment cooling water systems, and power transfers is considered a part of the more general "associated systems" for operability testing of the system as a whole.~~ Abnormal leakage of RHR coolant may be acceptable provided that (1) the RHR leakage does not impact safety functions under all conditions, and (2) containment is not impacted by RHR leakage.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
	associated structural and equipment cooling water system.	Functional testing is testing that assesses component and system operational readiness. The criterion was modified to reflect the passive nature of the FMR residual heat removal systems to mitigate AOOs or postulated accidents and the need to verify the ability to transition from standby active mode (if present) to passive mode during postulated accidents. Associated systems means testing any auxiliary or secondary systems needed to perform the passive heat removal function.

RAI FMR-DC 56:

For ARDC 56, *Containment Isolation*, the RG 1.232 includes the following statement:

> 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.

Although GA-EMS TR Table 1, "FMR Principal Design Criteria," indicates that FMR-DC 56, *Containment Isolation*, is the same as ARDC 56 in RG 1.232, the above statement was omitted from the column "FMR-DC Title and Content" for FMR-DC 56. Please clarify whether the omission was intentional and, if so, provide the basis for the removal of the statement regarding location and effect of loss of actuating power from FMR-DC 56.

Response to RAI FMR-DC 56:

The statement referred to in this RAI should not have been deleted from the FMR-DC 56 and will be added to the FMR PDC consistent with ARDC 56.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
56	*Containment isolation.* Each line that connects directly to the containment atmosphere and penetrates the 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: (1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or	Same as ARDC FMR-DC 51–57 support FMR-DC 50, which specifically applies to non-LWR designs that use a fixed containment structure. Therefore, the word "structure" is added to each of these DC to clearly convey the understanding that this criterion applies to designs employing containment structures. The word "primary" in the title and the text was removed, and the word "reactor" was also removed because the containment is a barrier between the fission products and the environment. There are diverse advanced reactor designs and, hence, there is no single containment concept. In all cases,

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
	(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or (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 (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. 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.	the rules for containment penetrations to fulfill containment isolation would apply. How this is accomplished should be left to the designer of the particular advanced reactor design, without being too prescriptive as to whether it is a primary or secondary or reactor containment. There may be a need for a containment structure outside the reactor region.

RAI FMR-DC 17(A):

Table 1, "FMR Principal Design Criteria," of the TR provides the FMR-DC content for Criterion 17, "Electric Power Systems." RG 1.232 states that for Modular High-Temperature Gas-Cooled Reactor (MHTGR) Criterion 17, "[i]f electric power is not needed for anticipated operational occurrences or postulated accidents, the design shall demonstrate that power for important to safety functions is provided." This is deleted from the GA-EMS FMR-DC 17.

Please explain the deletion and if power to important to safety functions are not required (i.e., Is this not applicable since there will be safety-related onsite power?).

Response to RAI FMR-DC 17(A):

The statement referred to in this RAI will be added to the FMR PDC consistent with ARDC 17 and MHTGR-DC 17. The phrase "important to safety" was added to the first sentence of FMR-DC 17 but is now unnecessary with the addition of the statement referred to in this RAI. The rationale will also be modified to be consistent with MHTGR-DC 17.

RAI FMR-DC 17(B):

Table 1 of the TR provides the content for GA-EMS FMR-DC 17. RG 1.232, MHTGR-DC 17 "Electric power systems," states in part "[t]he electric power systems shall include an onsite power system and an additional power system. […] An additional power system shall have sufficient independence and testability to perform its safety function." Requirements for an additional power system are not provided in the GA-EMS FMR-DC 17. In addition, the rationale for GA-EMS FMR-DC-17 in Table 1 of the TR, states that 'The GDC text related to "…supplies, including batteries, and the onsite distribution system," was deleted to allow increased flexibility in the design of offsite power systems for advanced reactor designs.'

Please explain if there are any offsite or other power systems required besides the onsite power system.

Response to RAI FMR-DC 17(B):

The section of MHTGR-DC-17 referred to in this RAI will be added to FMR-DC 17 consistent with MHTGR-DC 17 along with the associated rationale for adaptations to the GDC. The specific reference to "…supplies, including batteries, and the onsite distribution system," will be removed from the rationale and replaced with the rationale provided in MHTGR-DC 17.

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
17	*Electric power systems.* Electric power systems shall be provided when required to permit functioning of structures, systems, and components ~~important to safety~~. The safety function for ~~the systems~~each power system shall be to provide sufficient capacity~~,~~ and capability~~, and reliability~~ to ensure that (1) specified acceptable fuel design limits and ~~design conditions of~~ the reactor helium pressure boundary design limits are not exceeded as a result of anticipated operational occurrences and (2) ~~vital~~ safety functions that rely on electric power are maintained in the event of postulated accidents. The electric power systems shall include an onsite power system and an additional power system. The onsite electric power system~~s~~ shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. An additional power system shall have sufficient independence and testability to perform its safety function. If electric power is not needed for anticipated operational occurrences or postulated accidents, the design shall demonstrate that power for important to safety functions is provided.	~~A reliable~~The electric power systems ~~is~~ are required to provide reliable power for SSCs during anticipated operational occurrences and postulated accident conditions when those SSCs' safety functions require electric power. The safety functions are established by the safety analyses (i.e., design basis accidents). Where electric power is needed for anticipated operational occurrences or postulated accidents, the electric ~~Power~~ power systems shall be sufficient in capacity~~,~~ and capability~~, and reliability~~ to ensure ~~vital~~ that safety functions as well as important to safety functions are maintained. The electric power systems provide redundancy and defense-in-depth since there would be a minimum of two power systems. Compared to GDC 17, more~~The~~ emphasis is placed herein on requiring reliability of power ~~sources~~ supply scheme rather than fully prescribing how such reliability can be attained. For example, reference to offsite electric power systems was deleted to provide for those reactor designs that do not depend on offsite power for the functioning of SSCs important to safety or do not connect to a power grid. The onsite power system is envisioned as a fully Class 1E power system and the additional power system is left to the discretion of the designer as long as it meets the performance criteria in paragraph one and the design criteria of paragraph two. ~~The GDC text related to "…supplies, including batteries, and the onsite distribution system," was deleted to allow increased flexibility in the design of offsite power systems for advanced reactor designs. However, such onsite systems are still expected to remain capable of performing assigned safety functions during~~

Criterion	FMR-DC Title and Content	Rationale for Adaptions to GDC
		~~accidents as a condition of requisite reliability.~~ In this context, important to safety functions refer to the broader, potentially non-safety related functions such as post-accident monitoring, control room habitability, emergency lighting, radiation monitoring, communications and/or any others that may be deemed appropriate for the given design. The electric power system for important to safety functions could be non-Class 1E and would not be required to have redundant power sources. “Reactor coolant pressure boundary” has been relabeled as “reactor helium pressure boundary” to conform to standard terms used for MHTGRs and the FMR.