University of Illinois Urbana-Champaign High Temperature Gas-cooled Research Reactor: Micro Modular Reactor (MMR™) Principal Design Criteria

TOPICAL REPORT

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EXECUTIVE SUMMARY

This topical report (TR) summarizes the methodology for development of the principal design criteria (PDC) for the University of Illinois Urbana-Champaign (UIUC) Micro-Modular Reactor (MMR™) designed by the Ultra Safe Nuclear Corporation (USNC). The PDC were developed based on the key design features of the MMR™ technology and use of the modular high-temperature gas-cooled reactor design criteria (MHTGR-DC) provided in Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors." The resultant PDCs incorporate the key design features of the MMR™ technology for licensing of the MMR™ design for deployment at UIUC.

UIUC is requesting the U.S. Nuclear Regulatory Commission (NRC) to provide a safety evaluation of the proposed USNC MMR™ Principal Design Criteria described in Section 4 and listed Appendix A.

Additionally, USNC will be requesting a joint review with the Canadian Nuclear Safety Commission (CNSC) under the Memorandum of Cooperation (MOC), dated August 2019.

ACRONYMS & ABBREVIATIONS

This list contains the acronyms and abbreviations used in this document.

Abbreviation or Acronym	Definition
AC	Alternating Current
AGR	Advanced Gas Reactor
AOO	Anticipated Operational Occurrence
ARDC	Advanced Reactor Design Criteria
CNSC	Canadien Nuclear Safety Commission
CP	Construction Permit
ECCS	Emergency Core Cooling System
EU	Enriched Uranium
FCM®	Fully Ceramic Micro-encapsulated
GDC	General Design Criteria (10 CFR 50, Appendix A)
HALEU	High-Assay Low-Enriched Uranium (i.e., enriched 5% to 20% in ^{235}U, exclusive)
LEU	Low-Enriched Uranium (i.e., enriched 0.72% to 4.95% in ^{235}U)
LWR	Light Water Reactor
MOC	Memorandum of Cooperation
MHTGR	Modular High-Temperature Gas-cooled Reactor
MHTGR-DC	Modular High-Temperature Gas-cooled Reactor - Design Criteria
MMR™	Micro-Modular Reactor
NRC	[U.S.] Nuclear Regulatory Commission
PDC	Principal Design Criteria
RCCS	Reactor Cavity Cooling System
RCSS	Reactivity Control and Shutdown System
RG	Regulatory Guide
SARRDL	Specified Acceptable Radionuclide Release Design Limit
SiC	Silicon Carbide
SSC	Structures, Systems and Components
TR	Topical Report
TLDC	Top Level Design Criteria
TRISO	Tristructural Isotropic
UIUC	University of Illinois Urbana-Champaign
USNC	Ultra Safe Nuclear Corporation

1.0 INTRODUCTION

The Micro Modular Reactor (MMR^{TM}) design is being developed by Ultra Safe Nuclear Corporation (USNC) to be licensed and deployed as a non-power research reactor for the University of Illinois Urbana-Champaign (UIUC) in accordance with the applicable regulatory requirements of the U.S. Nuclear Regulatory Commission (NRC).

The Principal Design Criteria (PDC) provided in this report are based on the key design features of the USNC MMR technology, as summarized in Section 2, and the similarity to the MHTGR-DC design criteria that the NRC provides for advanced reactors in Regulatory Guide 1.232, Revision 0, Appendix C, dated April 2018. The demonstration that the MMR design satisfies these PDC will be provided in the UIUC license application documents (e.g., safety analysis reports, topical reports, etc.) required to be submitted by NRC regulations.

1.1. PURPOSE

This report provides the proposed PDCs for the MMR design developed by USNC using the guidance in RG 1.232 for review and approval by the NRC that will be deployed at UIUC.

1.2. SCOPE

NRC regulations in 10 CFR 50.34(a)(3)(i) require that applicants for a construction permit (CP) include the PDC for a proposed facility. USNC's proposed MMR PDCs are intended for use by UIUC for the non-power research reactor.

1.3. RELATIONSHIP TO OTHER DOCUMENTS

USNC has developed Top Level Design Criteria (TLDC) were referenced primarily from US NRC Regulatory Guide (RG) 1.232, Rev. 0. USNC then used the TLDC as the basis for the PDC that are applicable to the USNC MMR^{TM} design.

NRC regulations in 10 CFR 50, Appendix A provide General Design Criteria (GDC) that establish the minimum requirements for PDC for light water reactors (LWRs). The regulations note that the GDC are generally applicable to other types of reactor units and are intended to provide guidance in establishing the PDC for such other units. That is, the GDC in 10 CFR 50, Appendix A are guidance, not regulatory requirements, for non-LWRs. The NRC published RG 1.232, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" (Ref. 2), dated April 2018, that provides guidance for establishing the PDC for non-light water reactor designs. RG 1.232 includes PDCs for the Modular High-Temperature Gas-Cooled Reactor (MHTGR). USNC has used the advanced reactor design criteria guidance provided by the NRC in RG 1.232 for MHTGRs to develop its proposed PDCs for the USNC MMR^{TM} design for UIUC.

1.4. ACTION REQUESTED

UIUC requests an NRC safety evaluation of the USNC MMR^{TM} PDCs provided in Section 4 and listed in Appendix A to be used for the UIUC MMR^{TM}.

Additionally, USNC will be requesting a joint review with the Canadian Nuclear Safety Commission (CNSC) under the Memorandum of Cooperation (MOC), dated August 2019. USNC has determined that Canada is included as an authorized destination for the sharing of information contained within this Topical Report (TR) in accordance with 10 CFR Part 810, Appendix A, without the imposition of prescribed restrictions.

1.5. DEFINITIONS

1.5.1 Defense in Depth (DiD): A hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions.

1.5.2 Functional Containment: A barrier or set of barriers taken together, that effectively limit the physical transport and release of radionuclides to the environment across a full range of normal operating conditions, AOEs, and accident conditions.

1.5.3 Non-Safety Related (NSR): Relating to SSCs, items, and human actions that are not classified as safety related.

1.5.4 Safety Function: A specific purpose that must be accomplished for safety for a facility or activity to prevent or to mitigate radiological consequences of normal operation, anticipated operational occurrences and accident conditions.

Note: This guidance is commonly condensed into a succinct expression of three fundamental safety functions for nuclear power plants: (a) Control of reactivity; (b) Cooling of radioactive material; (c) Confinement of radioactive material.

1.5.5 Safety Related (SR): Relating to SSCs, items, and human actions that have an impact on safety, and are relied upon to remain functional during and following design basis events to ensure the three fundamental safety functions as defined in 1.5.4 are satisfied. The three fundamental safety functions are used in lieu of the functions for safety related SSCs in 10 CFR 50.2.

2.0 DESIGN FEATURES

The MRR is a modular high temperature gas cooled reactor that uses proprietary Fully Ceramic Micro-Encapsulated (FCM®) pellets that are stacked in columns in solid hexagonal graphite blocks. The FCM pellets incorporate fuel comprised of tristructural isotropic (TRISO) particles embedded in silicon carbide (SiC). The MMR uses an inert gas (helium) as the heat transfer medium. The MMR is designed with a passive safety response to accidents and relies on functional containment as the primary means to limit release of radioactivity to the environment.

The MMR design uses technology and safety capabilities considerably different from the Light Water Reactor (LWR) technology that is the focus of many of the NRC regulations. For example, the MMR does not require an active or passive emergency core cooling system (ECCS) to rapidly replenish primary coolant to recover the fuel in the event of a rupture of the primary pressure boundary. Large safety margins are provided by both the fuel and the reactor design.

- The fuel is comprised of TRISO particles, which provide a highly effective fission product retention capability. The superior fission product retention capability of TRISO fuel particles enables the concept of “functional containment” in which these particles serve as the first containment barrier when operated within the range of qualification parameters.

- The TRISO particles in MMR fuel are encased in an FCM pellet of SiC that provides an additional layer of defense-in-depth for the retention of fission products by functional containment.
- The low power density of the active fuel region leads to slow fuel heat-up during loss of heat removal events.
- Low thermal power results in a small inventory available for release of the most limiting short-lived fission products for public safety, such as ^{131}I and ^{85}Kr. The increased inventory of long-lived fission products associated with a long core life is addressed by the defense-in-depth approach to functional containment.
- The low power rating also reduces the decay heat that must be removed in postulated accidents, simplifying passive decay heat removal.
- Heat transfer fluid used for core cooling during normal operation is an inert, chemically stable, single-phase gas (helium) at operating pressures less than those of LWRs.
- Safety-related core cooling is passive and capable of maintaining fuel and component temperatures below limits with no helium, electrical power, or operator action.
- Secondary heat transfer is performed by a molten salt loop that effectively isolates the reactor from transients in the adjacent plant power conversion system.
- The reactor is located below grade. Although it does not have nor need a leak-tested containment building, it is surrounded by a concrete structure (the citadel) that serves as a barrier to release of radioactivity to the environment and provides protection against external hazards.

Table 2-1 below provides a comparison of the MMR design features to those of the other MHTGR designs that differ from LWRs.

Table 2-1 Comparison of MMR design features with MHTGR design

Design Feature	MHTGR	MMR
Core Design	Fully ceramic TRISO pebble fuel	Fully ceramic micro-encapsulated TRISO particle fuel
Power density	Low	Low
Heat transport (coolant)	Helium gas	Helium gas
Coolant activity	Low (graphite/air)	Low (graphite/air)
Moderator	Graphite	Graphite
Operating Pressure	High	High (but lower than LWRs)
Fission product mobility following fuel damage	Low (retained in fuel)	Low (retained in fuel)
Containment	N/A (based on functional containment concept)	N/A (based on functional containment concept)
Decay Heat Removal	Passive	Passive
Intermediate loop between primary and power conversion	No	Yes (intermediate heat exchanger with molten salt loop)

3.0 MMR PDC DEVELOPMENT METHODOLOGY

This section describes the process used by USNC to develop the PDC for the MMR design to be constructed at UIUC.

The MMR PDC development process began with a review of the advanced reactor design criteria (ARDC) from RG 1.232, Appendix C, to determine the relevance of the MHTGR-DC to the key design features of the MMR technology. Each ARDC in Appendix C of RG 1.232 was reviewed for applicability to the MMR design, considering the underlying safety basis for the ARDC and the supporting information in Appendix C of RG 1.232. In some cases, the ARDC in RG 1.232 adopts the GDC from 10 CFR 50, Appendix A without change.

Based on the similarities with many design features of MHTGR technologies, the MHTGR-DC were specifically reviewed for relevancy to the MMR design to determine whether the MHTGR-DC in RG 1.232, Appendix C, should be considered for inclusion in the proposed PDC for the MMR design. When the USNC review of the MHTGR-DC concluded that those specific ARDC could be directly adopted as written for the MMR design, the MHTGR-DC were selected as the PDC for the MMR design.

For those MHTGR-DC that did not fully apply to the key design features of the MMR design, the MHTGR-DC were assessed to determine if changes to the MHTGR-DC could be made such that they were representative of the MMR design without compromising safety. This assessment is based on technical relevance and the amount of modification that would be necessary to conform to the MHTGR-DC to be representative of the MMR design. Modifications were made to reflect the design of the MMR and the departures from the underlying criteria are annotated (underlined/strikethrough) during development of the proposed MMR PDCs. In most cases, the MHTGR-DC provided in Appendix C to RG 1.232 did not need to be changed for applicability to the MMR design and were adopted as written.

Once the complete set of proposed MMR PDC were developed, a methodical review was performed to ensure that the PDC collectively provide a comprehensive design and regulatory framework for the MMR design. This was done by evaluating each of the major unique design attributes of the MMR design and comparing it against the set of proposed PDC to ensure that there is a PDC that captures the attribute or topic.

The RG 1.232 review method described above was performed by USNC personnel knowledgeable in the MMR technology and development of the MMR design. The results of the review are documented along with a basis for selection of the MMR PDC. The results of the review and the proposed MMR PDC are provided in Section 4. The MMR PDC were internally reviewed by USNC engineering and licensing personnel.

For the MMR standard design, the proposed MMR PDC are intended to be applicable to all SSCs identified as important to safety. However, the MMR at UIUC is intended to be licensed as a non-power research reactor. Consequently, the safety classification methodology for the UIUC application only includes two SSC classifications: safety related, and non-safety related. Therefore, all references of “important to safety” SSCs and functions in the proposed PDC in Section 4.0 and Appendix A should be interpreted as SSCs and functions classified as “safety-related” for the UIUC MMR. The term important to safety is retained in this TR to maintain consistency with MMR standard design documents.

4.0 PROPOSED MMR PDC

The proposed MMR PDCs are subdivided into categories similar to those used for the MHTGR-DC in RG 1.232, Appendix C:

1. Overall Requirements
2. Multiple Barriers
3. Reactivity Control
4. Heat Transport Systems
5. Fuel and Radioactivity Control

Proposed changes to RG 1.232 MHTGR design criteria to accommodate the USNC MMR design to be deployed at UIUC are documented in the table provided in Appendix A. Changes are identified by strikeouts to indicate language removed from the MHTGR-DC and underlines are provided for language additions to the MMR PDC. Example provided below.

This PDC indicates that USNC has replaced the term *reactor building* with *citadel*.

EXAMPLE:

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comments
72	Provisions for periodic ~~reactor building~~ inspection. 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.	Provisions for periodic citadel inspection. The <u>citadel</u> shall be designed to permit (1) appropriate periodic inspection of all important structural areas and the depressurization pathway, and (2) an appropriate surveillance program.	Minor deviations from RG 1.232. Consistent with the intent of MHTGR-DC.

Consistent with the ARDCs provided for MHTGRs in RG 1.232, the proposed PDCs for the MMR design do not include PDCs associated with a containment structure. As discussed in Appendix C to RG 1.232, the GDCs associated with the containment structure are very specific to a pressure retaining containment structure and include containment design basis, fracture prevention of containment pressure boundary, capability for containment leakage rate testing, provisions for containment testing and inspection, piping systems penetrating containment, reactor coolant boundary penetrating containment, containment isolation, and closed system isolation valves. As noted in Appendix C to RG 1.232, the MHTGR designs do not have a pressure retaining reactor containment structure. The USNC MMR relies upon a multi-barrier functional containment fuel pellet to control the release of radionuclides. On that basis, the eight criteria associated with the containment structure were deemed to be not applicable to the MHTGR-DC. Based on the similarity of the key design features between the MMR and MHTGR designs, the MHTGR-DC approach of not including PDCs associated with pressure retaining containment structures is applicable to the MMR design.

A comparison of the proposed MMR PDCs with the advanced reactor MHTGR-DC in RG 1.232, Appendix C, is provided as Attachment A to this report. This comparison provides notes for differences between the USNC MMR PDCs and the MHTGR-DC with a suitable justification for necessary changes.

4.1 OVERALL REQUIREMENTS

4.1.1. Quality standards and records (PDC-1)

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.

4.1.2. Design bases for protection against natural phenomena (PDC-2)

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 (3) the importance of the safety functions to be performed.

4.1.3. Fire protection (PDC-3)

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. Non-combustible and fire-resistant materials shall be used wherever practical throughout the unit, particularly in locations with structures, systems, or components important to safety. 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 ensure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.

4.1.4. Environmental and dynamic effects design bases (PDC-4)

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 originating both inside and outside the reactor helium pressure boundary, 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 Regulator demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

4.1.5 Sharing of structures, systems, and components (PDC-5)

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.

4.2 MULTIPLE BARRIERS

4.2.1. Reactor design (PDC-10)

The reactor system and associated heat removal, control, and protection systems shall be designed with appropriate margin to ensure that specified acceptable system radionuclide release design limits (SARRDL) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

4.2.2. Reactor inherent protection (PDC-11)

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.

4.2.3. Suppression of reactor power oscillations (PDC-12)

The reactor core and associated control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable system radionuclide release design limits (SARRDL) are not possible or can be reliably and readily detected and suppressed.

4.2.4. Instrumentation and control (PDC-13)

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 ensure adequate safety, including those variables and systems that can affect the fission process and the integrity of the reactor core, reactor helium pressure boundary, and functional containment. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges.

4.2.5. Reactor helium pressure boundary (PDC-14)

The reactor helium pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, of gross rupture, and of unacceptable ingress of moisture, air, secondary coolant, or other fluids.

4.2.6. Reactor helium pressure boundary design (PDC-15)

The reactor system, vessel system, and heat removal systems, and the associated auxiliary control and protection systems, shall be designed with sufficient margin to ensure that the design conditions of the reactor helium pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences.

4.2.7. Containment design (PDC-16)

Technical basis for FCM fuel satisfying the requirement for reactor functional containment, consisting of multiple barriers in both the TRISO fuel and FCM matrix, shall be provided. The functional containment provided by FCM will control the release of radioactivity to the environment and ensure the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

4.2.8. Electric power systems (PDC-17)

With electrical power not needed for anticipated operational occurrences or postulated accidents, the design shall demonstrate that power for important to safety functions is provided.

Electrical power is not needed for anticipated operational occurrences or postulated accidents. The design shall demonstrate that power for important to safety functions is provided.

4.2.9. Inspection and testing of electric power systems (PDC-18)

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.

4.2.10. Control room or secure remote monitoring facility (PDC-19)

A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and either a control room or a remote monitoring facility shall be provided to monitor it under accident conditions. 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 2 rem (20 mSv) total effective dose equivalent 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. 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.

4.2.11 Citadel design basis - Release during Depressurization Accident (PDC-71b).

The design of the citadel shall be such that, during postulated accidents, it structurally protects the geometry to provide a pathway for the release of reactor helium from the building in the event of depressurization accidents.

4.2.12. Provisions for periodic Citadel inspection (PDC-72)

The Citadel shall be designed to permit (1) appropriate periodic inspection of all important structural areas and the depressurization pathway, and (2) an appropriate surveillance program.

4.3 REACTIVITY CONTROL

4.3.1. Protection system functions (PDC-20)

The protection system shall be designed (1) to initiate automatically the operation of appropriate systems, including the reactivity control systems, to ensure that the specified acceptable system radionuclide release design limit (SARRDL) is 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.

4.3.2. Protection system reliability and testability (PDC-21)

The protection system shall be designed for high functional reliability and in service 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.

4.3.3. Protection system independence (PDC-22)

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.

4.3.4. Protection system failure modes (PDC-23)

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.

4.3.5. Separation of protection and control systems (PDC-24)

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 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.

4.3.6. Protection system requirements for reactivity control malfunctions (PDC-25)

The protection system shall be designed to ensure that specified acceptable system radionuclide release design limits (SARRDL) are not exceeded during any anticipated operational occurrence, accounting for a single malfunction of the reactivity control systems.

4.3.7. Reactivity control systems (PDC-26)

The reactivity control systems or means shall provide: a) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the specified acceptable system radionuclide release design limits (SARRDL) and the reactor helium pressure boundary design limits are not exceeded, and safe shutdown is achieved and maintained during normal operation, including anticipated operational occurrences. b) A means which is independent and diverse from the other(s), shall be capable of controlling the rate of reactivity changes resulting from planned, normal power changes to assure that the SARRDL and the reactor helium pressure boundary design limits are not exceeded. c) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the capability to cool the core is maintained and a means of shutting down the reactor and maintaining, at a minimum, a safe shutdown condition following a postulated accident. d) A means for holding the reactor shutdown under conditions which allow for interventions such as inspection and repair shall be provided.

4.3.8. Reactivity limits (PDC-28)

The reactor core, including the reactivity control systems, shall be designed with appropriate limits on the potential amount and rate of reactivity increase to ensure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor helium pressure boundary greater than limited local yielding, nor (2) sufficiently disturb the core, its support structures, or other reactor vessel internals to impair significantly the capability to cool the core.

4.3.9. Protection against anticipated operational occurrences (PDC-29)

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.

4.3.10. Reactor vessel and reactor system structural design basis (PDC-70b)

The design of the reactor vessel and reactor system shall be such that their integrity is maintained during postulated accidents to permit sufficient insertion of the neutron absorbers to provide for reactor shutdown.

4.4 HEAT TRANSPORT SYSTEMS

4.4.1. Quality of reactor helium pressure boundary integrity including reducing fluid ingress (PDC-30)

Components that are part of the reactor helium pressure boundary shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor helium leakage. Means shall be provided for detecting ingress of moisture, air, secondary coolant, or other fluids to within the reactor helium pressure boundary.

4.4.2. Fracture prevention of reactor helium pressure boundary (PDC-31)

The reactor helium pressure boundary shall be designed with sufficient margin to ensure that, when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures, service degradation of material properties, creep, fatigue, stress rupture, and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation and helium composition, including contaminants and reaction products, on material properties, (3) residual, steady-state, and transient stresses, and (4) size of flaws.

4.4.3. Inspection of reactor helium pressure boundary (PDC-32)

Components that are part of the reactor helium pressure boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leak tight integrity, and (2) an appropriate material surveillance program for the reactor vessel as applicable or justification if not required.

4.4.4. Passive residual heat removal (PDC-34)

A passive system to remove residual heat shall be provided for normal operations and anticipated operational occurrences, the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core to an ultimate heat sink at a rate such that specified acceptable system radionuclide release design limits (SARRDL) and the design conditions of the reactor helium pressure boundary are not exceeded. During postulated accidents, the system safety function shall provide effective 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.

4.4.5. Inspection of passive residual heat removal system (PDC-36)

The passive residual heat removal system shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system.

4.4.6. Testing of passive residual heat removal system (PDC-37)

The passive residual heat removal system shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leak tight integrity of its components <u>as applicable</u>, (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 associated systems, for AOO or postulated accident decay heat removal to the ultimate heat sink and, if applicable, any system(s) necessary to transition from active normal operation to passive mode.

4.4.7. Structural and equipment cooling (PDC-44)

In addition to the heat rejection capability of the passive residual heat removal system, systems to transfer heat from structures, systems, and components important to safety to an ultimate heat sink shall be provided, as necessary, to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions. Suitable redundancy in components and features and suitable interconnections leak detection, and isolation capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.

4.4.8. Inspection of structural and equipment cooling systems (PDC-45)

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.

4.4.9. Testing of structural and equipment cooling systems (PDC-46)

The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural and leak tight 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.

4.4.10. Citadel design basis (PDC-70a)

The design of the reactor vessel and reactor system shall be such that their integrity is maintained during postulated accidents to ensure the geometry for passive removal of residual heat from the reactor core to the ultimate heat sink.

4.4.11. Citadel design basis – Residual Heat Removal (PDC-71a)

The design of the Citadel 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.

4.5 FUEL AND RADIOACTIVITY CONTROL

4.5.1. Control of releases of radioactive materials to the environment (PDC-60)

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.

4.5.2. Fuel storage and handling and Radioactivity control (PDC-61)

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.

4.5.3. Prevention of criticality in fuel storage and handling (PDC-62)

Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.

4.5.4. Monitoring fuel and waste storage (PDC-63)

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.

4.5.5. Monitoring radioactivity releases (PDC-64)

Means shall be provided for monitoring the Citadel atmosphere, effluent discharge paths, and plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

5.0 CONCLUSIONS AND RECOMMENDATIONS

USNC performed a comprehensive review of the advanced reactor design criteria provided by the NRC in RG 1.232, Appendix C, for modular high-temperature gas-cooled reactors and developed a set of proposed principal design criteria (PDC) for its MMR design based on the MHGTR-DC that meet the requirements of 10 CFR 50.34(a)(3)(i) and the underlying safety objectives of 10 CFR 50 Appendix A as applicable. In addition, the proposed PDCs meet the requirements of 10 CFR 52.47(a)(3)(i), 10 CFR 52.79(a)(4)(i), 10 CFR 52.137(a)(3)(i), and 10 CFR 52.157(a).

These proposed PDC reflect the key features of the MMR design and provide an appropriate set of requirements to facilitate the licensing of the MMR design. As such, once approved, these PDC apply for use by UIUC and future license applicants for the USNC MMR design under 10 CFR 50 or 10 CFR 52.

6.0 REFERENCES

6.1 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.232, “Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors,” Rev. 0, dated April 2018.

6.2 USNC “MMR Top Level Design Criteria Specification”, Release 02, dated 06 October 2023.

7.0 APPENDICES

7.1 APPENDIX A: Comparison of RG 1.232 Appendix C MHTGR DC and USNC MMR PDC

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
I. OVERALL REQUIREMENTS			
1	**Quality standards and records.** 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.	**Quality standards and records.** 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
2	**Design bases for protection against natural phenomena.** 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	**Design bases for protection against natural phenomena.** 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	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	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.	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.** 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. Non-combustible and fire-resistant materials shall be used wherever practical throughout the unit, particularly in locations with structures, systems, or components important to safety. 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 ensure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.	**Fire protection.** 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. Non-combustible and fire-resistant materials shall be used wherever practical throughout the unit, particularly in locations with structures, systems, or components important to safety. 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 ensure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
4	**Environmental and dynamic effects design bases.** Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles originating both inside and outside the reactor helium pressure boundary, 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.	**Environmental and dynamic effects design bases.** Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles originating both inside and outside the reactor helium pressure boundary, 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 Regulator demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.	No deviations from RG 1.232. Consistent with MHTGR-DC.
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	**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	No deviations from RG 1.232. Consistent with MHTGR-DC. The UIUC research reactor deployment does not currently include plans for

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	accident in one unit, an orderly shutdown and cooldown of the remaining units.	accident in one unit, an orderly shutdown and cooldown of the remaining units.	more than one unit which will be noted in the SAR.
	II. MULTIPLE BARRIERS		
10	**Reactor design.** The reactor system and associated heat removal, control, and protection systems shall be designed with appropriate margin to ensure that specified acceptable system radionuclide release design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.	**Reactor design.** The reactor system and associated heat removal, control, and protection systems shall be designed with appropriate margin to ensure that specified acceptable system radionuclide release design limits (SARRDL) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.	Added acronym (SARRDL). No material deviations from RG 1.232. Consistent with MHTGR-DC.
11	**Reactor inherent protection.** 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.	**Reactor inherent protection.** 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
12	**Suppression of reactor power oscillations.** The reactor core and associated control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable system radionuclide release design limits are not possible or can be reliably and readily detected and suppressed.	**Suppression of reactor power oscillations**. The reactor core and associated control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable system radionuclide release design limits (SARRDL) are not possible or can be reliably and readily detected and suppressed.	Added acronym (SARRDL) No material deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
13	**Instrumentation and control.** 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 ensure adequate safety, including those variables and systems that can affect the fission process and the integrity of the reactor core, reactor helium pressure boundary, and functional containment. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges.	**Instrumentation and control.** 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 ensure adequate safety, including those variables and systems that can affect the fission process and the integrity of the reactor core, reactor helium pressure boundary, and functional containment. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges.	No deviations from RG 1.232. Consistent with MHTGR-DC.
14	**Reactor helium pressure boundary.** The reactor helium pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, of gross rupture, and of unacceptable ingress of moisture, air, secondary coolant, or other fluids.	**Reactor helium pressure boundary.** The reactor helium pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, of gross rupture, and of unacceptable ingress of moisture, air, secondary coolant, or other fluids.	No deviations from RG 1.232. Consistent with MHTGR-DC.
15	**Reactor helium pressure boundary design.** ~~All systems that are part of the reactor helium pressure boundary, such as~~ the reactor system, vessel system, and heat removal systems, and the associated auxiliary, control, and protection systems, shall be designed with sufficient margin to ensure that the design conditions of the reactor helium pressure boundary are not exceeded during	**Reactor helium pressure boundary design.** The reactor system, vessel system, and heat removal systems, and the associated auxiliary, control and protection systems, shall be designed with sufficient margin to ensure that the design conditions of the reactor helium pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences	Minor deviation from RG 1.232 to remove the phrase, “All systems that are part of the reactor helium pressure boundary, such as …” because of conflicting

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	any condition of normal operation, including anticipated operational occurrences.		definitions between the NRC terminology and the terminology used by USNC for the MMR design for the helium pressure boundary, to be described in the UIUC PSAR.
16	**Containment design.** A reactor functional containment, consisting of multiple barriers ~~internal and/or external to the reactor and its cooling system~~, shall be provided to control the release of radioactivity to the environment and to ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.	**Containment design.** Technical basis for FCM fuel satisfying the requirement for reactor functional containment, consisting of multiple barriers in both the TRISO fuel and FCM matrix, shall be provided. The functional containment provided by FCM will control the release of radioactivity to the environment and ensure the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.	Deviation from the language used in RG 1.232 to include the type and design of fuel used in the MMR core that provides functional containment and to define that functional containment is within the fuel, not external to the reactor.
17	**Electric power systems.** ~~Electric power systems shall be provided when required to permit functioning of structures, systems, and components. The safety function for each power system shall be to provide sufficient~~	**Electric power systems.** Electrical power is not needed for anticipated operational occurrences or postulated accidents. The design shall demonstrate that power for important to safety functions is provided.	Deviations from the language used in RG 1.232. The requirement for a specific

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	~~capacity and capability to ensure that (1) that the specified acceptable system radionuclide release design limits and the reactor helium pressure boundary design limits are not exceeded as a result of anticipated operational occurrences and (2) 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 shall have sufficient independence, redundancy, and testability to perform its 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.		additional power system is not needed for the MMR design due to its passive nature and the requirement for redundancy already included for the onsite electric power system. The proposed PDC is considered to be functionally consistent with this MHTGR-DC.
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	**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	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	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.	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.	
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 the control room under accident conditions without personnel receiving radiation exposures in excess of ~~5~~ rem total effective dose equivalent ~~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. 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.	**Control room or secure remote monitoring facility.** A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and either a control room or a remote monitoring facility shall be provided to monitor it under accident conditions. 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 2 rem (20 mSv) total effective dose equivalent 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. 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	Minor deviations from RG 1.232 due the passive cooling nature of the MMR design, no operator actions are credited nor required to maintain the reactor in a safe condition following an accident, therefore, the term “monitor” is used instead of “maintain”. Changed radiation exposure level from 5 rem to 2 rem to align with conservative dose limits recognized internationally that

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
		capability for subsequent cold shutdown of the reactor through the use of suitable procedures.	the MMR design is capable of achieving due to the significantly lower source term of typical LWRs.
71b	**~~Reactor building~~ design basis. [MHTGR-DC-71]** 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~~ provide~~s~~ a pathway for the release of reactor helium from the building in the event of depressurization accidents.	**Citadel design basis - Release during Depressurization Accident.** The design of the citadel shall be such that, during postulated accidents, it structurally protects the geometry to provide a pathway for the release of reactor helium from the building in the event of depressurization accidents.	MHTGR-DC-71 was separated and categorized resulting in two distinctive design criteria for functional clarity (71a & 71b).
72	**Provisions for periodic ~~reactor building~~ inspection.** 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.	**Provisions for periodic citadel inspection.** The citadel shall be designed to permit (1) appropriate periodic inspection of all important structural areas and the depressurization pathway, and (2) an appropriate surveillance program.	Minor deviations from RG 1.232. Consistent with the intent of MHTGR-DC.
III. REACTIVITY CONTROL			
20	**Protection system functions.** The protection system shall be designed (1) to initiate automatically the operation of appropriate systems, including the reactivity control systems, to ensure that the specified acceptable system radionuclide release design limits is not exceeded	**Protection system functions.** The protection system shall be designed (1) to initiate automatically the operation of appropriate systems, including the reactivity control systems, to ensure that the specified acceptable system radionuclide release design limits (SARRDL) is not	Added acronym (SARRDL) Minor deviations from RG 1.232. Consistent with the

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	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.	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.	intent of MHTGR-DC.
21	**Protection system reliability and testability.** The protection system shall be designed for high functional reliability and in service 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.	**Protection system reliability and testability.** The protection system shall be designed for high functional reliability and in service 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
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,	**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,	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	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.	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.	
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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
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 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.	**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 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
25	**Protection system requirements for reactivity control malfunctions.**	**Protection system requirements for reactivity control malfunctions.**	Added acronym (SARRDL)

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	The protection system shall be designed to ensure that specified acceptable system radionuclide release design limits are not exceeded during any anticipated operational occurrence, accounting for a single malfunction of the reactivity control systems.	The protection system shall be designed to ensure that specified acceptable system radionuclide release design limits (SARRDL) are not exceeded during any anticipated operational occurrence, accounting for a single malfunction of the reactivity control systems.	No material deviations from RG 1.232. Consistent with MHTGR-DC.
26	**Reactivity control systems.** ~~A minimum of two~~ reactivity control systems or means shall provide: (1) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the specified acceptable system radionuclide release design limits and the reactor helium pressure boundary design limits are not exceeded and safe shutdown is achieved and maintained during normal operation, including anticipated operational occurrences. (2) A means which is independent and diverse from the other(s), shall be capable of controlling the rate of reactivity changes resulting from planned, normal power changes to assure that the specified acceptable system radionuclide release design limits and the reactor helium pressure boundary design limits are not exceeded. (3) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the capability to cool the core is maintained and a	**Reactivity control systems.** The reactivity control systems or means shall provide: (1) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the specified acceptable system radionuclide release design limits (SARRDL) and the reactor helium pressure boundary design limits are not exceeded, and safe shutdown is achieved and maintained during normal operation, including anticipated operational occurrences. (2) A means which is independent and diverse from the other(s), shall be capable of controlling the rate of reactivity changes resulting from planned, normal power changes to assure that the SARRDL and the reactor helium pressure boundary design limits are not exceeded. (3) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the capability to cool the core is maintained and a means of shutting down the reactor and	Minor deviations from the language used in RG 1.232. Otherwise, consistent with MHTGR-DC. Deleted: “A minimum of two” and replaced with “The”. The wording in the original text was suggesting that there must be two of each for the four sections mentioned. USNC interpretation is that two systems must satisfy at least one of the four sections, and not all.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	means of shutting down the reactor and maintaining, at a minimum, a safe shutdown condition following a postulated accident. (4) A means for holding the reactor shutdown under conditions which allow for interventions such as ~~fuel loading~~, inspection and repair shall be provided.	maintaining, at a minimum, a safe shutdown condition following a postulated accident. (4) A means for holding the reactor shutdown under conditions which allow for interventions such as inspection and repair shall be provided.	
27	**Combined reactivity control systems capability.** DELETED—Information incorporated into MHTGR-DC 26	**N/A**	No deviations from RG 1.232. Consistent with MHTGR-DC.
28	**Reactivity limits.** The reactor core, including the reactivity control systems, shall be designed with appropriate limits on the potential amount and rate of reactivity increase to ensure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor helium pressure boundary greater than limited local yielding, nor (2) sufficiently disturb the core, its support structures, or other reactor vessel internals to impair significantly the capability to cool the core.	**Reactivity limits.** The reactor core, including the reactivity control systems, shall be designed with appropriate limits on the potential amount and rate of reactivity increase to ensure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor helium pressure boundary greater than limited local yielding, nor (2) sufficiently disturb the core, its support structures, or other reactor vessel internals to impair significantly the capability to cool the core.	No deviations from RG 1.232. Consistent with MHTGR-DC.
29	**Protection against anticipated operational occurrences.** The protection and reactivity control systems shall be designed to assure an extremely high	**Protection against anticipated operational occurrences.** The protection and reactivity control systems shall be designed to assure an extremely high	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	probability of accomplishing their safety functions in the event of anticipated operational occurrences.	probability of accomplishing their safety functions in the event of anticipated operational occurrences.	
70b	**Reactor vessel and reactor system structural design basis. [MHTGR-DC-70]** 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.	**Reactor vessel and reactor system structural design basis.** The design of the reactor vessel and reactor system shall be such that their integrity is maintained during postulated accidents to permit sufficient insertion of the neutron absorbers to provide for reactor shutdown.	MHTGR-DC-70 items 1 and 2 are separated and categorized resulting in two distinctive design criteria for functional clarity as 70a & 70b.
	IV. HEAT TRANSPORT SYSTEMS		
30	**Quality of reactor helium pressure boundary.** Components that are part of the reactor helium pressure boundary shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor helium leakage. Means shall be provided for detecting ingress of moisture, air, secondary coolant, or other fluids to within the reactor helium pressure boundary.	**Quality of reactor helium pressure boundary integrity including reducing fluid ingress.** Components that are part of the reactor helium pressure boundary shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor helium leakage. Means shall be provided for detecting ingress of moisture, air, secondary coolant, or other fluids to within the reactor helium pressure boundary.	No material deviations from RG 1.232. Consistent with MHTGR-DC. Title changed for clarity.
31	**Fracture prevention of reactor helium pressure boundary.** The reactor helium pressure boundary shall be designed with sufficient margin to ensure that,	**Fracture prevention of reactor helium pressure boundary.** The reactor helium pressure boundary shall be designed with sufficient margin to ensure that,	No deviations from RG 1.232. Consistent with MHTGR-DC.

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	when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures, service degradation of material properties, creep, fatigue, stress rupture, and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation and helium composition, including contaminants and reaction products, on material properties, (3) residual, steady-state, and transient stresses, and (4) size of flaws.	when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures, service degradation of material properties, creep, fatigue, stress rupture, and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation and helium composition, including contaminants and reaction products, on material properties, (3) residual, steady-state, and transient stresses, and (4) size of flaws.	
32	**Inspection of reactor helium pressure boundary.** Components that are part of the reactor helium pressure boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leak tight integrity, and (2) an appropriate material surveillance program for the reactor vessel.	**Inspection of reactor helium pressure boundary.** Components that are part of the reactor helium pressure boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leak tight integrity, and (2) an appropriate material surveillance program for the reactor vessel <u>as applicable or justification if not required</u>.	Added at the end of paragraph (2) “as applicable or justification if not required “ It is not currently clear whether this requirement will be necessary, hence included for now, but as design progresses, it may become unnecessary, which will be

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			justified at the time and included in the SAR.
33	**Reactor coolant makeup.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
34	**Passive residual heat removal.** A passive system to remove residual heat shall be provided. For normal operations and anticipated operational occurrences, the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core to an ultimate heat sink at a rate such that specified acceptable system radionuclide release design limits and the design conditions of the reactor helium pressure boundary are not exceeded. During postulated accidents, the system safety function shall provide effective 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.	**Passive (source range) residual heat removal.** A passive system to remove residual heat shall be provided. For normal operations and anticipated operational occurrences, the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core to an ultimate heat sink at a rate such that specified acceptable system radionuclide release design limits (SARRDL) and the design conditions of the reactor helium pressure boundary are not exceeded. During postulated accidents, the system safety function shall provide effective 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.	Added acronym (SARRDL) No material deviations from RG 1.232. Consistent with MHTGR-DC.
35	**Emergency core cooling.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
36	**Inspection of passive residual heat removal system.**	**Inspection of passive residual heat removal system.**	No deviations from RG 1.232.

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	The passive residual heat removal system shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system.	The passive residual heat removal system shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system.	Consistent with MHTGR-DC.
37	**Testing of passive residual heat removal system.** The passive residual heat removal system 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 associated systems, for AOO or postulated accident decay heat removal to the ultimate heat sink and, if applicable, any system(s) necessary to transition from active normal operation to passive mode.	**Testing of passive residual heat removal system.** The passive residual heat removal system shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leak tight integrity of its components <u>as applicable</u>, (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 associated systems, for AOO or postulated accident decay heat removal to the ultimate heat sink and, if applicable, any system(s) necessary to transition from active normal operation to passive mode.	Minor deviation from the language used in RG 1.232. Otherwise, consistent with MHTGR-DC.
38	**Containment heat removal.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
39	**Inspection of containment heat removal system.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
40	**Testing of containment heat removal system.**	**N/A**	No deviations from RG 1.232.

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	Not applicable to MHTGR.		
41	**Containment atmosphere cleanup.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
42	**Inspection of containment atmosphere cleanup systems.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
43	**Testing of containment atmosphere cleanup systems.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
44	**Structural and equipment cooling.** In addition to the heat rejection capability of the passive residual heat removal system, systems to transfer heat from structures, systems, and components important to safety to an ultimate heat sink shall be provided, as necessary, to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions. Suitable redundancy in components and features and suitable interconnections leak detection, and isolation capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.	**Structural and equipment cooling.** In addition to the heat rejection capability of the passive residual heat removal system, systems to transfer heat from structures, systems, and components important to safety to an ultimate heat sink shall be provided, as necessary, to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions. Suitable redundancy in components and features and suitable interconnections leak detection, and isolation capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.	No deviations from RG 1.232, consistent with MHTGR-DC.
45	**Inspection of structural and equipment cooling systems.**	**Inspection of structural and equipment cooling systems.**	No deviations from RG 1.232,

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
	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.	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.	consistent with MHTGR-DC.
46	**Testing of structural and equipment cooling systems.** The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural and leak tight 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.	**Testing of structural and equipment cooling systems.** The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural and leak tight 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.	No deviations from RG 1.232, consistent with MHTGR-DC.
70a	**Reactor vessel and reactor system structural design basis. [MHTGR-DC-70]** 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~~.	**Reactor vessel and reactor system structural design basis.** The design of the reactor vessel and reactor system shall be such that their integrity is maintained during postulated accidents to ensure the geometry for passive removal of residual heat from the reactor core to the ultimate heat sink.	MHTGR-DC-70 items (1) & (2) are separated and re-categorized resulting in two distinctive design criteria for functional clarity as PDCs 70a & 70b. There are no changes to RG

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
			1.232 MHTGR-DC-70, item (1).
71a	**~~Reactor building~~ design basis. [MHTGR-DC-71]** 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 the release of reactor helium from the building in the event of depressurization accidents.~~	**Citadel design basis – Residual Heat Removal.** The design of the Citadel 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.	MHTGR-DC-71 was separated and categorized resulting in two distinctive design criteria for functional clarity (71a & 71b).
	V. REACTOR CONTAINMENT		
50	**Containment design basis.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
51	**Fracture prevention of containment pressure boundary.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
52	**Capability for containment leakage rate testing.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
53	**Provisions for containment testing and inspection.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
54	**Piping systems penetrating containment.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.

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55	**Reactor coolant boundary penetrating containment.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
56	**Primary Containment isolation.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
57	**Closed system isolation valves.** Not applicable to MHTGR.	**N/A**	No deviations from RG 1.232.
VI. FUEL AND RADIOACTIVITY CONTROL			
60	**Control of releases of radioactive materials to the environment.** 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.	**Control of releases of radioactive materials to the environment.** 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.
61	**Fuel storage and handling and radioactivity control.**	**Fuel storage and handling and radioactivity control.**	No deviations from RG 1.232.

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	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.	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.	Consistent with MHTGR-DC.
62	**Prevention of criticality in fuel storage and handling.** Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.	**Prevention of criticality in fuel storage and handling.** Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.	No deviations from RG 1.232. Consistent with MHTGR-DC.
63	**Monitoring fuel and waste storage.** 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.	**Monitoring fuel and waste storage.** 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.	No deviations from RG 1.232. Consistent with MHTGR-DC.

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
64	**Monitoring radioactivity releases.** Means shall be provided for monitoring the ~~reactor building~~ atmosphere, effluent discharge paths, and plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.	**Monitoring radioactivity releases.** Means shall be provided for monitoring the <u>Citadel</u> atmosphere, effluent discharge paths, and plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.	Minor deviation from RG 1.232 to replace "reactor building" with "Citadel", otherwise, consistent with MHTGR-DC.
	VII. Additional MHTGR-DC		
70	**Reactor vessel and reactor system structural design basis.** 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.	**Reactor vessel and reactor system structural design basis.** See PDC-70a and 70b.	MHTGR-DC-70 was separated and categorized resulting in two distinctive design criteria for functional clarity (70a & 70b).
71	**Reactor building design basis.** 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 the release of reactor helium from the building in the event of depressurization accidents.	See PDC-71a and 71b.	MHTGR-DC-71 was separated and categorized resulting in two distinctive design criteria for functional clarity (71a & 71b).

PDC No.	NRC RG 1.232, Appendix C MHTGR-DC Title and Content	USNC MMR PDC	Comment
72	**Provisions for periodic reactor building inspection.** 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.	See comment	MHTGR-DC-72 is provided in Section 4.2 and Appendix A, category II as a “Multiple Barrier”