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GENERAL ATOMICS ELECTROMAGNETIC SYSTEMS – SAFETY EVALUATION OF TOPICAL REPORT 30599T00005, FAST MODULAR REACTOR PRINCIPAL DESIGN CRITERIA, REVISION 2 (EPID NO. L-2022-TOP-0033)

SPONSOR AND SUBMITTAL INFORMATION

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Correspondence Dates and ADAMS Accession Nos:

- U.S. Nuclear Regulatory Commission (NRC) Staff Completeness Determination, dated July 07, 2022, (ML22181B171).
- NRC staff's requests for additional information (RAIs), dated October 05, 2022, (ML22321A310).
- GA-EMS RAI responses, dated November 07, 2022, (ML22311A472).
- GA-EMS Topical Report (TR) 30599T00005, Fast Modular Reactor Principal Design Criteria Revision 2, dated January 5, 2023, (ML23005A290).

1.0 BRIEF DESCRIPTION OF TOPICAL REPORT AND BACKGROUND

By letter dated June 3, 2022 [1], General Atomics – Electromagnetic Systems (GA-EMS) submitted TR 30599T00005, "Fast Modular Reactor Principal Design Criteria," Revision 1 [2], for the NRC staff's review. The TR contains a brief overview of the GA-EMS Fast Modular Reactor (FMR) design, a summary of how the principal design criteria (PDC) were developed, and the PDC selected for the FMR (referred to as the FMR-DC in the TR). GA-EMS requested the NRC staff's review and approval of the FMR PDC TR so it may be referenced by applicants using the FMR design under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 "Domestic Licensing of Production and Utilization Facilities," or 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." Documentation that the PDCs are satisfied will be provided within the license application and is not part of the subject TR.

By email dated July 7, 2022, the NRC staff informed GA-EMS that the TR provided sufficient information for the NRC staff to conduct a detailed technical review [3]. By email dated October 5, 2022, the NRC staff issued RAIs to GA-EMS [4]; GA-EMS responded to the NRC staff's RAIs by letter dated November 7, 2022 [5]. By letter dated January 5, 2023, GA-EMS submitted Revision 2 of the FMR PDC TR [6].

2.0 REGULATORY EVALUATION

The regulations under 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," provide general design criteria (GDC) for water-cooled nuclear power plants similar to those historically licensed by the NRC. Under the provisions of 10 CFR Parts 50 and 52, applicants for a construction permit (CP), operating license (OL), design certification (DC), combined license (COL), standard design approval (SDA), or manufacturing license (ML) must submit PDCs for the proposed facility.

Specifically, the following Commission regulations pertain to the PDCs:

- 10 CFR 50.34(a)(3)(i), which requires, in part, that applications for a CP include PDCs for the facility. An OL would reference a CP, which would include PDCs.
- 10 CFR 52.47(a)(3)(i), which requires, in part, that applications for a DC include PDCs for the facility.
- 10 CFR 52.79(a)(4)(i), which requires, in part, that applications for a COL include PDCs for the facility.
- 10 CFR 52.137(a)(3)(i), which requires, in part, that applications for an SDA include PDCs for the facility.
- 10 CFR 52.157(a), which requires, in part, that applications for an ML include PDCs for the reactor to be manufactured.

The regulations under 10 CFR 50.34(a)(3)(i) state that 10 CFR Part 50, Appendix A, establishes the minimum requirements for the PDCs for water-cooled nuclear power plants similar in design and location to plants for which CPs have previously been issued by the Commission and provides guidance to applicants in establishing PDCs for other types of nuclear power units. Since the GA-EMS FMR is not a water-cooled nuclear power plant, PDCs are required but they do not necessarily align with the minimum requirements in the GDCs in 10 CFR Part 50, Appendix A.

Recognizing that the GDCs in 10 CFR Part 50, Appendix A may not be appropriate for non-light-water reactors (non-LWRs), the NRC issued Regulatory Guide (RG) 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," [7] which serves as guidance to develop PDCs for non-LWR designs.

The PDCs are integral to the review of the facility design and should be considered in the development of the facility and the structures, systems, and component (SSC) design bases. PDCs aid in the NRC staff's evaluation of other regulations and allow the NRC staff to have reasonable assurance that the design will conform to the design bases with adequate margins for safety.

3.0 TECHNICAL EVALUATION

3.1 FMR Design Features

As discussed in Section 2, “Design Features of GA-EMS FMR,” of the TR [2] and Section 2.2, “Plant Description” of the GA-EMS regulatory engagement plan [8] the proposed conceptual design for the FMR is a modular high temperature gas-cooled fast spectrum reactor. The reactor is fueled with uranium dioxide pellets loaded into silicon carbide composite clad fuel rods, similar to accident tolerant fuel types proposed for use in operating light-water reactors (LWRs). The fuel rods are arranged in assemblies in a triangular-pitch lattice typical of fast reactor designs, which enables them to be packed more closely than the rectangular-pitch lattice seen in operating LWRs. The primary system coolant is helium. The FMR uses a direct power conversion system with a gas turbine, as shown in Section 2 of the TR [2] and in more detail in Section 2.3, “Power Operation,” of the regulatory engagement plan [8]. Because a direct power conversion system is used, there is no intermediate or secondary loop; the primary system helium coolant is used to drive the turbine to produce electricity. Heat from the power conversion system is transferred to the ultimate heat sink (a dry, forced convection cooling tower) using a water loop.

Rather than a functional containment concept, which is often considered for high temperature gas reactors (HTGRs) (originally considered by the NRC staff in SECY-93-092 [9]), the FMR design includes a leak-tight containment. The reactor and power conversion system are within a structural containment located below grade. Emergency cooling is achieved using a passive system known as the reactor vessel cooling system (RVCS). The RVCS relies on natural circulation of water between structures absorbing heat radiated by the below-grade reactor vessel and an above-grade heat sink to provide continuous heat removal.

In summary, the FMR has different characteristics in common with several different reactor types. The core arrangement, neutron spectrum, and reactor physics are similar to sodium-cooled fast reactors (SFRs), though the FMR fuel is more similar to certain types of accident tolerant fuel proposed for use in LWRs. The reactor coolant system, power conversion system, electric power system, and balance of plant are similar to HTGRs. The use of a leak-tight containment is similar to LWRs and SFRs. The design features of the FMR and their similarity to other types of reactors was used by GA-EMS to inform the development of the FMR PDCs.

3.2 PDC Development Methodology

In Section 3, “FMR PDC Development,” of the TR, GA-EMS stated that the advanced reactor design criteria (ARDCs) in RG 1.232 were used as a starting point for the development of the FMR PDCs. The ARDCs in RG 1.232 were informed by the GDCs and provide guidelines for PDCs for non-LWR designs. The ARDCs are intended to be technology inclusive, and the RG provides technology-specific design criteria for the SFR and the modular high temperature gas reactor (MHTGR). GA-EMS chose to apply both the technology-inclusive ARDCs and technology-specific criteria, as applicable, because the FMR has design elements similar to those used in developing the SFR- and MHTGR-design criteria (SFR-DC and MHTGR-DC, respectively).

To develop the FMR-DCs, GA-EMS refined the ARDCs by adapting and applying them to the FMR design. In refining the design criteria, the underlying safety basis for each GDC was considered. In cases where the ARDC was not fully applicable to the FMR design, GA-EMS considered the SFR-DC and MHTGR-DC. In determining which of the two technology-specific criteria were most relevant for a given PDC, GA-EMS considered which design (SFR or MHTGR) was most similar to the FMR for the SSC(s) covered by the particular PDC in question. The most relevant technology-specific criterion was then used as the basis for the development of the FMR PDC, which in some cases was further adapted to accommodate the details of the FMR design.

The NRC staff considers this overall approach to be acceptable as it uses the NRC staff-approved guidance in RG 1.232 as a basis for developing design-specific criteria applicable to the FMR.

3.3 Evaluation of FMR Principal Design Criteria

Sections 3.1, "Overall Requirements (FMR Design Criteria 1-5)," through 3.6, "Fuel and Radioactivity Control (FMR Design Criteria 60-64)," of the TR provide an overview of the FMR-DC and highlight important decisions made in developing the criteria. Section 4, "FMR Principal Design Criteria," of the TR provides Table 1 "FMR Principal Design Criteria," containing all the FMR-DCs and the rationale for adaptations to the GDC for each FMR-DC, similar to tables of PDCs presented in RG 1.232.

3.3.1 Overall Requirements (FMR-DC 1-5)

FMR-DC 1, 2, and 5 provide criteria for quality standards and records, protection against natural phenomena, and sharing of SSCs, respectively. Consistent with the corresponding ARDCs, these PDCs are unchanged from GDCs 1, 2, and 5. The NRC staff finds that these ARDCs 1, 2, and 5 are sufficiently broad to apply to the FMR, and the rationale for the underlying safety basis documented in RG 1.232 remains applicable. As such, the NRC finds FMR-DC 1, 2, and 5 to be acceptable.

FMR-DC 3 provides criteria for fire protection. The language adopted for this PDC is the same as ARDC 3. The NRC staff finds that FMR-DC 3 is acceptable because no further adaptation is needed for ARDC 3 and its underlying safety basis, as documented in RG 1.232, is applicable to the FMR design.

FMR-DC 4 provides criteria for the environmental and dynamic effects design basis. While the design criterion does not exclusively relate to the coolant system design, the differences between ARDC 4, SFR-DC 4, and MHTGR-DC 4 are primarily due to considerations resulting from the coolant system design. For FMR-DC 4, GA-EMS adopted MHTGR-DC 4, which is appropriate considering the FMR utilizes a helium coolant system similar to the MHTGR. Because MHTGR-DC 4 is sufficiently broad to apply to the FMR, and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff considers FMR-DC 4 to be acceptable.

3.3.2 Protection by Multiple Fission Product Barriers (FMR-DC 10-19)

Section 3.2, “Protection by Multiple Fission Product Barriers,” of the TR notes that the FMR fission product barriers include fuel pellets, fuel cladding, reactor vessel, and the containment building and associated systems. The FMR fuel safety design approach seeks to control radionuclides primarily at the source during normal operation and accident conditions. The FMR-DC accordingly use the concept of the specified acceptable fuel design limit (SAFDL), as found in GDC 10.

FMR-DC 10 uses language identical to GDC 10, but replaces the word “coolant” with “heat removal.” The FMR uses helium coolant, like the MHTGR. Therefore, this adaptation was chosen to be consistent with MHTGR-DC 10. The rationale for adaptations to the GDC for MHTGR-DC 10 notes the following: “[t]he word ‘coolant’ has been replaced with ‘heat removal,’ as helium coolant inventory control for normal operation and AOOs [anticipated operational occurrences] is not necessary to meet the SARRDLs [specified acceptable radiological release design limits], due to the reactor system design.” Though GA-EMS does not propose the use of specified acceptable radiological release design limits (SARRDLs) for the FMR-DC, the NRC staff finds that this adaptation of GDC 10 is appropriate because the FMR is a helium-cooled reactor and, consistent with the other FMR-DC, does not need helium coolant inventory control for normal operation and anticipated operational occurrences (AOOs). The NRC staff notes that wholesale adoption of the MHTGR-DC for the FMR design is not appropriate because the FMR-DC use SAFDLs rather than SARRDLs.

FMR-DC 11, which ensures the FMR has desirable inherent feedback characteristics, is the same as ARDC 11. The NRC staff finds FMR-DC 11 acceptable as ARDC 11 is sufficiently broad to apply to the FMR and the rationale for the underlying safety basis documented in RG 1.232 remains applicable.

FMR-DC 12 requires suppression of reactor power oscillations to preserve fuel integrity. The language in FMR-DC 12, as described in the GA-EMS response to RAI FMR-DC 12 [5] and as modified in Revision 2 of the FMR PDC TR [6], is almost identical to MHTGR-DC 12 but replaces SARRDLs with SAFDLs and includes the effects of structures on power oscillations. GA-EMS’s rationale for using MHTGR-DC 12 as the basis for FMR-DC 12 is that the helium coolant does not affect core susceptibility to coolant-induced power oscillations, and it is therefore appropriate to remove the word “coolant,” as used in GDC 12. The effects of structures associated with the reactor core were added to FMR-DC 12 because items such as reflectors – which may be considered either outside or not part of the core – may affect susceptibility of the core to power oscillations. The addition of “associated structures” reflects the same language used in ARDC 12. Based on the above discussion, the NRC staff finds that FMR-DC 12 appropriately captures potential contributors to reactor power oscillations in a gas-cooled fast spectrum reactor and is, thus, acceptable.

FMR-DC 13 ensures instrumentation will be able to monitor important variables and systems, and controls will be provided to maintain these variables and systems within prescribed operating ranges. In RG 1.232, the primary differences between ARDC 13, SFR-DC 13, and MHTGR-DC 13 relate to the coolant system design and the containment design. FMR-DC 13 adopts the same language as ARDC 13 but replaces the words “reactor coolant boundary” with "reactor helium pressure boundary," similar to MHTGR-DC 13. The use of "reactor helium pressure boundary" is appropriate given the helium coolant system design for the FMR and does not affect the underlying safety basis documented in RG 1.232, which remains applicable. The NRC staff therefore determined that FMR-DC 13 is acceptable.

FMR-DC 14 and 15 provide design criteria for the reactor helium pressure boundary and adopts the language from MHTGR-DC 14 and 15. The NRC staff finds the use of MHTGR-DC 14 and 15 to be appropriate because the FMR's helium coolant system design is very similar to that of an MHTGR. Because MHTGR-DC 14 and 15 are appropriate for use with the FMR and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FM-DC 14 and 15 are acceptable.

FMR-DC 16 provides a design criterion for the containment. FMR-DC 16 is consistent with SFR-DC 16, which replaces the concept of an "essentially leak-tight" containment from GDC 16 with a concept for a containment "consisting of a low-leakage, pressure retaining structure" with leakage "restricted to less than that needed to meet the acceptable onsite and offsite dose consequence limits as specified in 10 CFR 50.34 for postulated accidents." The basis for SFR-DC 16 is discussed in SECY-93-092 [9], where the Commission agreed that an advanced reactor using a low-leakage, pressure-retaining containment concept should not be required to meet the "essentially leak-tight" statement in GDC 16, provided the containment leakage is less than that needed to meet the acceptable onsite and offsite dose consequence limits. Thus, the NRC staff finds FMR-DC 16 to be consistent with NRC policy for a reactor and containment design of the type used in the FMR and is, therefore, acceptable.

FMR-DC 17 provides design requirements for electric power systems. The NRC staff noted departures from concepts in RG 1.232 for this criterion in the FMR-DC TR. Specifically, MHTGR-DC 17, states, in part, "[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," which was deleted from FMR-DC 17. The NRC staff asked GA-EMS in RAI FMR-DC 17(A) [4], to explain the deletion and clarify whether power is required for important to safety functions. In response to the RAI [5], GA-EMS provided additional information and stated that the deleted statement will be added to the FMR-DC consistent with ARDC 17 and MHTGR-DC 17. Consistent with its response to the RAI [5] GA-EMS added the statement to FMR-DC 17 in Revision 2 of its FMR PDC TR [6].

The NRC staff also noted that requirements for an additional power system were not provided, in FMR-DC 17. Specifically, MHTGR-DC 17 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." The NRC staff requested additional information on any additional power systems in RAI FMR-DC 17(B) [4]. In its response to the RAI [5], GA-EMS provided additional information and stated that language regarding the additional power source will be added to the FMR-DC 17 consistent with MHTGR-DC 17. Consistent with its response to the RAI [5], GA-EMS added the statement to FMR-DC 17 in Revision 2 of its FMR PDC TR [6].

Further, the NRC staff noted that the rationale for FMR-DC 17 in Table 1 of the TR, states, in part, 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." The NRC staff requested clarification regarding the deletion in RAI FMR-DC 17(B) [4]. In its response [5], GA-EMS provided additional information and stated that 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. Specifically, GA-EMS added "[t]he 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," to the rationale for FMR-DC 17. The rationale in MHTGR-DC 17 is applicable to FMR-DC 17 since the FMR is very similar to an MHTGR design for the purposes of the electric power system, as discussed in Section 3.1 of this SE. Consistent with its response to the RAI [5], GA-EMS added the rationale in MHTGR -DC 17 into FMR-DC 17 in Revision 2 of its FMR PDC TR [6]. In conclusion, the NRC staff compared FMR-DC 17 and MHTGR-17 in RG 1.232. The NRC staff verified that FMR-DC 17 and its rationale is the same as that provided in the NRC staff's guidance for MHTGR-DC 17 in RG 1.232. Because MHTGR-DC 17 is appropriate for use with the FMR and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff finds FMR-DC 17 to be acceptable.

FMR-DC 18 provides a criterion for inspection and testing of electric power systems. For FMR-DC 18, Table 1 in the TR states that FMR-DC 18 is the same as ARDC 18 and is applicable to the FMR design. The NRC staff compared FMR-DC 18 and ARDC 18 in RG 1.232 and verified that FMR-DC 18 is the same as the ARDC 18 in RG 1.232. Because ARDC 18 is sufficiently broad to apply to the FMR, and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff finds FMR-DC 18 to be acceptable.

FMR-DC 19 provides control room design criteria. The TR states that FMR-DC 19 is the same as MHTGR-DC 19, but RG 1.232 also states that MHTGR-DC 19 is the same as ARDC 19. ARDC 19 is sufficiently broad to apply to the FMR, and the rationale for the underlying safety basis documented in RG 1.232 remains applicable; therefore, the NRC staff determined that FMR-DC 19 is acceptable.

3.3.3 Protection and Reactivity Control Systems (FMR-DC 20-29)

FMR-DC 20 through 24 provide design criteria for protection system functions, reliability and testability, independence, and failure modes and the separation of protection and control systems. these PDCs are the same as ARDC 20 through 24 (which are the same as GDC 20 through 24). The NRC staff determined that ARDCs 20 through 24 are sufficiently broad to apply to the FMR design without adaptation and their underlying safety basis remains applicable. Therefore, the NRC staff determined that FMR-DC 20 through 24 are acceptable.

FMR-DC 25 provides design criteria for the protection system requirements for control rod malfunctions. FMR-DC 25 and the associated rationale is identical to ARDC 25. Because ARDC 25 is sufficiently broad to apply to the FMR design without adaptation and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FMR-DC 25 is acceptable.

FMR-DC 26 provides criteria for the reactivity control system. The language used is identical to ARDC 26, except that the effects of xenon burnout are explicitly mentioned. This deviation from ARDC 26 is acceptable to the NRC staff because it results in a more restrictive criterion, though the effects of xenon are expected to be minimal for fast reactors. This modification to ARDC 26 is minor and does not affect the underlying safety basis documented in RG 1.232; therefore, the NRC staff determined that FMR-DC 26 is acceptable. The NRC staff notes that GA-EMS did not propose an FMR-DC 27, as the criteria of GDC 27 are incorporated into FMR-DC 26, consistent with ARDC 26. This is also acceptable to the NRC staff because the underlying basis achieved by GDC 27 is incorporated into FMR-DC 26.

FMR-DC 28 provides criteria for reactivity limits and is the same as MHTGR-DC 28. This is acceptable to the NRC staff because MHTGR-DC 28 refers to reactivity control limits protecting the reactor helium pressure boundary from postulated reactivity accidents, which is consistent with the FMR design. Because MHTGR-DC 28 is appropriate for use with the FMR and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FMR-DC 28 is acceptable.

FMR-DC 29 provides criteria for protection against AOOs. The language used is identical to that in ARDC 29 (which is itself the same as GDC 29), and is acceptable to the NRC staff because it is sufficiently broad such that it is applicable to the FMR without modification and the underlying safety basis documented in RG 1.232 remains applicable.

3.3.4 Fluid Systems (FMR-DC 30-46)

FMR-DC 30 through 32 provide criteria for the reactor helium pressure boundary. The language used for these PDCs is the same as the respective MHTGR-DCs, which refer to the reactor helium pressure boundary because the MHTGR uses helium as its primary coolant. This is acceptable to the NRC staff because helium is also used as the FMR primary coolant. Because MHTGR-DC 30 through 32 apply to the FMR design and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FMR-DC 30 through 32 are acceptable.

GA-EMS did not propose a criterion for FMR-DC 33. GDC 33 provides requirements for reactor coolant makeup systems for LWRs. GA-EMS stated in the TR that no similar criterion is applicable for the FMR because reactor coolant inventory makeup is not needed to meet SAFDLs for small leaks. The NRC staff finds that this is consistent with the RG 1.232 rationale for non-applicability of GDC 33 to MHTGRs and is, therefore, acceptable.

FMR-DC 34 provides design criteria for the residual heat removal system. As provided by GA-EMS in its response to RAI FMR-DC 34 [5] and Revision 2 of its FMR PDC TR, the NRC staff notes that the language used is almost identical to MHTGR-DC 34 except it refers to "[s]ystem(s) to remove residual heat" rather than a single "passive system." Similarly, the rationale for adaptations to GDC 34 for FMR-DC 34 is consistent with that provided for MHTGR-DC 34, but states that both active non-safety related systems and passive safety-related systems are available to remove residual heat. Since both active non-safety-related and passive safety-related systems are available in the design, the NRC staff finds that it is reasonable for the FMR-DC to encompass all these systems. Because these adaptations to GDC 34 in MHTGR-DC 34 are appropriate for the FMR design, the NRC staff determined that FMR-DC 34 is acceptable.

GA-EMS did not propose a criterion for FMR-DC 35. GDC 35 provides requirements for emergency core cooling systems (ECCS) for LWRs. GA-EMS stated that ECCS criteria are not applicable to the FMR because it is not necessary to maintain helium coolant inventory to provide emergency core cooling and because postulated accident heat removal is accomplished by the passive residual heat removal system described in FMR-DC 34. This rationale is consistent with the rationale from RG 1.232 regarding emergency core cooling in MHTGRs and therefore is acceptable to the NRC staff.

FMR-DC 36 provides criteria for inspection of the passive residual heat removal system. This PDC is the same as MHTGR-DC 36. This is appropriate because the residual heat removal system described in MHTGR-DC 36 is consistent with the proposed design of the FMR. Because MHTGR-DC 36 is appropriate for use with the FMR, and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FMR-DC 36 is acceptable.

FMR-DC 37, as updated in GA-EMS response to RAI FMR-DC 37 and Revision 2 of the FMR PDC TR [5], provides criteria for testing of the residual heat removal systems. FMR-DC 37 is similar to MHTGR-DC 37, with a change to indicate that multiple systems, both passive safety-related systems and active non-safety-related systems, may be relied upon for residual heat removal. This is consistent with FMR-DC 34, regarding the design of the residual heat removal system. As with FMR-DC 34, the NRC staff finds it reasonable to include both active non-safety-related systems and passive safety-related systems in FMR-DC 37 because both types of systems are available in the design to remove residual heat. Because of the consistency with FMR-DC 34 and similarity to MHTGR-DC 37, which is the most relevant criterion from RG 1.232, the NRC staff determined that FMR-DC 37 is acceptable.

FMR-DC 38 through 43 provide criteria related to systems that help maintain containment integrity and enhance performance during and following postulated accidents, including the containment heat removal system and the containment atmosphere cleanup system (and provisions for the inspection and testing of both systems). The language used for these PDCs is the same as the corresponding ARDCs. The NRC staff finds that these PDC are acceptable because the FMR is utilizing a leak-tight containment design, consistent with the bases for these ARDCs.

FMR-DC 44 through 46 provide criteria related to structural and equipment cooling systems, including the inspection and testing of such systems. For all of these PDCs, the language used is the same as the corresponding ARDC. Because ARDCs 44 through 46 are sufficiently broad to apply to the FMR design and the underlying basis documented within RG 1.232 remains applicable, the NRC staff determined that FMR-DC 44 through 46 are acceptable.

3.3.5 Reactor Containment (FMR-DC 50-57)

FMR-DC 50 through 53 provide criteria related to the design of the FMR structural leak-tight containment, including penetrations, and provisions for testing and inspection of portions important for the leak-tight performance of the structure. For these PDCs, the language used is the same as ARDCs 50 through 53. The NRC staff finds that these criteria are acceptable because the FMR is utilizing a leak-tight containment design, consistent with the bases for these ARDC.

FMR-DC 54 describes general criteria for the design of FMR piping systems penetrating containment, including provisions for leak detection, isolation, and testing. FMR-DC 54 is identical to SFR-DC 54, except for the deletion of the word "reactor" from "reactor containment structure" used in SFR-DC 54. GA-EMS described that the word "reactor" was removed from the FMR-DC 54 because the containment is a barrier between fission products and the environment. Because the direct Brayton cycle power conversion system could have fission products in the helium working fluid, this change is appropriate to identify the presence of major SSCs within containment besides the reactor itself. The FMR conceptual design provides containment around the reactor and power conversion system, consistent with the function to contain fission products. Both SFR-DC 54 and FMR-DC 54 differ from ARDC 54 by the replacement of the phrase "having redundancy, reliability, and performance capabilities that reflect the importance to safety of isolating these piping systems" with "that have redundancy, reliability, and performance capabilities necessary to perform the containment safety function and that reflect the importance to safety of preventing radioactivity releases from containment through these piping systems." As described in RG 1.232 and by GA-EMS, the intent of the change is to accommodate designs capable of demonstrating that containment isolation valves are not necessary for certain piping penetrations that do not provide a credible release path to the atmosphere, such as a closed passive residual heat removal system or intermediate cooling loop. The FMR conceptual design includes the RVCS and intermediate power conversion system heat removal loops that could be designed to achieve the containment function without isolation valves, consistent with the basis for SFR-DC 54. Regardless of the means, FMR-DC 54 specifies that the design capabilities necessary to perform the containment safety function and prevent radioactivity releases from containment will be present. Therefore, the NRC staff finds that FMR-DC 54 is acceptable.

FMR-DC 55 through 57 provide the criteria for the design and configuration of piping penetration isolation capability. FMR-DC 55 and 57 are identical to ARDC 55 and ARDC 57, respectively, except for the replacement of "reactor coolant boundary" with "reactor helium pressure boundary" in FMR-DC 55 (both title and text) and 57 (text only). In its response to RAI FMR-DC 56 [5] GA-EMS stated it would incorporate a modification to FMR-DC 56 that would add 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" to make it identical to ARDC 56. Consistent with its response to the RAI, GA-EMS incorporated this statement into FMR-DC 56 in its Revision 2 of the FMR PDC TR [6]. The replacement of "reactor coolant boundary" with "reactor helium pressure boundary" merely describes the FMR coolant. The FMR conceptual design includes a structural containment with piping penetrations that may include isolation valves, which is consistent with the bases for ARDCs 55 through 57. Therefore, the NRC staff finds that FMR-DC 55 through 57 are acceptable.

3.3.6 Fuel and Radioactivity Control (FMR-DC 60-64)

FMR-DC 60 provides criteria for the capability to control releases of radioactive material to the environment during normal reactor operation, including AOOs. FMR-DC 60 is identical to ARDC 60 (which is itself identical to GDC 60). Since the types of radioactive material addressed by ARDC 60 are applicable to the FMR, ARDC 60 is appropriate to use with the FMR and the underlying safety basis documented in RG 1.232 remains applicable. Therefore, the NRC staff determined that FMR-DC 60 is acceptable.

FMR-DC 61 provides criteria for the fuel storage and handling and radioactivity control under normal and postulated accident conditions. FMR-DC 61 is identical to ARDC 61 for fuel storage. The criteria are sufficiently general to be consistent with expected FMR fuel storage and handling operations and are modified from GDC 61 to provide for a variety of methods for fuel cooling. Because ARDC 61 is appropriate for use with the FMR design and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined FMR-DC 61 is acceptable.

FMR-DC 62 provides a criterion for preventing criticality in fuel storage and handling systems. The language used is the same as the ARDC 62 (which is itself the same as GDC 62). Because ARDC 62 is applicable without modification to the FMR design and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined FMR-DC 62 is acceptable.

FMR-DC 63 provides a criterion for monitoring fuel and waste storage. The language used is the same as ARDC 63 (which is itself the same as GDC 63), which is sufficiently broad to apply to the FMR without modification. Because ARDC 63 is applicable and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined FMR-DC 63 is acceptable.

FMR-DC 64 provides a criterion for monitoring releases of radioactivity. The language used is the same as ARDC 64. For this criterion, RG 1.232 provides SFR and MHTGR-specific PDCs, but the ARDC appears to be the best fit for the FMR design since it is consistent with the pressure-retaining containment approach used for the FMR. Because ARDC 64 is sufficiently broad to apply to the FMR and the underlying safety basis documented in RG 1.232 remains applicable, the NRC staff determined that FMR-DC 64 is acceptable.

4.0 CONCLUSION

Based on the above evaluation, the NRC staff concludes that GA-EMS has considered each of the design aspects presented in RG 1.232 and developed a sufficient set of PDCs that are appropriate for establishing requirements for the FMR design. These PDCs establish the necessary design, fabrication, construction, testing, and performance design criteria for safety significant SSCs to provide reasonable assurance that an FMR could be operated without undue risk to the health and safety of the public. The subject TR is therefore suitable for referencing in future licensing applications for the GA-EMS FMR, provided that the plant design is consistent with that discussed in Section 2 of the TR. If the design differs from that discussed in the TR, justification must be provided as to why the PDCs remain applicable.

5.0 REFERENCES

[1] GA-EMS, “Transmittal of GA-EMS Fast Modular Reactor Principal Design Criteria Topical Report,” dated June 03, 2022, (ML22154A557).

[2] GA-EMS, “Fast Modular Reactor Principal Design Criteria,” 30599T00005, Revision 1, dated May 2022, (ML22154A556).

[3] U.S. NRC, “Completeness Determination for General Atomics Fast Modular Reactor Principal Design Criteria Topical Report,” dated July 07, 2022, (ML22181B171).

[4] U.S. NRC, “Transmittal of Requests for Additional Information - General Atomics-Electromagnetic Systems Fast Modular Reactor Principal Design Criteria Topical Report,” dated October 05, 2022, (ML22321A310).

[5] GA-EMS, “Transmittal of Responses to Request for Additional Information on GA-EMS Fast Modular Reactor Principal Design Criteria Topical Report,” dated November 07, 2022, (ML22311A472).

[6] GA-EMS, "Transmittal of Revised GA-EMS Fast Modular Reactor Principal Design Criteria Topical Report," Revision 2, dated January 5, 2023, (ML23005A290).

[7] U.S. NRC, “Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors,” Regulatory Guide 1.232, dated April 2018, (ML17325A611).

[8] General Atomics, “Fast Modular Reactor Pre-Application Regulatory Engagement Plan,” 30599T00003, Revision 2, dated March 2022, (ML22087A510).

[9] U.S. NRC, “Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements,” SECY-93-092, dated April 1993, (ML040210725).

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