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Technical Data Record

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Key Pebble Bed Reactor Design Requirements

BEA Contract No. 000 75310

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Does this document contain assumptions requiring verification? ☐ YES ☒ NO

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1.0 OBJECTIVE

The objective of this document is to identify the key design requirements for the Pebble Bed Reactor (PBR) concept for the Next Generation Nuclear Plant (NGNP). The design requirements will include significant plant, system and component requirements. The AREVA team will use these design requirements to support the PBR technology status assessment effort.

1.1 Acronyms

ALARA	As Low As Reasonably Achievable
AOO	Anticipated Operating Occurrence
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel Code
CTF	Component Test Facility
DBA	Design Basis Accident
DC	Direct Current
DOE	Department of Energy
EAB	Exclusion Area Boundary
EPA	Environmental Protection Agency
FHS	Fuel Handling System
FIMA	Fissions per initial metal atom
FOAK	First-of-a-kind
HTGR	High Temperature Gas-Cooled Reactor
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
ITAAC	Inspections, Tests, Analyses, and Acceptance Criteria
LEU	Low Enriched Uranium
LWR	Light Water Reactor
MHC	Main Helium Circulator
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NGNP	Next Generation Nuclear Plant
NHSS	Nuclear Heat Supply System
NOAK	N^{th}-of-a-kind
NRC	Nuclear Regulatory Commission
PBR	Pebble Bed Reactor
PCS	Power Conversion System
RCCS	Reactor Cavity Cooling System
PGA	Peak Ground Acceleration
RPV	Reactor Pressure Vessel

SCS	Shutdown Cooling System
SG	Steam Generator
UPS	Uninterruptable Power Supply

2.0 BACKGROUND

The ideal method for developing the key PBR design requirements would be to use a full functional analysis process. A full functional analysis process starts with top level requirements, which are imposed on the design process at the beginning and then gradually develops more detailed and more specific requirements in the proceeding sections. In general, the process for developing the full functional analysis is as follows:

- Decomposing requirements into subordinate parts
- Allocating resulting subcomponents to different subsystems and components, and
- Deriving required lower tier requirements necessary to meet the higher level requirements.

As stated in the statement of work [1], AREVA will not do a full functional analysis process to develop a new set of requirements. Instead AREVA will screen the current NGNP System Requirements Manual [2] and Key Design Requirements for the High Temperature Gas-cooled Reactor Nuclear Heat Supply System [3] to identify key requirements for the purpose indicated in the project statement of work. However, in some cases it may be appropriate to derive new requirements.

3.0 REQUIREMENT SELECTION PROCESS/CRITERIA

The NGNP System Requirements Manual [2] and Key Design Requirements for the High Temperature Gas-cooled Reactor Nuclear Heat Supply System [3] contain a wide range of requirements. Not all of these requirements are applicable to assessing the PBR technology. Therefore, the following selection process was used to screen the key design requirements [2] & [3] and pull all applicable PBR functional key requirements.

The first step was to remove all requirements that were not applicable to the PBR technology. These requirements consisted of the following:

- Programmatic requirements not clearly linked to the PBR technology or design concept.
- Prismatic reactor concept requirements.
- Generic requirements that any design would satisfy when complete.

Next, all of the remaining requirements were screened and all applicable requirements were collected based on the following selection criteria:

- Discriminating Requirements - a requirement that clearly discriminates whether or not a design is adequate.
- Core Requirements - a requirement for a characteristic that is central to the NGNP concept (i.e. process heat/steam)

- Relevant Requirements - a requirement relevant to the level of detail in the current design and assessment process.

- Inherent Characteristics/Capabilities for the Design - a requirement that establishes the fundamental aspects of the desired design concept.

Finally, any requirement that AREVA felt was important to assessing the PBR technology was derived and added to the requirements list. Appendix A and B of this document contains the resulting set of design requirements required to assess the PBR technology, which is based on selection process illustrated above.

4.0 SUMMARY OF KEY PBR REQUIREMENTS

The Key PBR Requirements were generated using a similar approach as described in section 3.0 "Requirements Selection Process/Criteria" of this document (i.e. started with the INL project requirements [2] & [3], screened for relevant PBR requirements, derived new requirements as required). Once the NGNP requirements were generated (Appendix A and B), then the critical key PBR requirements were selected. The critical key PBR requirements are the requirements that are central to driving the PBR design. The following list contains all critical key PBR requirements that the PBR design must meet. These critical key requirements define the basic essence of the HTGR concept.

- Must have a heat source based on the HTGR concept.
- Must use forced circulation helium as the heat transport fluid.
- Must have a plant design lifetime of 60 years.
- Must meet NRC regulations (as agreed upon for HTGR technology).
- Must be designed such that it can be design certified for a broad range of applications and sites.
- Must meet all applicable federal, state and local codes and standards.
- Must support complete design, licensing, construction and startup testing for initial operation by 2021 (per EPACT 2005).
- Must supply high temperature steam.
- Must be applicable to a broad range of cogeneration application supplying, singly or in combination, electricity, steam, and hot gas.
- Must have a reactor gas outlet temperature in the range of 750ºC to 800ºC.
- Must support process steam, electricity, and cogeneration.
- Must be able to distribute electricity on the commercial grid.
- Must be capable of co-location with process heat users.
- Must be economically competitive with long-term fossil fuel prices.

- Must have passive decay heat removal to cool the core from full power to safe shutdown conditions.
- Must be safe for plant personal, general population, and the environment.

5.0 TRACEABILITY

The requirements in appendix A and B are structured in the same manner as the NGNP System Requirements Manual [2]. For traceability reasons, the object numbers and requirement identifications can be linked back to the NGNP System Requirements Manual [2]. New derived AREVA requirements are shown with an "A" in the object or requirement field following the specific ID number.

6.0 REFERENCES

1. Statement of Work for Modular Pebble Bed Technology Status Assessment, SOW-9139 Revision 1, September 10, 2010.
2. NGNP System Requirements Manual, INL/EXT-07-12999 Revision 3, September 10, 2009.
3. Key Design Requirements for the High Temperature Gas-cooled Reactor Nuclear Heat Supply System, INL/EXT-10-19887, September 2010.

APPENDIX A: NGNP PROGRAMMATIC REQUIREMENTS

A.1 Regulatory Requirements

Object #	Requirement ID	Requirements Statements
2		**Regulatory Documents**
2.1		**NRC/EPA Regulatory Documents**
	2.1-1	The following documents shall, as a minimum, become complied with for the NGNP Project
	2.1-2	51 CFR 28044 - Policy Statement on Safety Goals for the Operation of Nuclear Power Plants
	2.1-3	10 CFR 20 - Standards for Protection Against Radiation, (Permissible dose levels and activity concentrations in restricted and unrestricted areas).
	2.1-4	10 CFR 50 - Domestic Licensing of Production and Utilization Facilities (applicable portions as needed)
	2.1-5	10 CFR 51 - Environmental Protection Regulation for Domestic Licensing and Related Regulatory Functions
	2.1-7	10 CFR 52 - Licenses, Certifications, and Approvals for Nuclear Power Plants
	2.1-9	10 CFR 50, Appendix I - Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "as Low as is Reasonably Achievable."
	2.1-10	10 CFR 73 - Physical Protection of Plants and Materials
	2.1-11	10 CFR 74 - Material Control and Accounting of Special Nuclear Material
	2.1-12	10 CFR 75 - Safeguards on Nuclear Material - Implementation of US/IAEA (International Atomic Energy Agency) Agreement
	2.1-14	10 CFR 95, Facility Security Clearance and Safeguarding of National Security Information and Restricted Data
	2.1-15	10 CFR 100 - Reactor Site Criteria, (Numerical dose guidelines for determining the exclusion area boundary, low population zone, and population center distances)
	2.1-16	10 CFR 835 - Occupational Radiation Protection
	2.1-17	29 CFR 1910 - Occupational Safety and Health Standards, Subpart H, Hazardous Materials
	2.1-18	40 CFR 50-99 - Clean Air Act
	2.1-19	40 CFR 100-149 - Clean Water Act
	2.1-20	40 CFR 190 - Environmental Radiation Protection Standards for Nuclear Power Operations
	2.1-21	40 CFR 1502 - Environmental Impact Statement
	2.1-22	EPA - 520/1-75-001 - Protective Action Guide Doses for Protective Actions for Nuclear Incidents
	2.1-23	47 CFR 47073 - Accident Radioactive Contamination of Human Food and Animal Feed; Recommendations for State and Local Agencies

Object #	Requirement ID	Requirements Statements
	2.1-25	Nuclear Regulatory Commission, NUREG-1860, Vols. 1 and 2, Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing, December 2007. (NGNP plant licensing shall be consistent with the NRC new regulatory framework developed as a guide for future plant licensing for advanced [non-light water] reactors).
	2.1-26	Nuclear Regulatory Commission, 10 CFR Part 50 [NRC-2008- 0237], Policy Statement on the Regulation of Advanced Reactors, Final policy statement (FR Doc E8-24268), effective November 13, 2008.
	2.1-27	Nuclear Regulatory Commission, Regulatory Guide 1.206, Combined License Applications for Nuclear Power Plants (LWR Edition), June 2007
	2.1-28	Nuclear Regulatory Commission, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, March 2007
2.2		**DOE Documents**
	2.2-1	The acquisition strategy for the NGNP project may include a combination of requirements from both the federal and commercial sectors.
	2.2-2	DOE O 413.3A - Program and Project Management for the Acquisition of Capital Assets
	2.2-3	DOE O 420.1B - Facility Safety
	2.2-4	DOE O 435.1 - Radioactive Waste Management
	2.2-5	DOE Policy 450.4 - Safety Management System Policy
	2.2-6	DOE O 450.1A - Environmental Protection Program
	2.2-7	10 CFR 851 - Worker Safety and Health Program.
	2.2-8	DOE M 470.4-2 Chg.1, Physical Protection.
2.4		**State of Idaho Regulations**
	2.4-2a	If the NGNP is sited at the INL, the NGNP shall meet applicable state requirements and observe treaties with sovereign nations such as the Shoshone -Bannock.
2.5		**Indian Reservation Rights**
	2.5-1	DOE has committed to additional interaction and exchange of information with the Shoshone-Bannock Tribes at the Fort Hall Reservation.
2.6A		**Gulf Coast Regulations**
	2.6-1A	If the NGNP is sited on the Gulf Coast, the NGNP shall meet applicable state requirements.
3		**Requirements Applicable to Multiple Systems, Buildings and Structures**
3.1		**Environmental Requirements**
	3.1-2	The NGNP plant shall be capable of controlling the transport of radionuclides to the end products at levels below the concentration or exposure requirements for the product (e.g., tritium in steam, gas, hydrogen). (Initial acceptable tritium levels will be set at a fraction of the U.S. Environmental Protection Agency [EPA] limits for drinking water and air.)
	3.1-3	The NGNP and hydrogen production facilities shall comply with applicable requirements of the Clean Air Act/Air Programs.

Object #	Requirement ID	Requirements Statements
	3.1-4a	The NGNP shall identify all waste streams generated in NGNP by type and estimated quantity.
	3.1-4b	The NGNP shall provide a disposition pathway within the applicable regulatory framework.
	3.1-5a	The NGNP Project shall minimize the generation of all waste, including radioactive, nonradioactive, and mixed waste.
	3.1-5b	The NGNP Project shall comply with applicable DOE orders, NRC regulations, and EPA regulations in the treatment of these wastes.
3.2		**Codes and Standards Requirements**
	3.2-1a	The design of the NGNP shall comply with all applicable federal, state, and local codes and standards.
	3.2-1b	Codes and standards pertinent to the nuclear industry shall only be utilized in the design, fabrication, and installation of the structures, systems, and equipment where such codes and standards are applicable.
3.3		**Quality Assurance Requirements**
	3.3-1	The NGNP project shall use the U.S. national consensus standard ASME Nuclear Quality Assurance (NQA)-1-2000, "Quality Assurance Program Requirements for Nuclear Facilities Applications."
3.4		**Physical Protection, Material Control and Safeguards - IAEA**
	3.4-1	The NGNP shall comply with the following: (A) A design that include considerations for safety and security requirements together in the design process such that security issues (e.g., newly identified threats of terrorist attacks) can be effectively resolved through facility design and engineered security futures, and formulation of mitigation measures, with reduced reliance on human actions,
	3.4-2	(B) a design with features to eliminate or reduce the potential theft of nuclear materials, and
	3.4-3	(C) a design that emphasize passive barriers to potential theft of nuclear materials.
	3.4-7	The design of the NGNP shall comply with 10 CFR 73.55, Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage.
	3.4-8	The design of the NGNP shall comply with 10 CFR 73.67, Licensee fixed site and in-transit requirements for the physical protection of special nuclear material of moderate and low strategic significance.
	3.4-9a	The design of the NGNP shall include preparation and update of a Security Assessment, "High Assurance Evaluation and Mitigative Measures Evaluation" per NUREG-800 Sections 13.6.4.
	3.4-9b	The design of the NGNP shall include the development of Physical Security Hardware Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) per NUREG-0800 Section 14.3.12.
	3.4-9c	The results of and insight from the above evaluations and the ITAAC shall be used to integrate safeguards by design into the NGNP.

Object #	Requirement ID	Requirements Statements
	3.4-11	The NGNP design shall comply with NRC requirements for the control and accounting of special nuclear material including 10 CFR 74.19, Recordkeeping.
	3.4-12	The design of the NGNP shall comply with 10 CFR 75, Safeguards on Nuclear Material-Implementation of US/IAEA Agreement.
	3.4-13	The design of the NGNP shall incorporate design features to facilitate the application of international safeguards under INFCIRC/57, The Text of the Agreement for the Application of Agency Safeguards to United States Reactor Facilities, and INFCIRC/540, Model Protocol Additional to the Agreement(s) Between State(s) and International Atomic Energy Agency for Application of Safeguards.
4		**Public and Worker Exposure Limits Bounding Condition**
	4.1	Protection Criteria for the Worker and the Public 4.1-1 Upper bound offsite doses during design basis events shall meet 10 CFR 50.34 with margin.
	4.1-1	Upper bound offsite doses during design basis events shall meet 10 CFR 50.34 with margin.
	4.1-2a	There shall be a technical basis for eliminating or minimizing the need for offsite emergency planning.
	4.1-2b	This technical basis (for eliminating or minimizing the need for offsite emergency planning) shall consider a risk-informed, realistic assessment of design basis and beyond design basis accidents and shall demonstrate high confidence that the EPA Protection Action Guidelines are met.
	4.1-2c	The NGNP design shall effectively demonstrate that off-site emergency plan requirements may be minimized (e.g., eliminate requirements for emergency drills, sirens, etc.).
	4.1-3	Exposure to the Worker and the Public under normal operation shall meet 10 CFR 20 and ALARA (as low as reasonably achievable) as quantified in Appendix I of 10 CFR 50.
4.2		**Bounding Condition - 005**
	4.2-1	Fuel specifications, operating conditions, and plant shielding shall be sufficient to meet NRC and Environmental Protection Agency (EPA) exposure limits for the public and workers under normal operation and calculated accident conditions. These limits are as follows:
	4.2-2	Under accident conditions, the release rates shall be limited to meet the EPA Protective Action Guidelines limits and 10% of the 10 CFR 100 limit at the exclusion area boundary (EAB; 400+ meters).
	4.2-3	Exposure to the public under normal plant operation shall not exceed 0.1 rem in a year, exclusive of the dose contributions from background radiation.
	4.2-4	The occupational dose to individual adults shall be limited on an annual basis to 10% of the 10 CFR 20 limits.
	4.2-5	Tritium concentration control shall be sufficient to meet activity limits in the products of the plant.
	4.2-6a	Tritium concentrations in products shall not exceed 100 Bq/liter (~10% of the EPA limit for drinking water, 740 Bq/liter).

Object #	Requirement ID	Requirements Statements
	4.2-6b	Tritium concentrations in liquid effluents shall not exceed 100 Bq/liter (~10% of the EPA limit for drinking water, 740 Bq/liter).
	4.2-7	Tritium concentrations in gaseous effluents and products shall not exceed 3.7 Bq/liter (the NRC limit for air).
4.4		**Bounding Condition - 007**
	4.4-1a	Characterization of dust circulation in the primary system shall be required to ensure acceptable levels of dust-borne activity in the system.
	4.4-1b	Control of dust circulation in the primary system shall be required to ensure acceptable levels of dust-borne activity in the system.
	4.4-1c	Characterization of dust circulation in the primary system shall be required to minimize the impact on operability of primary system components (e.g., the control rods and circulators) and abrasion of primary system components.
	4.4-1d	Control of dust circulation in the primary system shall be required to minimize the impact on operability of primary system components (e.g., the control rods and circulators) and abrasion of primary system components.

A.2 Legislative Requirements

No Requirements currently exist.

A.3 End User Requirements

No Requirements currently exist.

A.4 Stakeholder Requirements

Object #	Requirement ID	Requirements Statements
2		**NGNP TOP-LEVEL REQUIREMENTS**
2.1		**NGNP Program Requirements**
2.1.1		**Overall Objectives**
	2.1.1-2	The plant shall be capable of completing design, licensing, construction, and startup testing for initial operation by 2021.
2.1.2		**NGNP Project Requirements**
	2.1.2-10	Costs for anticipated “Nth”-of-a-kind (NOAK), based on design certification, construction, and operation of first-of-a-kind (FOAK) design, shall support a viable economic business model (competitive with natural gas price at $8/MMBtu)
3		**NGNP Project Scope**
	3-1-6	The NGNP project shall complete all federal permitting required for construction and operation, including support for DOE National Environmental Policy Act (NEPA) activities.
	3-1-6	The NGNP project shall complete all state permitting required for construction and operation, including support for DOE National Environmental Policy Act (NEPA) activities.
5		**Pre-Conceptual Design Scope, Planning, and Execution**

Object #	Requirement ID	Requirements Statements
5-1.1		**Pre-Conceptual Design Project Requirements**
	5-1.1-1	NGNP shall be designed, constructed, licensed, and operating by 2021
	5-1.1-2	NGNP design configuration shall consider cost and risk profiles to ensure that NGNP establishes a sound foundation for future commercial deployment.
	5-1.1-3	NGNP shall be licensed by the NRC as a commercial cogeneration facility producing electricity and hydrogen.
2		**Requirements Applicable to Multiple Systems, Buildings and Structures**
2.1		**Operational Requirements**
	2.1-3	The NGNP shall demonstrate a minimum 18-month refueling interval capability (if applicable).
	2.1-4	The NGNP shall implement the technologies important to achieving the functional performance and design requirements determined through close collaboration with commercial industry end-users.
	2.1-5	The NGNP shall demonstrate the basis for commercialization of the nuclear system, a heat transfer/transport system, a hydrogen production process, and a power conversion concept. An essential part of the hydrogen operations will be demonstrating that the requisite reliability and capacity factor can be achieved over an extended period of operation.
	2.1-6a	NGNP nuclear heat source shall be based on the HTGR concept
	2.1-6b	The NGNP nuclear heat source shall utilize passive safety features to cool the core from full power to safe shutdown conditions.
	2.1-7a	The NGNP shall produce high-efficiency electricity and generate hydrogen on a scale that sets a foundation for future commercial deployment.
	2.1-7b	NGNP shall generate hydrogen on a scale that sets a foundation for future commercial deployment.
	2.1-8	NGNP shall include provisions for future testing.
	2.1-9a	The NGNP shall enable demonstration of energy products utilizing its nuclear heat source.
	2.1-9b	The NGNP shall enable demonstration of energy processes utilizing its nuclear heat source.
	2.1-10	The NGNP shall limit normal maintenance exposure of no more than 50 person-REM/year per module in a refueling year.
	2.1-11	The NGNP shall have an availability factor of greater than or equal to 90%.
	2.1-12	The NGNP shall have a plant design lifetime of 60 years (calendar).
	2.1-14	The NGNP reactor gas outlet temperature shall be in the range of 750°C to 800°C.
	2.1-15A	The NGNP supplied steam conditions temperature shall be in the range of 540°C to 630°C.
3		**Requirements Applicable to Nuclear Heat Source**
3.1		**Reactor System**
	3.1-2	The NGNP core shall use forced circulation helium as the heat transport fluid.
	3.1-3a	The NGNP non-replaceable structural materials in contact with helium shall resist erosion during plant cycle life.

Object #	Requirement ID	Requirements Statements
	3.1-3b	The NGNP non-replaceable structural materials in contact with helium shall resist erosion during plant cycle life.
6		**Reactor Design Power Level**
6.1		**Bounding Condition - 002**
	6.1-1	The NGNP shall be capable of operation at power levels up to 600 Mwt, depending on the core design, and core power densities that will demonstrate the technical and economic feasibility of commercial HTGRs with a passive safety basis such that maximum fuel temperatures under normal and abnormal conditions are acceptable.
	6.1-3-1	The peak time averaged fuel temperature does not exceed 1250°C under normal operating conditions.
	6.1-3-2	The peak fuel temperature shall not exceed 1600°C under accident conditions.
	6.1-4	In addition, the core design shall result in a self-consistent set of operating parameters (e.g., power density, core delta T) and material choices (e.g., fuel, graphite, core barrel, reactor vessel) that demonstrate adequate safety margin when uncertainties in operating parameters and in the associated calculation methods (typically at 95% confidence) are explicitly accounted.
	6.1-5	Final design work is required to verify that the calculated fuel temperatures meet the specified ranges under all conditions after appropriately accounting for uncertainties in the calculations.
	6.1-9	Clearly identify the lower-power design requirements in further evaluations with the private sector and through evaluation of other factors (e.g., availability of components, transportation of large vessels and components, potential for mass production, licensing)
	6.1-10	The lower-power designs by the vendors shall be developed through scaling, where possible, of the current designs to meet the private sector needs
7		**Reactor Gas Outlet Temperature**
7.1		**Bounding Condition - 003**
	7.1-1	The reactor island shall be designed for operation at the highest temperature achievable for the reactor core design and the maximum power level (see specific fuel temperature requirements above).
	7.1-2	NGNP shall be capable of operating at lower power and temperature to accommodate a period of plant operation below design conditions.
8		**Reactor Gas Inlet Temperature**
8.1		**Bounding Condition - 004**
	8.1-1	The reactor gas inlet temperature shall be compatible with the maximum reactor power, gas outlet temperature, and required gas flow rate to achieve acceptable fuel operating temperatures (see design limits above) and material choices, particularly the RPV.
9		**Containment**
9.1		**Bounding Condition - 015**

Object #	Requirement ID	Requirements Statements
	9.1-1	NGNP shall include reactor and reactor building containment features that, in combination with the other mechanisms for radionuclide containment (e.g., fission product retention capabilities of the fuel) and transport, (e.g., entrainment, plate out), result in calculated dose rates at the EAB that meet the criteria established above (see Public and Worker Exposure Limits) for normal operation, abnormal conditions, and accident conditions.
12		**Component Test Facility**
12.1		**Bounding Condition - 018**
	12.1-1	A CTF shall be provided as part of the infrastructure supporting HTGR technologies.
	12.1-2	The facility shall be capable of completing proof-of performance testing of major HTGR and NGNP components at engineering or full scale.

APPENDIX B: NGNP FUNCTIONAL, OPERATIONAL, AND TECHNICAL REQUIREMENTS

B.1 Nuclear Heat Supply Requirements

B.1.1 Reactor Pressure Vessel

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Multiple Systems, Buildings and Structures**
2.1		**Surveillance and In-Service Inspection requirements**
	2.1-1	The NGNP design shall provide access to the primary and secondary loop pressure boundary to permit In-Service Inspection as required by appropriate sections of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code.
2.2		**Vessel System Function and Design**
	2.2-2	The duration of maintenance shall be minimized.
	2.2-2	The duration of repair/replacement operations of the vessel system shall be minimized.
	2.2-3	All parts of the vessel system shall be designed for an operating duration of 60 years.
	2.2-4	Lifetime of isolation valves, piping and cross-vessels (where applicable) of the vessel system shall be optimized according to the investment cost and replacement duration.
	2.2-5	The vessel system shall be designed for design basis duty-cycle events.
3		**Requirements Applicable to Nuclear Heat Source**
3.1		**Vessel System**
3.1.1		**Reactor Vessel**
	3.1.1-3	During normal operation, the reactor vessel shall maintain its operating temperature through a thermal balance between the core heat flux, core inlet helium flow, and the reactor cavity cooling system.
	3.1.1-4	The reactor vessel shall maintain the primary pressure boundary integrity.
	3.1.1-5	The operating conditions shall be considered according to the following statements:
	3.1.1-5-1	In normal operation, creep effects on the reactor vessel shall be avoided (negligible creep).
	3.1.1-5-2	No leakage shall result from Anticipated Operating Occurrences (AOO).
	3.1.1-5-3	For AOOs and DBAs, the reactor vessel shall not prevent restarting of the plant.
3.1.1.1		**Vessel System**
	3.1.1.1-1	The vessel system shall contain and support the components of the reactor core, reactor internal supports and structures, and the nuclear heat transport components.
3.1.2		**Cross Vessels (where applied)**
	3.1.2-2	The cross vessels shall maintain the primary pressure boundary integrity.
	3.1.2-3	The cross vessels shall provide the primary heat transport path to/from the reactor vessel and steam generator (SG) vessels, as applicable.

Object #	Requirement ID	Requirements Statements
3.1.3A		**SG Vessels (where applied)**
	3.1.3-1A	The function of the SG vessel shall be to support the SG modules.
	3.1.3-2A	The SG vessels shall maintain the primary pressure boundary integrity.
3.1.4		**Vessel Supports**
	3.1.4-1A	The SG vessel supports shall support the vertical load.
	3.1.4-2A	The SG vessel supports shall include keying for lateral support.
	3.1.4-3A	The SG vessel supports shall accommodate thermal expansion.
	3.1.4-4A	The SG vessel supports shall accommodate duty-cycle events.
	3.1.4-5A	The SG vessel supports shall withstand coupled vibration from the circulator.
	3.1.4-6	The reactor vessel shall provide core support and maintain its relative position to the control rods.
	3.1.4-7	The reactor vessel shall provide decay heat and residual heat removal by radial conduction during loss-of-forced circulation events.
3.1.5		**Pressure Relief System**
	3.1.5-2	In case of primary overpressure, the safety valves shall open to eliminate the overpressure and reclose once the overpressure condition terminates.
	3.1.5-3	The pressure relief system shall provide the primary coolant loop's overpressure protection as required by ASME pressure relief code.
4		**Primary System Pressure Vessels Condition**
4.1		**Bounding Condition - 008**
	4.1-1	The nuclear heat supply system, which includes the heat transfer/transport system, shall be designed to minimize schedule risk for the primary pressure vessels at full design power level and inlet and outlet temperatures.
	4.1-2	In this regard, the design of the primary pressure vessels, including the RPV, shall incorporate standard LWR RPV material (e.g., SA 508/533).
	4.1-5	The reactor system shall be designed to provide passive residual heat removal under conditions of loss of forced cooling and loss of coolant.
	4.1-6	The reactor system shall be designed such that the reactor core is maintained in a coolable geometry under all normal operating, abnormal operating, and postulated design basis and beyond design basis accident conditions.
	4.1-7	The reactor system shall be designed for an operational lifetime of 60 years (calendar). Excluding those portions of the system that can be replaced.
	4.1-8	The core shall use forced circulation helium as the heat transport fluid.
	4.1-9	Non-replaceable structural materials in contact with helium shall resist corrosion and erosion during plant life as to avoid failure and or need for replacement.

B.1.2 Reactor Vessel Internals

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Nuclear Heat Source**
2.1		**Reactor System**
2.1.1		**Reactor Internals**
	2.1.1-1	The reactor internals shall be designed to properly control bypass flows.

Object #	Requirement ID	Requirements Statements
	2.1.1-2	The reactor internals shall be designed to transport residual and decay heat from the reactor core to the reactor vessel.
	2.1.1-3	The reactor internals shall be designed to channel primary coolant to and from the reactor core for transfer of heat to the Primary Heat Transport System (PHTS).
	2.1.1-4	The reactor internals shall be designed to provide radiological shielding to limit neutron fluence to the reactor vessel.
	2.1.1-5	The reactor internals shall be designed to limit gamma radiation exposure to the plant personnel and equipment.
	2.1.1-6	The reactor internals shall be designed to limit damage to plant components during conduction cooldown events.
	2.1.1-7	The reactor internals shall maintain reactor core geometry.
	2.1.1-8	The reactor internals shall provide heat transfer during conduction cooldown.
	2.1.1-9	The reactor internals shall conserve neutrons in the reactor core and provide shielding.

B.1.3 Reactor Core and Core Structures

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Nuclear Heat Source**
2.1		**Reactor System**
2.1.1		**Reactor Core**
	2.1.1-1	The decay heat removal shall be possible by passive heat transfer means (conduction and radiation) from the fuel to the reactor internals without reaching unacceptable fuel temperatures during all DBA conditions.
	2.1.1-2	The core shall utilize thermal spectrum neutrons for fission reaction.
	2.1.1-3	The core shall be moderated with graphite.
	2.1.1-4	The active core height shall ensure the axial stability of the neutron flux and preclude the risk of xenon oscillations.
	2.1.1-5	Reference fuel shall be LEU-based (UCO or UO2) with an enrichment limited to <20.0% (in mass) and with a peak burn-up limited to 20% fissions per initial metal atoms (FIMA).
	2.1.1-7	The core bypass flow shall be maintained within an acceptable range [TBD], to ensure fuel temperatures in normal and accidental conditions are maintained within [TBD] limits (existence of a minimum amount of bypass in lateral reflector).
	2.1.1-8	The reactivity temperature coefficient shall be sufficiently negative to shutdown the nuclear chain reaction before an unacceptable fuel temperature is reached, and maintain the core in a safe state for a time offering the certainty to reliably introduce absorber elements.
	2.1.1-10	The reactor core shall generate heat.
	2.1.1-11	The reactor core shall transfer heat to coolant and/or reactor internals.

B.1.4 Nuclear Instrumentation

Currently, no requirements exist.

B.1.5 Fuel Elements

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Multiple Systems, Buildings and Structures**
2.1		**Operational Requirements**
	2.1-1	The NGNP shall be designed to use low enriched uranium (LEU) TRISO-coated particle fuel.
3		**Requirements Applicable to Fuel**
	3-3	The fuel performance shall allow for a source term calculation capable of obtaining an NRC license with an exclusion zone of no more than 400 meters (approximately) for the design power level.
	3-4	The fuel shall meet following requirement: As-manufactured Quality Requirements, at a 95% confidence level: Heavy metal contamination: 6.0 × 10 -5 (Pebble Bed)
	3-5	The fuel shall meet the following requirement: Asmanufactured Quality Requirements, at a 95% confidence level: SiC Defect Fraction: 6.0 × 10 -5 (Pebble Bed)
	3-6	The fuel shall meet the following requirement: In-service Fuel Performances Requirements, at a 95% confidence level: Fuel failure during normal operations: 4.6 × 10 -5 (Pebble Bed)
	3-7	The fuel shall meet the following requirement: In-service Fuel Performances Requirements, at a 95% confidence level: Incremental fuel failures during accident conditions: 5.0 × 10 -4 (Pebble Bed)

B.1.6 Reserve Shutdown System

Currently, no requirements exist.

B.1.7 Reactivity Control System

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Nuclear Heat Source**
2.1		**Reactor System**
	2.1-1	The reactor system shall generate heat and transfer it to the primary coolant.
	2.1-2	The reactor system shall maintain reactor shutdown.
2.1.1		**Neutron Control Elements**
	2.1.1-1	The neutron control elements shall be designed to provide sufficient negative reactivity to shut down the reactor and maintain it in subcritical condition for any state while compensating for the worst positive reactivity insertion.
	2.1.1-2	The neutron control elements shall control the nuclear chain reaction in the reactor core by absorbing neutrons in any operational mode.
2.2		**NHS Protection System**
	2.2-1	The protection system shall implement the relevant monitoring, analysis, and actuation functions necessary to reach the controlled state in case of abnormal events.
2.3		**NHS Control Room and Operator Interface System**

Object #	Requirement ID	Requirements Statements
	2.3-1	The NGNP facility design shall permit the operators to take control of the reactor and support processes from within a single integrated control room using the manual mode at any time.

B.1.8 Core Conditioning System (Shutdown Cooling)

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Nuclear Heat source**
2.1		**Reactor Support Systems**
2.1.1		**Shutdown Cooling System**
	2.1.1-9	The Shutdown Cooling System (SCS) if present shall limit the ingress of potential contaminants into the primary helium circuit from components of the SCS external to the primary HPB.
	2.1.1-11	The Shutdown Cooling System shall transport core residual and decay heat from the reactor system to the environment when the reactor system is shutdown and the PHTS is not operational. The helium primary coolant may be pressurized or depressurized.
	2.1.1-12	The Shutdown Cooling System shall transport core residual and decay heat from the reactor system to the environment when the helium primary coolant is depressurized during reactor core refueling operations.
	2.1.1-13	The Shutdown Cooling System shall transport core residual and decay heat from the reactor system to the environment when the helium primary coolant is depressurized during scheduled maintenance of core, vessel, and internal components.
	2.1.1-14	The Shutdown Cooling System shall transport core residual and decay heat from the reactor system to the environment when the helium primary coolant is depressurized during certain potential unscheduled maintenance or repair activities.
	2.1.1-15	The Shutdown Cooling System shall support cooling of the SG, as needed, and potentially for other components when the PHTS is not operating.
	2.1.1-16	The Shutdown Cooling System shall limit core bypass flow through its components during PHTS operation.

B.1.9 Reactor Cavity Cooling System

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Nuclear Heat Source**
2.1		**Reactor System**
	2.1-1	The reactor system shall be designed to provide passive residual heat removal under conditions of loss of cooling.
2.2		**Reactor Support Systems**
2.2.1		**Reactor Cavity Cooling System**
	2.2.1-3	The Reactor Cavity Cooling System (RCCS) shall operate continuously and maintain reactor cavity concrete temperatures to less than [90ºC] during normal operations and less than [150ºC] for off-normal events (short term).

Object #	Requirement ID	Requirements Statements
	2.2.1-4	The RCCS shall be designed to operate through the utility/user duty-cycle events for the number of cycles specified [TBD] plus those events and event combinations determined to be required by plant transient analysis.
	2.2.1-5	Inaccessible parts of the RCCS shall be designed for an operating life of 60 years.
	2.2.1-6	The need for access to individual components during normal plant operation and under accident conditions shall be considered in developing building and component arrangements.
	2.2.1-8	The RCCS shall accommodate continuous operation at any power level up to 100% of rated power.
	2.2.1-9	The RCCS shall incorporate features required to implement online surveillance and performance monitoring.
	2.2.1-10	The RCCS shall incorporate those features required to accomplish ISI activities within the time and scheduling constraints imposed by the allotted design planned outage time.
	2.2.1-11	The RCCS shall be required to operate continuously in all plant states, including shutdown following loss of forced reactor cooling by the PHTS and SCS with simultaneous loss of pumped circulation of RCCS cooling water and an SSE.
	2.2.1-12	The RCCS shall operate continuously in all plant states, including shutdown following loss of forced reactor cooling by the PHTS and SCS with simultaneous loss of pumped circulation of RCCS cooling water, where applicable.
	2.2.1-13	All components and piping of the RCCS shall meet seismic loads requirements.
	2.2.1-14	All components and piping inside the reactor building, including the connections for emergency water supply (fire brigade), shall be designed against external events (e.g., aircraft crash or pressure waves).
	2.2.1-15	The Reactor Cavity Cooling System shall protect the reactor cavity concrete structure, including the support structures of the reactor pressure vessel, from overheating during all modes of operation.
	2.2.1-16	The Reactor Cavity Cooling System shall provide an alternate means of reactor core heat removal from the reactor system to the environment when neither the PHTS nor the SCS is available.
2.2.2		**Nuclear Island Cooling System**
	2.2.2-3	The nuclear island cooling system shall serve the needs of the reactor and its associated components at all times under full power operating conditions.
	2.2.2-4	System makeup shall be provided from the plant Water Supply Treatment System.
	2.2.2-5a	Redundant components shall be provided for the nuclear island cooling system, as needed, to support continuous operation of the reactor.
	2.2.2-5b	Redundant components shall be provided for the nuclear island cooling system, as needed, to provide for on-line maintenance of the cooling system components.

B.1.10 General

Object #	Requirement ID	Requirements Statements
2		**Nuclear Heat Supply System - General Requirements**
2.1		**Requirements Applicable to Nuclear Heat Supply**
	2.1-1	The Nuclear Heat Supply System shall be design certified for a broad range of applications and sites. Note that the Nuclear Heat Supply System includes the nuclear island (e.g., the reactor, primary coolant system, and supporting systems) and the heat transfer/transport system. *This is goal for the future and not a current design requirement.
	2.1-2	The NHSS shall be licensed independent of the application. In this regard the licensing boundary and interface requirements shall be defined for the reference configurations (e.g., transients, feed and gas return chemistry.)
	2.1-5	Applicable to broad range of cogeneration applications supplying, singly or in combination, electricity, steam, and hot gas.
	2.1-6	Reactor gas outlet temperature in the range of 750 to 800°C.
	2.1-7	Capable of completing design, licensing, construction, and startup testing for initial operation by 2021.
	2.1-8	Capable of following process load variations.
	2.1-9	The NGNP design will be applicable to a broad range of cogeneration applications supplying, singly or in combination, electricity, steam, and hot gas.
	2.1-10	For the NGNP (FOAK), the designed reactor gas outlet temperature shall be in the range of 750 to 800°C.
	2.1-11	The NHSS shall be capable of controlling the transport of radionuclides to the end products at levels below the concentration or exposure requirements for the product (e.g., tritium in steam, gas, hydrogen) [Initial acceptable tritium levels will be set at a TBD fraction of the EPA limits for drinking water and air]
	2.1-12	The Nuclear Heat Supply System (NHSS) shall be design certified for a broad range of applications and sites.
	2.1-13	The NHSS shall be licensed independent of the application. In this regard the licensing boundary and interface requirements shall be defined for the reference configurations, (e.g., transients, feed and gas return chemistry).
	2.1-14	The NHSS designs shall be applicable, on economic, availability and reliability bases, to a broad range of cogeneration applications supplying, singly or in combination, electricity, steam, and hot gas (helium).
2.2		**System Configuration and Essentials Features Requirements**
		The NGNP nuclear heat source (NHS) shall use the HTGR concept.
	2.2-1	The NGNP NHS shall demonstrate commercial viability of the HTGR.
	2.2-2	The NGNP NHS shall be designed such that it can be design certified for a broad range of applications and sites.
2.3		**Operational Requirements**
	2.3-1	The NGNP NHS shall have an operational lifetime of 60 years (calendar).
	2.3-4	The NGNP shall be designed to operate during loss of hydrogen production and stabilize in the electricity generation phase.
	2.3-5	The NGNP plant shall be capable of following process load variations.

Object #	Requirement ID	Requirements Statements
	2.3-7	The NGNP shall demonstrate a minimum 18-month refueling interval capability (if applicable).
	2.3-8	The NGNP shall be designed to operate following loss of a secondary heat process, such as hydrogen production, and stabilize in the electricity generation phase.
2.4		**Surveillance and In-Service Inspection Requirements**
	2.4-1	The NGNP design shall provide access to the primary and secondary, if applicable, loop pressure boundary to permit ISI as required by appropriate sections of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, minimizing the need for requests for Code relief due to accessibility constraints.

B.2 Heat Transport System Requirements

B.2.1 Circulators

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Heat Transport System**
2.1		**Primary Heat Transport System**
	2.1-1	The Primary Heat Transport System shall transfer heat from the reactor core to the secondary circuit.
2.1.1		**Main Helium Circulator (MHC)**
	2.1.1-2	The MHC shall be driven by electrical motors capable of rated and variable speeds.
	2.1.1-4	Bearing design shall preclude contaminant (e.g., lubricating product) ingress in the primary circuit.
	2.1.1-5	Thermal insulation shall be required to protect the internal components by reducing heat migration due to primary system temperatures.
	2.1.1-6	The MHC shall be designed with a minimum lifetime of 10 years.
	2.1.1-7	The MHC shall be designed with hydraulic characteristics as stable as possible over the required speed range without distinctive reversal points and without pronounced peaks.
	2.1.1-8	The MHC shall maintain primary pressure boundary integrity.
	2.1.1-9	The Main Helium Circulator shall control the flow of helium to match the heat generation of the reactor core with the heat removal of the PHTS.
3		**Helium Circulators**
3.1		**Bounding Condition - 012**
	3.1-1	The ability to operate multiple circulators in parallel shall be evaluated and tested as an alternative to installation of a single high-power design that requires significant development.

B.2.2 Intermediate heat Exchangers

Currently, no requirements exist. The FOAK NGNP concept will not have intermediate heat exchanger.

B.2.3 Cross Vessel

Currently, no requirements exist.

B.2.4 Mixing Chamber

Currently, no requirements exist.

B.2.5 High Temperature Valves

Currently, no requirements exist.

B.2.6 General

Currently, no requirements exist.

B.3 Hydrogen Production System Requirements

B.3.1 Hydrogen Production System

Currently, no requirements exist.

B.4 Power Conversion System Requirements

B.4.1 Steam Generator (Secondary Side)

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Power Conversion System**
	2-1	The Power Conversion System shall convert energy from the PHTS or steam generator, as applicable, into electricity for distribution on the commercial gird.
2.1		**Steam Turbine and Generator**
	2.1-2	The steam turbine and generator shall be designed for superheated steam at a pressure of [TBD] and temperature of [TBD] at the turbine throttle.
	2.1-3	The steam turbine and generator shall be designed with a single shaft.
	2.1-4	The turbine shall be designed for main steam temperature variations of up to [TBD].
	2.1-5	The steam turbine generator rating shall be [TBD].
	2.1-6	The Steam Turbine and Generator shall produce electricity using steam.

B.4.2 Power Conversion System Equipment

Object #	Requirement ID	Requirements Statements
3		**Power Conversion System**
3.1		**Bounding Condition - 013**
	3.1-2	The steam conditions and configuration of the cycle shall be selected to result in a net generation efficiency of at least 42%; balancing cost with efficiency and reliability.

B.4.3 General

Object #	Requirement ID	Requirements Statements
2		**Power Conversion System - General Requirements**
2.1		**Requirements Applicable to Power Conversion System**
	2.1-2	The NGNP PCS shall be connected to a local public transmission line for external distribution.
	2.1-3	The NGNP PCS shall produce electricity at nominal 60 Hz.

Object #	Requirement ID	Requirements Statements
	2.1-4	The NGNP PCS shall be sized to produce electricity at commercial scale using 100% of the NGNP thermal energy from the reactor.
	2.1-5	The NGNP electrical output shall be delivered to the operating utility at the low-voltage bushings of the main power transformer.
2.2		**Main Feed-Water System**
	2.2-1	The Main Feedwater System shall deliver feedwater to the steam generator at the specified temperature, pressure, flow rate, and water chemistry.
	2.2-2	The Main Feedwater System shall provide storage to accommodate process fluid surge and volume fluctuations.
	2.2-3	The Main Feedwater System shall provide isolation of the feedwater to prevent water inflow to a failed steam generator.
2.3		**Main Steam System**
	2.3-1	The Main Steam System shall convey steam from the steam generator outlet nozzles to the inlet nozzles of the high-pressure turbines.

B.5 Balance of Plant Requirements

B.5.1 Fuel Handling System

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Multiple Systems, Buildings and Structures**
2.1		**Decommissioning Requirements**
	2.1-1a	Upon completion of its useful life, the NGNP nuclear heat source shall be put into a condition of safe storage for 10 years.
	2.1-1b	After the safe storage period of 10 years, the NGNP shall be decommissioned and dismantled to allow continued use of the land as a power plant or industrial site.
	2.1.1	The design of the NGNP shall incorporate features consistent with decommissioning and decontamination best practices.
3		**Requirements Applicable to Nuclear Heat Source**
3.1		**Reactor Support Systems**
3.1.1		**Fuel Handling Systems**
	3.1.1-9	For the pebble bed reactor design, the Fuel Handling System (FHS) shall be developed such that the fuel pebbles are circulated through the core to affect on-line plant refueling.
	3.1.1-10	The FHS shall provide shielding to protect workers from radiation during certain fuel handling operations, as applicable.
	3.1.1-11	The FHS shall limit the ingress of potential contaminants into the primary helium circuit from components of the FHS external to the primary HPB.
	3.1.1-13	The Fuel Handling System shall remove and replace fuel from the reactor core.
	3.1.1-14	The Fuel Handling System shall prepare new fuel for use in the reactor core.
	3.1.1-15	The Fuel Handling System shall store spent fuel.
	3.1.1-16A	The NGNP shall be designed to store 10 years of spent fuel on site, which includes initial startup and operation.
3.1.2		**Spent Fuel Cooling System**

Object #	Requirement ID	Requirements Statements
	3.1.2-3	The spent fuel cooling system shall be designed to operate continuously whenever spent fuel is located in storage.
	3.1.2-5A	Helium/Air quality requirements shall be maintained at all times.

B.5.2 Instrumentation and Control

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Multiple Systems, Buildings and Structures**
2.1		**Instrumentation and Control Requirements**
	2.1-2	The NGNP shall be capable of being controlled from a single control room.
	2.1-3	The main control room shall include controls for the PCS and high-temperature heat transport system.
	2.1-4	The NGNP design shall optimize the human-machine interface based on human factors engineering principles and operating experience to the extent possible without compromising plant safety.
2.2		**Maintenance Requirements**
	2.2-1	The NGNP design shall include provisions for monitoring equipment status, configuration, and performance and for detecting and diagnosing malfunctions as a basis for predictive maintenance plans and decision making.

B.5.3 General

Object #	Requirement ID	Requirements Statements
2		**Requirements Applicable to Balance of Plant**
2.4		**Electrical Systems**
	2.4-1	The Electrical Systems shall deliver power generated by the plant to the offsite transmission network.
	2.4-2	The Electrical Systems shall take power from the off-site transmission network for various plant operations, including startup.
	2.4-3	The Electrical Systems shall provide backup power to select auxiliaries when the plant power units and off-site power are not available.
2.4-5.5		**Direct Current/Uninterruptible Power Supply System**
	2.4-5.4-1	The Direct Current (DC)/Uninterruptible Power Supply (UPS) System shall provide a stored energy source for the all plant DC loads.
2.4-5.6		**Grounding System**
	2.4-5.6-1	The Grounding System shall protect personnel and equipment from system faults and lightning strikes.
	2.4-5.6-2	The Grounding System shall minimize electrical noise in signal cables.
2.4-5.7		**Communication and Lighting**
	2.4-5.7-1	Communication and Lighting shall provide intra-plant communications.
	2.4-5.7-2	Communication and Lighting shall provide internal and external lighting.
2.5		**Plant Control Room System**
	2.5-1	The NGNP facility design shall permit the operators to take control of the reactor and support processes from within a single integrated control room using the manual mode at any time.

Object #	Requirement ID	Requirements Statements
	2.5-2	The control room shall remain operable and capable of occupation during credible external events.
	2.5-4	The Plant Control Room System shall provide an interface between plant operators and each of the necessary systems within the plant.
2.7		**Fire Detection and Suppression System**
	2.7-1	The Fire Detection and Suppression System shall rapidly detect and annunciate the presence and location of combustion byproducts or the presence of fire within the plant.
	2.7-2	The Fire Detection and Suppression System shall control and extinguish fires that occur.
	2.7-3	The Fire Detection and Suppression System shall provide protection for PASSCs such that the performance of safety functions are not prevented.
2.8		**Communications System**
	2.8-1	The Communications System shall provide plant to off-site communications.
2.9		**Safeguards and Security System**
	2.9-1	The Safeguards and Security System shall provide physical protection of the plant.
2.13		**Structural Requirements**
	2.13-5	Can be collocated with the process; Protective Action Guidelines limits at site boundary of approximately 400 meters.
	2.13-6	The NGNP design will be such that the HTGR can be collocated with the process; PAG limits met at the site boundary of approximately 400 meters.
	2.13-7	NGNP PASSCs shall be designed and constructed using and demonstrating modular plant construction.
	2.13-8	The NGNP shall be designed for a reference safe shutdown earthquake (SSE) horizontal peak ground acceleration (PGA) of [0.3g].
	2.13-9	The NGNP shall be designed such that the minimum level at which a shutdown is required to evaluate the condition of the plant following an earthquake shall be [0.1g] PGA.
	2.13-10	A seismic margin assessment shall be performed to demonstrate that there is seismic margin in the NGNP beyond the design level SSE. The seismic margin earthquake used in the seismic margin assessment process shall be the NUREG/CR-0098 median shape curve anchored to a [0.5g] PGA.
	2.13-11	NGNP plant external structures, important to safety, shall be designed and constructed with consideration of aircraft impacts, as required by NRC final rule RIN 3150-AI19.
2.14		**Construction Requirements**
	2.14-1	Advanced techniques, such as the use of factory or field fabricated and assembled modules containing portions of systems and/or structures, shall be utilized (as appropriate) to reduce erection costs and schedule risks and to enhance quality control.
	2.14-2	The design of buildings and equipment shall facilitate plant construction and the installation, repair, and replacement of equipment.
2.15		**Safety Requirements**

Object #	Requirement ID	Requirements Statements
	2.15-1	The nuclear system safety basis shall not depend on active cooling systems during design basis accident (DBA) conditions.
2.16		**Physical Protection of Plants and Materials Requirements**
	2.16-1	The design of NGNP shall possess features to eliminate or reduce the potential theft of nuclear materials.
	2.16-2	The design of NGNP shall emphasize passive barriers to potential theft of nuclear materials.
	2.16-3	The design of the NGNP shall incorporate design features intended to provide physical protection against acts of sabotage that could create a radiological hazard to the personnel or a potential radioactive release to the public and the environment.
	2.16-4	Measures that have been designed into the NGNP for safety purposes shall be taken into account, to the extent practicable; these safety features should be designed and located within the NGNP in a manner that facilitates sabotage and theft protection, including consideration of damage control /recovery actions for sabotage attempts.
	2.16-5	There shall be concurrent consideration of safety and security, which will commence at the beginning of the design process.
	2.16-6	The NGNP shall incorporate design features facilitating implementation of material control and accounting procedures that are sufficient to enable the NGNP operating organization to account for the special nuclear material in its possession.
2.17		**Maintenance Requirements**
	2.17-1	The NGNP design shall include provisions for monitoring equipment status, configuration, and performance and for detecting and diagnosing malfunctions as a basis for predictive maintenance plans and decision making.
2.18		**NHS Protection System**
	2.18-1	The NHS Protection System shall maintain plant parameters within acceptable limits established for DBAs.
	2.18-2	The protection system shall implement the relevant monitoring, analysis, and actuation functions necessary to reach the controlled state in case of abnormal events.
	2.18-3	The protection system shall provide redundant, fail-safe protective functions.
	2.18-4	The protection system shall remain operable or fail-safe during credible external events.
3		**Requirements Applicable to Nuclear Heat Source**
3.1		**Reactor Support Systems**
3.1.1		**Helium Service System**
	3.1.1-1	The following is a required function of the helium service system: (A) Remove chemical and particulate contaminants from the primary coolant to maintain specified values,
	3.1.1-2	(B) Supply purified helium to systems filled with helium,
	3.1.1-3	(C) Remove helium from the primary system and the helium-filled supporting systems and store in a gas store for purified helium,

Object #	Requirement ID	Requirements Statements
	3.1.1-4	(D) Accept helium from helium-filled auxiliary and supporting systems during depressurization activities and, possibly, store radioactively contaminated helium,
	3.1.1-5	(E) Evacuate primary systems and helium supporting systems, and
	3.1.1-6	(F) Maintain chemical contaminants within required concentration bands.
	3.1.1-7	The Secondary Helium Purification System shall process a small side-stream of helium from the Secondary Heat Transport System to remove chemical and radioactive impurities.
	3.1.1-8	The Secondary Helium Purification System shall provide for tritium removal as required to meet tritium transport limits to plant effluents and products.
3.1.2		**Radioactive Waste and Decontamination System**
	3.1.2-1	The Radioactive Waste and Decontamination System shall provide for collecting radioactive (or potentially radioactive) liquid and gaseous wastes, including various forms of solid waste generated within the plant.
	3.1.2-1	The Radioactive Waste and Decontamination System shall provide for storing radioactive (or potentially radioactive) liquid and gaseous wastes, including various forms of solid waste generated within the plant.
	3.1.2-1	The Radioactive Waste and Decontamination System shall provide for processing, radioactive (or potentially radioactive) liquid and gaseous wastes, including various forms of solid waste generated within the plant.
	3.1.2-1	The Radioactive Waste and Decontamination System shall provide for monitoring radioactive (or potentially radioactive) liquid and gaseous wastes, including various forms of solid waste generated within the plant.
	3.1.2-2	The Radioactive Waste and Decontamination System shall provide equipment to remove radioactive surface contamination from components, as necessary, to facilitate control and minimize migration of radioactive contamination and to limit personnel exposure to radionuclides.
	3.1.2-3	The radioactive and potentially radioactive floor and equipment liquid runoff. Waste streams shall be routed to the liquid radioactive waste subsystem.
	3.1.2-4	Provisions shall be included to reduce activity levels contained in liquid effluent.
	3.1.2-5	Radioactive liquid waste system components shall be redundant to provide for both system reliability and on-line maintenance.
	3.1.2-6	The gas waste portion of the radioactive waste system shall have sufficient storage capacity to allow for radioactive decay prior to release.
	3.1.2-7	Decontamination equipment shall be skid mounted. Each decontamination skid shall provide steam, wash water (including detergent and/or additives), rinse water, drying air, and vacuuming service.
	3.1.2-8	Decontamination system wastes shall be collected locally and routed to the appropriate radioactive waste systems.
	3.1.2-9	All radioactive wastes generated within the facility shall be collected, monitored, treated, and processed onsite prior to shipment offsite.