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NGNP Plant Design Requirements Document

BEA Contract No. 000 75310

Safety Related? ☐ YES ☒ NO

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

Signature Block

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Record of Revision

Revision No.	Date	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	4/9/2009	ALL	Initial issue
001	6/8/2009	Page 18, Section 5.1.2	Added NRC Final Rule on New Reactor Aircraft Impact Assessments to the list.
001	6/8/2009	Page 21, TR-USR-002	Changed minimum specified electricity generation efficiency to 42%.
001	6/8/2009	Page 22, TR-PRG-011	Deleted TR-PRG-011 and renumbered subsequent requirements.
001	6/8/2009	Page 22, Section 5.3	Added clarification that project direction is via BEA/INL.
001	6/8/2009	Page 29, PR-SEC-004	Added Requirement PR-SEC-004 regarding operator action minimization and renumbered subsequent requirements.
001	6/8/2009	Throughout	Made editorial changes and added clarifications to text in response to INL comments.

Table of Contents

Page

Table of Contents
(continued)

Page

Table of Contents
(continued)

List of Figures

Page

Table of Acronyms

ALARA	As Low As Reasonably Achievable
AOO	Anticipated Operational Occurrences
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
BCCS	BOP Component Cooling Water System
BEA	Battelle Energy Alliance
CFR	Code of Federal Regulations
CWS	Circulating Water System
DBA	Design Basis Accident
DBD	Design Baseline Document
DBE	Design Basis Event
DOE	Department of Energy
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
ESS	Extraction Steam System
FB	Fuel Building
FDA	Food and Drug Administration
FDSS	Fire Detection and Suppression System
FERC	Federal Energy Regulatory Commission
FHSS	Fuel Handling and Storage System
FIMA	Fissions per Initial Metal Atom
FOAK	First-of-a-Kind
FY	Fiscal Year
He	Helium
HP	High Pressure
HPB	Helium Pressure Boundary
HSA	Helium Storage Area
HSS	Helium Services System

Table of Acronyms
(continued)

HTGR	High Temperature Gas-Cooled Reactor
HVAC	Heating, Ventilating and Air Conditioning
I&C	Instrumentation & Controls
IAEA	International Atomic Energy Agency
ICD	Interface Control Document
ICS	Plant Instrument and Control System
INL	Idaho National Laboratory
ISFSI	Independent Spent Fuel Storage Installation
ISI	In-Service Inspection
ITAAC	Inspections, Tests, Analyses and Acceptance Criteria
ITRG	Independent Technology Review Group
LEU	Low Enriched Uranium
LP	Low Pressure
LWR	Light-Water Reactor
MCS	Main Condensate System
MFS	Main Feedwater System
MHC	Main Helium Circulator
MHTS	Main Heat Transport System
MMBtu	One Million British Thermal Units
MSS	Main Steam System
NGNP	Next Generation Nuclear Plant
NHS	Nuclear Heat Source/Nuclear Heat Supply
NICS	Nuclear Island Cooling Water System
NIHS	Nuclear Island HVAC System
NOAK	"N^{th}"-of-a-Kind
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Guide
OSHA	Occupational Health and Safety Administration
PAG	Protective Action Guidelines

Table of Acronyms
(continued)

PCDR	Preconceptual Design Report
PCS	Power Conversion System
PDRD	Plant Design Requirements Document
PES	Plant Electrical System
PHTS	Process Heat Transport System
PLCS	Plant Communication System
PMSS	Plant Mechanical Services System
R&D	Research and Development
RAB	Reactor Auxiliary Building
RB	Reactor Building
RCCS	Reactor Cavity Cooling System
REM	Röntgen Equivalent Man
RPS	Reactor Protection System
RS	Reactor System
RWDS	Radioactive Waste and Decontamination System
Rx	Reactor
SAG	Senior Advisory Group
SCS	Shutdown Cooling System
SDD	System Design Description
SE	Systems Engineering
SFCS	Spent Fuel Cooling System
SFSS	Intermediate and Long Term Spent Fuel Storage System
SG	Steam Generator
SNM	Special Nuclear Material
SSC	Systems, Structures and Components
SSE	Safe Shutdown Earthquake
SSS	Safeguards and Security System
SWDS	Steam Water Dump System
SWS	Switchyard System
TBD	To Be Determined

Table of Acronyms
(continued)

TGS	Turbine Generator System
TLR	Top Level Requirement
VS	Vessel System

1.0 INTRODUCTION

This document is the focal point of the Next Generation Nuclear Plant (NGNP) design. It provides specific requirements and requirements hierarchy upon which the design of the NGNP systems, subsystems and components are based.

The objective of this document is to provide the NGNP plant level design requirements. These requirements are developed to satisfy the NGNP Top Level Requirements (TLRs) and drive the plant system functions and design requirements. The NGNP TLRs translate a set of program and design goals to a specific category of TLRs.

The NGNP program has now entered the conceptual design phase and the Plant Design Requirements Document (PDRD) is developed based on the preconceptual design requirements and the current status and direction of the NGNP program. This initial release of the PDRD provides a basic set of plant level and system level requirements to begin conceptual design of major NGNP plant systems. The PDRD will be maintained and updated throughout the conceptual design phase of the NGNP as the design information becomes available and the design matures.

The PDRD is structured by defining the NGNP program's goals. These goals have been established to meet the NGNP mission needs. TLRs are then presented.

The TLRs are segregated in three separate and distinct categories as follows: 1) Regulatory Requirements, 2) End-User Requirements, and 3) NGNP Program Requirements. The process of developing plant and system functions and design requirements is then described, followed by the plant level requirements section and system functions and design requirements section.

This release of the PDRD is at the start of the NGNP conceptual design phase; therefore, it is by no means complete. The requirements in this document will evolve and be revised as necessary by the NGNP Systems Engineering functional organization as the NGNP design progresses. The revisions to this document will be controlled and managed by the NGNP Systems Engineering functional organization.

2.0 NGNP GOALS

The NGNP project mission is the development of a commercial plant demonstration that (a) provides high-efficiency electricity generation, (b) provides CO_2-free process heat production, and (c) is based on high-temperature, gas-cooled, graphite moderated reactor technology as the heat source.

The goals and objectives defined for the NGNP project, as modified by the Independent Technical Review Group (ITRG) recommendations, are presented in this section. Later in the document these goals are transformed into TLRs for the NGNP project.

The following Program Goals and Design Goals have been established to meet the NGNP mission needs.

2.1 Program Goals

High-level NGNP program goals that support the mission needs are, as identified in Reference 1:

1. Develop and implement the technologies important to achieving the functional performance and design requirements determined through close collaboration with commercial industry end-users.

2. Demonstrate the basis for commercialization of the nuclear system, a heat transfer/transport system, a process heat process, and a power conversion concept. An essential part of the process heat operations will be demonstrating that the requisite reliability and capacity factor can be achieved over an extended period of operation.

3. Establish the basis for licensing the commercial version of the NGNP by the Nuclear Regulatory Commission (NRC). This will be achieved through licensing of the prototype by the NRC and initiating the process for certification of the nuclear system design.

4. Foster rebuilding of the U.S. nuclear industrial infrastructure and contributing to making the U.S. industry self-sufficient for our nuclear energy production needs.

2.2 Design Goals

The high-level Design Goals that support the mission needs are:

1. The NGNP plant shall be capable of generating electricity and process heat in the form of steam.

2. The NGNP plant shall be commercially viable in a product-cost comparison with natural gas-fired plants with comparable capabilities for projected future markets.

3. The NGNP plant shall use a modular gas-cooled reactor concept with prismatic core design as the Nuclear Heat Source (NHS).

4. The NGNP shall be capable of passive decay heat removal.

5. The NGNP design shall be consistent with the international objectives developed for the Generation IV reactor concepts. This includes safety, sustainability, non-proliferation, and security.

6. The fuel for NGNP shall be Low Enriched Uranium (LEU) <20% enrichment.

3.0 REQUIREMENTS DEVELOPMENT PROCESS

The NGNP plant design requirements are based on a set of NGNP TLRs. The TLRs are in three categories 1) Regulatory Requirements (federal, state, etc.), 2) End-User Requirements (at this point largely undefined), and (3) the NGNP Program Requirements (References 1 and 2). Section 5 of this document lists the current NGNP TLRs in each of these categories. The plant and system level design requirements are then developed and presented in Sections 6 and 7.

The requirements documentation hierarchy is depicted in Figure 3-1. The PDRD (this document) provides a summary description of the NGNP design (Section 4) to setup the framework for the NGNP design, followed by the TLRs applicable to the NGNP. The plant level requirements are then listed. This document also contains the NGNP system functions and design requirements. The development and maturation of the PDRD contents follow the NGNP design progression. As the design becomes more and more advanced and plant level analysis results are developed, this document will be updated on a regular basis, determined by the system integration function, to reflect the governing NGNP plant and systems design requirements.

The NGNP Design Baseline Document (DBD) (Reference 12) is created to provide a snapshot of the NGNP design data as the design progresses. As the NGNP plant level requirements evolve and mature, the NGNP system functions and design requirements are developed and documented in the PDRD. The NGNP system level functions and design requirements defined in the PDRD provide requirements for the design of the NGNP systems. The system design description (SDD) documents, yet to be developed, will provide system level design information. The design of each system will be performed independently; however, the system interfaces will be tightly controlled. The system interface control is performed by the design integration function and will be controlled by interface control document(s) yet to be developed. See Figure 3-1 for the requirements and document hierarchy beyond the PDRD.

Normally, a formal Systems Engineering (SE) process based on functional analysis is used to convert the TLRs to plant level requirements (further decomposed into lower level plant requirements), and finally followed by allocation of plant level requirements to systems and definition of system functions and design requirements. However, as directed by the work scope statement for this initial document revision, the plant level requirements are derived from those defined in the NGNP System Requirements Manual (Reference 1).

The plant level requirements are provided in Section 6. The NGNP Systems Functions and Requirements are provided in Section 7.

The top level and plant level requirements are identified and separated from supporting descriptive text by identifying a unique requirement number in bold text followed by the requirement in bold italic text, all enclosed in a box frame, as in the following example:

TR-YYY-000	***Text of specific requirement***

TLRs are identified by the leading TR designator, followed by a three letter code which identifies the source of the requirement, followed by a unique number within that series. The plant level requirements are identified by the leading PR designator, followed by a three letter code which identifies the subject area of the requirement, followed by a unique number.

System required functions and design requirements are identified as simple numbered lists under the appropriate section headings.

Within each requirements set, specific values for individual requirements may be enclose within square brackets. This indicates that the value is preliminary in nature and that subsequent detailed analysis is expected to result in update of the number.

This initial revision of the NGNP PDRD provides a starting point for the plant designers to begin the conceptual design work. The PDRD development is ultimately an iterative and interactive process with the design progression activities. As the design matures, the PDRD becomes more detailed.

Going forward with the update and future refinement of the PDRD, AREVA intends to switch to a formal SE methodology for requirements management and development. This includes functional analysis, requirements allocation, requirements traceability and requirements verification. AREVA intends to use a computerized requirements management tool to manage the NGNP requirements. Such rigor becomes necessary as the design progresses into the conceptual design phase and more detailed requirement interrelationships are developed.

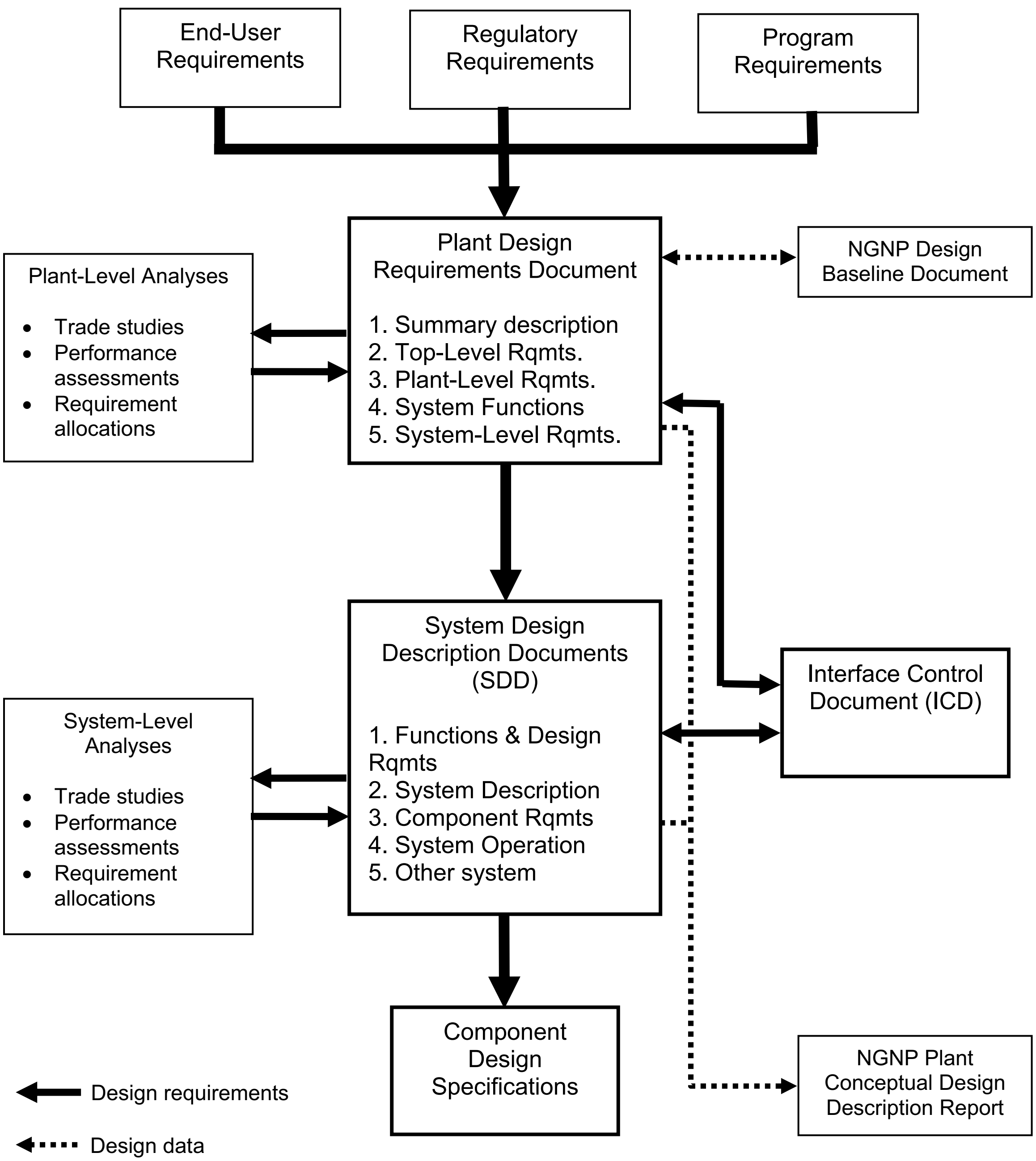

Figure 3-1: NGNP Requirements and Document Hierarchy

4.0 NGNP SUMMARY DESCRIPTION

This section provides a high-level description of the NGNP plant concept envisioned in the development of these requirements. This description is provided for information only as an aid in the understanding and interpretation of the plant design requirements. The design is formally described in the design documentation as referenced in the Design Baseline Document (Reference 12). This description is NOT a design requirement.

The Prismatic Conventional Steam Cycle NGNP plant is a high-temperature, gas-cooled, graphite-moderated reactor design utilizing an indirect cycle configuration to supply high temperature steam for both electricity generation and process heat applications. It is envisioned to be co-located with a commercial industrial facility and to be used to provide energy in the form of process steam and/or electricity to that facility. Given the commercial nature of this configuration, there is no consideration of a smaller, experimental hydrogen production loop, nor is consideration given to allow plant operation at higher-than-full power allowed temperatures. That is, there is no special allowance for operation at very high temperature at low reactor powers.

The Conventional Steam Cycle NGNP consists of two helium heat transport primary loops in parallel, each with a gas-to-water steam generator unit. Primary coolant carries reactor heat directly to the steam generators to produce steam in the secondary loop. Electricity is generated with conventional multi-stage steam turbines by the steam produced in the steam generators. The steam produced by the steam generators also provides energy to one or more steam reboilers, which provide process steam to industrial processes through a tertiary process steam loop.

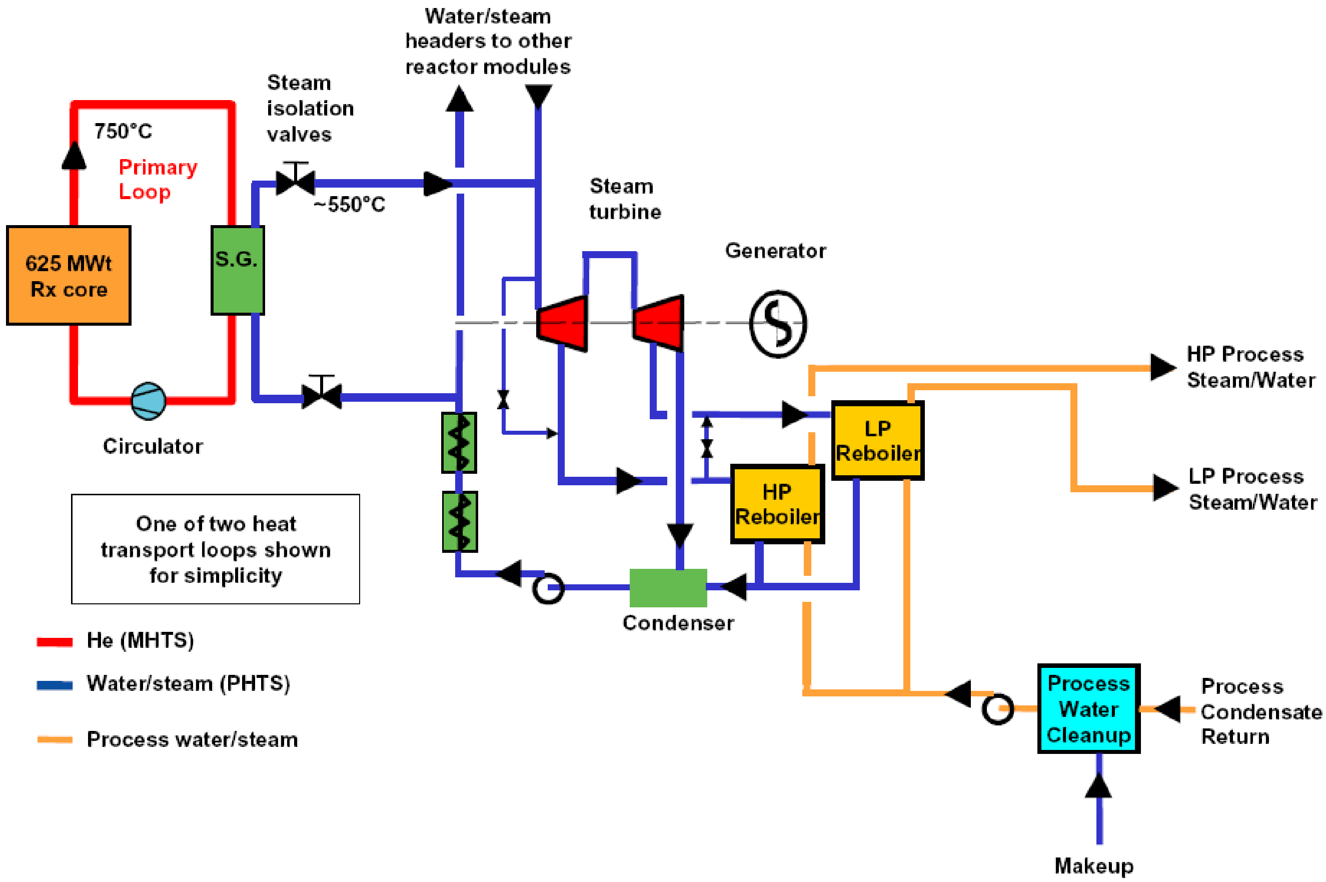

Figure 4-1: NGNP Schematic Representation

5.0 TOP LEVEL NGNP REQUIREMENTS

The NGNP TLRs are based on requirements from three main sources (1) Regulatory Requirements, (2) End-User Requirements, and (3) the NGNP Program Requirements. These requirements are identified in the following sections.

5.1 Regulatory Requirements

Federal regulatory requirements are defined by the Code of Federal Regulations (CFR), which is controlled by several regulatory bodies, such as the NRC and the Environmental Protection Agency (EPA). The NGNP shall comply with the requirements established in the following regulatory documents from various regulatory bodies unless regulatory relief is requested and granted through processes such as 10 CFR Part 50 License Exemptions and Conditions.

5.1.1 DOE Orders

TR-REG-001	***The NGNP shall comply with applicable DOE orders.***

The acquisition strategy for the NGNP project may include a combination of requirements from both the federal and commercial sectors. Until a better definition of the commercial participant(s) is obtained, the DOE Acquisition Management System will be used as a guide in establishing the appropriate work scope, including the documents listed below (see Reference 1). It is anticipated that many of these requirements will be superseded by the requirements imposed by the eventual builder of the NGNP, whether a commercial consortium or a government/commercial alliance. Specific DOE Orders considered may include:

1. DOE O 420.1B, Facility Safety
2. DOE O 435.1, Radioactive Waste Management
3. DOE Policy 450.4, Safety Management System Policy
4. DOE O 450.1A, Environmental Protection Program
5. 10 CFR 851, Worker Safety and Health Program
6. DOE M 470.4-2 Chg.1, Physical Protection

5.1.2 NRC Regulations

TR-REG-002	***The NGNP shall comply with applicable NRC regulations.***

Specific applicable NRC documents include, as a minimum:

1. 51 CFR 28044, Policy Statement on Safety Goals for the Operation of Nuclear Power Plants
2. 10 CFR 20, Standards for Protection Against Radiation (permissible dose levels and activity concentrations in restricted and unrestricted areas)

3. 10 CFR 50, Domestic Licensing of Production and Utilization Facilities (applicable portions as needed)
4. 10 CFR 51, Environmental Protection Regulation for Domestic Licensing and Related Regulatory Functions
5. 10 CFR 52, Licenses, Certifications, and Approvals for Nuclear Power Plants
6. 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" for Radioactive Material
7. 10 CFR 73, Physical Protection of Plants and Materials
8. 10 CFR 74, Material Control and Accounting of Special Nuclear Material
9. 10 CFR 75, Safeguards on Nuclear Material – Implementation of US/IAEA (International Atomic Energy Agency) Agreement
10. 10 CFR 95, Facility Security Clearance and Safeguarding of National Security Information and Restricted Data
11. 10 CFR 100, Reactor Site Criteria (numerical dose guidelines for determining the exclusion area boundary, low population zone, and population center distances)
12. 10 CFR 835, Occupational Radiation Protection
13. The 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 in 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.
14. 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
15. Nuclear Regulatory Commission, Regulatory Guide 1.206, Combined License Applications for Nuclear Power Plants (LWR Edition), June 2007
16. Nuclear Regulatory Commission, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, March 2007
17. NRC Final Rule on New Reactor Aircraft Impact Assessments, NRC News 09-030, February 17, 2009

5.1.3 EPA Regulations

TR-REG-003	***The NGNP shall comply with applicable EPA regulations.***

The EPA provides regulations related to radiation exposure to the public as well as defined radioactive materials releases from the facility. Specific documents include:

1. 40 CFR 50−99, Clean Air Act
2. 40 CFR 100−149, Clean Water Act
3. 40 CFR 190, Environmental Radiation Protection Standards for Nuclear Power Operations
4. 40 CFR 1502, Environmental Impact Statement
5. EPA, 520/1-75-001, Protective Action Guide Doses for Protective Actions for Nuclear Incidents

5.1.4 FDA Regulations

TR-REG-004	***The NGNP shall comply with applicable FDA regulations.***

The US Food and Drug Administration (FDA) provides limits on radioactive contaminants that can enter the nation's food supply. Specific documents include:

1. 47 FR 47073, Accidental Radiation Contamination of Human Food and Animal Feed; Recommendations for State and Local Agencies

5.1.5 OSHA Regulations

TR-REG-005	***The NGNP shall comply with applicable OSHA regulations.***

The Occupational Health and Safety Administration provides regulations that help protect plant workers from physical injury, including providing exposure limits for hazardous materials. Specific documents include:

1. 29 CFR 1910, Occupational Safety and Health Standards, Subpart H, Hazardous Materials

5.1.6 FERC Regulations

TR-REG-006	***The NGNP shall comply with applicable FERC regulations.***

The Federal Energy Regulatory Commission (FERC) sets requirements for all electricity being fed into the national power grid. Because the NGNP is expected to produce electricity for commercial use, it must follow applicable FERC requirements.

Individual requirements are TBD at this time.

5.1.7 State Regulations

TR-REG-007	***The NGNP shall comply with applicable laws and regulations of the state in which the plant is sited.***

Should the NGNP be sited at the Idaho National Laboratory (INL), as indicated in the 2005 Energy Policy Act (EPAct), the NGNP must meet applicable state requirements and observe treaties with sovereign nations such as the Shoshone-Bannock.

Should the NGNP be sited at another location, the laws of that state shall be observed including any treaties with sovereign nations should the site include land of that nation.

5.1.8 County Regulations

TR-REG-008	***The NGNP shall comply with applicable laws and regulations of the county in which the plant is sited.***

Regulations imposed by the county in which the NGNP will be built are TBD at this time, and will be developed once a site is selected for the reactor.

5.1.9 Local Regulations

TR-REG-009	***The NGNP shall comply with applicable laws and regulations of the locality in which the plant is sited.***

Regulations imposed by the locality in which the NGNP will be built are TBD at this time, and will be identified and developed once a site is selected for the reactor.

5.1.10 Indian Reservation Rights

TR-REG-010	***The NGNP shall comply with applicable agreements with Indian Tribes upon whose sovereign reservations the plant is sited or whose rights might be impacted.***

Detailed requirements will be developed after the location of the NGNP is finalized. As an example of the types of considerations that must be addressed related to Indian Reservation rights, a summary of the situation for the INL site is presented in the next paragraph.

The Shoshone-Bannock Tribes are the region's primary Native American residents. Because they believe the land is sacred, the entire INL reserve is potentially culturally important to them. They consider cultural resources to the Shoshone-Bannock peoples include all forms of traditional life ways and usage of all natural resources. This includes not only prehistoric archaeological sites, which are important in religious or cultural heritage context, but also features of the natural landscape, air, plant, water, or animal resources that might have special significance. DOE has committed to additional interaction and exchange of information with the Shoshone-Bannock Tribes at the Fort Hall Reservation.

5.2 End-User Requirements

An important aspect of the NGNP TLRs is the End-User Requirements. Since no specific industrial end user has been identified for the NGNP, the requirements in this section are developed as a place holder for a “generic” industrial facility that utilizes process heat in the form of high pressure steam and electricity.

TR-USR-001	***The NGNP shall be designed, constructed, licensed, and operating in accordance with the established project schedule.***
TR-USR-002	***The NGNP shall produce electricity at a high-efficiency [> 42%] on a scale that sets a foundation for future commercial deployment.***
TR-USR-003	***The NGNP shall generate reliable [> 90%] process heat in the form of high pressure steam on a scale that sets a foundation for future commercial deployment.***
TR-USR-004	***The NGNP shall be licensed by the NRC as a commercial cogeneration facility producing electricity and process heat.***
TR-USR-005	***The NGNP shall be capable of operation in any one of three modes: 100% electricity production, 100% process heat generation, or a mix of electricity production and process heat generation.***
TR-USR-006	***The NGNP shall enable demonstration of high reliability [99.9%] of process heat energy products and processes utilizing its NHS as part of an integrated process steam supply system.***
TR-USR-007	***The NGNP shall enable demonstration of high reliability [> 90%] of process heat energy products and processes utilizing its NHS as a stand-alone single reactor module.***

5.3 Program Requirements

The following requirements were adapted from Reference 1, as modified by the specific requirements of the proposed AREVA NGNP design.

TR-PRG-001	***The NGNP shall be designed, constructed, licensed, and operating by 2021.***
TR-PRG-002	***The NGNP design configuration shall consider cost and risk profiles to ensure that NGNP establishes a sound foundation for future commercial deployment.***
TR-PRG-003	***The NGNP NHS shall be based on the HTGR with prismatic core configuration concept.***
TR-PRG-004	***The NGNP NHS shall utilize passive safety features to cool the core from full power to safe shutdown conditions.***
TR-PRG-005	***The NGNP shall produce high-efficiency electricity and provide high temperature steam for process heat applications on a scale that sets a foundation for future commercial deployment.***
TR-PRG-006	***The NGNP shall be licensed by the NRC as a commercial cogeneration facility producing electricity and process heat in the form of high temperature steam.***

TR-PRG-007	***The NGNP shall include provisions for optimizing electricity vs. process heat production mix.***
TR-PRG-008	***The NGNP shall enable demonstration of industrial process energy production and usage utilizing its NHS.***
TR-PRG-009	***The NGNP project shall include identification of necessary and sufficient research and development (R&D) technical scope and priorities.***
TR-PRG-010	***NGNP licensing shall support potential future NRC technology neutral rule-making activities (i.e., risk-informed, performance-based alternative to 10 CFR Part 50).***
TR-PRG-011	***The NGNP design shall be consistent with the international objectives developed for the Generation IV reactor concepts. This includes safety, sustainability, non-proliferation and security.***
TR-PRG-012	***The NGNP fuel shall be Low Enriched Uranium (LEU) <20% enrichment.***

A Senior Advisory Group (SAG) comprised of senior personnel from the HTGR suppliers, owner operators, and potential end-users was formed to advise the NGNP project on commercial interests in application of the HTGR technology. In September and October 2008, the SAG was convened to provide its perspective on the priorities for the 2009 NGNP project work scope. The SAG also identified the range of potential applications that would most likely be acceptable to the commercial sector for a first-of-a-kind (FOAK) plant demonstrating the capabilities of the HTGR technology. The SAG considers that these include providing electricity and steam in a cogeneration application and/or in recovery of oil sands or shale. The HTGR suppliers then provided recommended reference plant configurations considered best suited to these applications. Reflecting the products offered by the suppliers and the SAG recommendations, BEA/INL directed two configurations be studied; one based on the pebble bed reactor design, the other based on the prismatic reactor design. This document focuses on the prismatic reactor design requirements.

The prismatic reference design configuration includes a steam generator in the primary loop with a secondary steam loop supplying the energy conversion processes (e.g., steam turbine generator producing electricity and process heat steam for industrial applications). Using the list of potential applications and the reference configurations as the basis, the SAG developed a list of HTGR fundamental requirements for the NGNP as a FOAK plant. The deliberations and detailed list of these requirements are documented in Reference 11.

This list is based on the SAG's collective view of the fundamental requirements that the NGNP must meet in order to support development of a viable commercial HTGR offering. This list of requirements is not fully consistent with the requirements of the EPAct that informed the NGNP preconceptual design.

Specifically, the SAG recommendations do not include a hydrogen process in the FOAK plant, the plant could be sited at a commercial facility or at INL and the reactor outlet temperature will be lower than that assumed in the Preconceptual Design Report (PCDR) (750°C to 800°C instead of 900°C to 950°C).

In anticipation that the NGNP SAG views will persist and inform the direction of the public-private partnership, the NGNP project has adopted the requirements recommended by the SAG for ongoing conceptual design work.

These requirements are included as appropriate throughout this PDRD as top level plant requirements:

TR-PRG-013	***The NGNP NHS shall support future design certification for a broad range of applications and sites. Note that the NHS includes the nuclear island (e.g., the reactor, primary coolant system, and supporting systems) and the heat transfer/transport system.***
TR-PRG-014	***The NGNP reference design configuration shall include a steam generator in the primary loop with a secondary steam loop supplying the energy conversion processes.***
TR-PRG-015	***The NGNP design shall be applicable to a broad range of cogeneration applications supplying, singly or in combination, electricity and process heat in the form of high temperature steam.***
TR-PRG-016	***The NGNP reactor gas outlet temperature shall be in the range of [750 to 800°C].***
TR-PRG-017	***The NGNP project shall be capable of completing design, licensing, construction, and startup testing for initial operation by 2021.***
TR-PRG-018	***The NGNP design shall be capable of controlling the transport of radionuclides to the end products to levels below the concentration or exposure requirements for the product (e.g., tritium in steam, gas, or hydrogen). Initial acceptable tritium levels shall be set at a fraction of the U.S. EPA limits for drinking water and air.***
TR-PRG-019	***The NGNP plant can be co-located with the commercial/industrial application with Protective Action Guidelines (PAG) limits met at the nuclear plant site boundary.***
TR-PRG-020	***The NGNP plant shall be capable of following industrial process load demand variations.***
TR-PRG-021	***Costs for anticipated "N^{th}"-of-a-kind (NOAK), shall be based on design certification, construction, and operation of FOAK NGNP design, and shall support a viable economic business model (competitive with natural gas price at [TBD $/MMBtu]).***
TR-PRG-022	***The NGNP shall meet normal maintenance exposure target limits of no more than 50 person-REM/year per module in a refueling year.***
TR-PRG-023	***The target NGNP availability factor shall be [≥ 90%].***
TR-PRG-024	***The target plant design lifetime shall be 60 years (calendar).***

6.0 PLANT LEVEL REQUIREMENTS

The subsections below summarize the NGNP functional and operational requirements, technical requirements, and plant design requirements, as defined at the beginning of the conceptual design phase. These are based on the FY 2007 preconceptual design work for the NGNP, as partially updated by SAG involvement and early conceptual design work (see Reference 1). These requirements will be updated as the project matures, particularly after the nuclear system design, plant operating conditions, and plant configuration are finalized. A uniform requirements numbering system is being developed. Once the project develops and adopts a requirements numbering system; it will be instituted consistent with the configuration of the plant.

The requirements listed in this section constitute the categorized, high-level requirements.

6.1 Plant System Configuration and Essential Features Requirements

System configuration and essential features requirements are as follows:

PR-CFG-001	***The NGNP NHS shall use the HTGR prismatic core concept.***
PR-CFG-002	***The NGNP shall demonstrate commercial viability of the HTGR.***
PR-CFG-003	***The NGNP NHS shall be designed such that it can support certification of the commercial design for a broad range of applications and sites.***
PR-CFG-004	***The NGNP design shall be applicable to a broad range of cogeneration applications supplying, singly or in combination, electricity and process heat in the form of high temperature [TBD °C] steam.***
PR-CFG-005	***The NGNP design shall assure that the site PAG limits are met at the site boundary, such that the HTGR can be co-located with an industrial process heat user plant.***
PR-CFG-006	***The costs for the anticipated NOAK plant, based on design certification, construction, and operation of the NGNP, shall support a viable economic business model (i.e., competitive with natural gas at [TBD $/MMBtu]).***
PR-CFG-007	***For the NGNP, the designed reactor gas outlet temperature shall be in the range of [750 to 800°C].***
PR-CFG-008	***The NGNP design shall use steam generators in the primary circuit.***
PR-CFG-009	***The NGNP shall be a cogeneration plant capable of producing both process heat and electricity.***
PR-CFG-010	***The NGNP shall support dedicated process heat supply.***
PR-CFG-011	***The NGNP shall support dedicated electricity generation.***
PR-CFG-012	***The NGNP design shall support NOAK (multi-module) electricity supply applications ranging from [50 MWe] to [1200 MWe].***
PR-CFG-013	***The NGNP shall be designed to use LEU TRISO-coated particle fuel.***

The following are the parameters and performance requirements for the Process Heat Transport System (PHTS):

PR-CFG-014	***The PHTS shall receive steam at temperatures up to [550°C] and distribute heat at a rate of up to [TBD MWth] to the end-user facility steam distribution system.***
PR-CFG-015	***The NGNP design shall support NOAK (multi-module) process steam supply applications ranging from [300 MWt] to [2000 MWt].***

PR-CFG-016	***The process heat distribution system pressure range shall be [TBD to TBD].***
PR-CFG-017	***The NGNP shall enable demonstration of high reliability [99.9%] of process heat energy products and processes utilizing its NHS as part of an integrated process steam supply system. That is, the overall reliability of the process heat being delivered to the associated industrial process by all components of the system of which the NGNP NHS is part, including backup or redundant fossil boilers, electric heaters, and/or additional reactor modules, shall enable demonstration of the required reliability.***
PR-CFG-018	***The NGNP shall enable demonstration of high reliability [> 90%] of process heat energy products and processes utilizing its NHS as a stand-alone single reactor module. This reliability requirement applies to the NGNP NHS module as a stand-alone unit.***

The following are the requirements for the PHTS configuration:

PR-CFG-019	***The PHTS shall be physically separated from the remainder of the NGNP consistent with end-user plant economic and risk tradeoffs.***
PR-CFG-020	***The interfaces between the PHTS and the remainder of the industrial facility shall be designed to ensure that failures or upset conditions in the PHTS do not result in failures or adverse impacts to the remainder of the industrial facility and vice-versa.***
PR-CFG-021	***The interfaces between the PHTS and the remainder of the NHS shall be designed to minimize the impacts of upset conditions in the NHS on the PHTS.***
PR-CFG-022	***Steam produced in the PHTS shall be made available for distribution in accordance with the end-user requirements.***
PR-CFG-023	***No central storage of steam shall be included at the PHTS other than steam header, as required for efficient operations. The PHTS will provide for pressure relief, venting, valving, instrumentation, and maximum allowable quantities to limit over- pressure conditions.***
PR-CFG-024	***The interface system between the process heat plant and the remainder of the NGNP shall be designed to ensure that tritium migration into the PHTS is limited, such that the maximum amount of tritium released to the PHTS does not exceed [TBD%] of EPA water standard.***

6.2 Safety Requirements

Safety requirements are as follows:

PR-SAF-001	***The nuclear system safety basis shall not depend on active cooling systems during design basis accident (DBA) conditions.***

PR-SAF-002	***The process heat distribution systems shall comply with the requirements of 29 CFR 1910.103, Occupational Safety and Health Standards.***
PR-SAF-003	***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.***
PR-SAF-004	***Upper bound off-site doses during design basis events shall meet 10 CFR 50.34 with margin at the site boundary.***
PR-SAF-005	***The plant shall be designed to minimize the need for off-site emergency planning.***
PR-SAF-006	***Exposure to workers 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.***
PR-SAF-007	***The total concentration of radioactive contaminants in the PHTS shall be minimized to ensure that worker and public dose limits do not exceed NRC regulatory limits of [TBD].***
PR-SAF-008	***The total concentration of radioactive contaminants in the end products of the industrial process shall be minimized to ensure that worker and public dose limits do not exceed NRC regulatory limits of [TBD].***

6.3 Operational Requirements

Operational requirements are as follows:

PR-OPR-001	***The NGNP NHS shall be designed for an operational lifetime of 60 years (calendar).***
PR-OPR-002	***The NGNP plant shall be capable of operating in base-load or load-following mode.***
PR-OPR-003	***The NGNP plant shall be capable of process heat load follow between [30 to 80%] load at a rate of [10%] per hour and between [80 to 100%] load at [5%] per hour.***
PR-OPR-004	***The NGNP shall be designed to continue operation during a complete loss of process heat load demand, and stabilize in the electricity generation mode.***
PR-OPR-005	***The NGNP shall demonstrate a refueling interval capability consistent with process plant availability requirements.***
PR-OPR-006	***The NGNP shall be capable of achieving an 18 month refueling interval.***
PR-OPR-007	***The NGNP shall be designed so as to support the anticipated NOAK design to have a normal maintenance exposure target limit of no more than 50 person-REM/year per module in a refueling year.***
PR-OPR-008	***The NGNP shall support operational transitions between process heat supply, electricity generation and cogeneration.***

PR-OPR-009	***The configuring of the PHTS shall eliminate the need for active control of end-user processes in the NRC operating license.***

6.4 Maintenance Requirements

Maintenance requirements are as follows:

PR-MTN-001	***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.***
PR-MTN-002	***Each plant system design shall identify required preventive maintenance plans consistent with required system reliability.***
PR-MTN-003	***Each plant system design shall identify a required on-hand spare parts inventory necessary to meet required system reliability.***

The following are the requirements for the PHTS maintenance:

PR-MTN-004	***The PHTS shall be designed to allow all components to be removed, replaced (if necessary), and reinstalled.***
PR-MTN-005	***The PHTS 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.***

6.5 Instrumentation and Control Requirements

Instrumentation and control (I&C) requirements are as follows:

PR-I&C-001	***The NGNP shall be capable of being controlled from a single control room.***
PR-I&C-002	***The main control room shall include controls for the NHS, power conversion system (PCS), and PHTS.***
PR-I&C-003	***The NGNP design shall optimize the human-machine interface based on human factors engineering principles and operating experience to enhance plant safety.***
PR-I&C-004	***The NGNP shall be designed such that no operator action would be required to mitigate DBEs for a period of [72 hours].***

6.6 Structural Requirements

Structural requirements are as follows:

PR-STR-001	***NGNP systems, structure, and components (SSCs) shall be designed and constructed using and demonstrating modular plant construction techniques where appropriate.***
PR-STR-002	***The NGNP shall be designed for the reference safe shutdown earthquake (SSE) horizontal peak ground acceleration (PGA) of [0.3g].***
PR-STR-003	***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.***
PR-STR-004	***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.***

6.7 Codes and Standards Requirements

Codes and standards requirements are as follows:

PR-C&S-001	***The design of the NGNP shall comply with all applicable federal, state, and local codes and standards.***
PR-C&S-002	***NUREG/CR-5973 shall be used as a starting point for the identification of codes and standards to be followed during conceptual design of the NHS portion of the NGNP.***
PR-C&S-003	***Should the NGNP be built within a DOE facility and interface with other existing facilities, the plant designer shall evaluate DOE orders to ensure that the NGNP can interface with the DOE site and be acceptable to DOE.***

6.8 Quality Assurance Requirements

The Quality Assurance requirement is as follows:

PR-QAL-001	***The NGNP project shall use the U.S. national consensus standard American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA)-1-[2000], "Quality Assurance Program Requirements for Nuclear Facilities Applications".***

The NGNP project is currently evaluating implementation of NQA-1-2008, pending NRC acceptance.

6.9 Safeguards and Security Requirements

These requirements are presented in the context of physical protection against theft, sabotage, and other terrorist activities; protection, control, and accountability of nuclear materials; and international safeguards. These are covered principally under 10 CFR 73, 10 CFR 74, and 10 CFR 75, although some DOE directives (especially DOE G 413.3-3 and the DOE 470 P, O, and M series) are also relevant. NRC, DOE (including National Nuclear Security Administration), and IAEA policies and regulations are evolving, significantly, affecting design policy now and likely continuing into the future. Further issues include methodologies to provide concurrent consideration of safety and security (including safeguards) through their integration into the design process. In opening the policy, NRC states that international safeguards shall be considered during the design.

As compared to current generation light-water reactors, NRC expects that advanced reactors will provide enhanced margins of safety; and use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions. In the policy statement on the regulation of advanced reactors, the NRC identified various desirable attributes to be considered during the design process including:

1. The design shall 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 features, and formulation of mitigation measures, with reduced reliance on human actions.

2. The design shall include features that would eliminate or reduce the potential theft of nuclear materials.

3. The design shall emphasize passive barriers to potential theft of nuclear materials.

In concluding the policy, "Finally, the NRC also believes that it will be in the interest of the public as well as the design suppliers and the prospective license applicants to address security issues early in the design stage to achieve a more robust and effective security posture for future nuclear power reactors."

Physical protection of the plant and nuclear material requirements are as follows:

PR-SEC-001	***The design of the NGNP shall comply with 10 CFR 73, Physical Protection of Plants and Materials.***
PR-SEC-002	***The design of the NGNP shall possess features to eliminate or reduce the potential theft of nuclear materials.***
PR-SEC-003	***The design of the NGNP shall emphasize passive barriers to potential theft of nuclear materials.***
PR-SEC-004	***Reliance on operator actions in mitigation measures for the consequences of security and safeguards events shall be minimized.***
PR-SEC-005	***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.***
PR-SEC-006	***Measures which have been designed into the NGNP for safety purposes shall be taken into account, to the extent that is practical in the consideration of sabotage and theft protection, including consideration of damage control/recovery actions from sabotage attempts.***
PR-SEC-007	***There shall be concurrent consideration of safety and security, which will commence at the beginning of the design process.***

PR-SEC-008	***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 and 13.6.5, and the development of Physical Security Hardware Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) per NUREG-0800 Section 14.3.12. The results of and insight from these evaluations and the ITAAC shall be used to integrate safeguards by design into the NGNP.***

Material control and accounting of special nuclear material requirements are as follows:

PR-SEC-009	***The design of the NGNP shall comply with 10 CFR 74, Material Control and Accounting of Special Nuclear Material.***
PR-SEC-010	***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.***

Safeguards on nuclear material requirements are as follows:

PR-SEC-011	***The design of the NGNP shall comply with 10 CFR 75, "Safeguards on Nuclear Material - Implementation of US/IAEA Agreement".***
PR-SEC-012	***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 Agreements(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards".***

6.10 Insurability

The insurability requirements are as follows:

PR-INS-001	***The NGNP shall demonstrate insurability to the maximum limit of private nuclear utilization facility insurance.***
PR-INS-002	***Features mandated to meet nuclear plant insurance requirements shall be incorporated into the NGNP design.***

Both the owner of the process and the owner of the NGNP could have additional requirements imposed by this proximity and the DBE scenarios at each facility.

6.11 Fuel Requirements

The requirements on the NGNP fuel are:

PR-FUL-001	***The expected fuel performance during both operation and accident conditions shall allow for a source term calculation capable of supporting an NRC license with an exclusion zone equal to or less than the site boundary for the design power level.***
PR-FUL-002	***The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences expected at least once in the lifetime of the plant.***

6.12 Surveillance and In-Service Inspection Requirements

Surveillance and In-Service Inspection (ISI) requirements are as follows:

PR-ISI-001	***The NGNP design shall include a recommended In-Service Inspection plan covering all components identified as requiring periodic inspection by the ASME Boiler and Pressure Vessel (B&PV) Code.***
PR-ISI-002	***The NGNP design shall provide means of access to the primary loop pressure boundary as necessary to permit applicable ISI activities and minimize the need for requests for code relief due to accessibility constraints.***

These ISI requirements are focused on the primary system. ISI requirements for other systems will be developed as these systems are better defined.

6.13 Decommissioning Requirements

Upon completion of its useful life, the NGNP NHS shall be capable of being decommissioned and dismantled to allow continued use of the land as a power plant or industrial site. In support of this goal,

PR-DEC-001	***The design of the NGNP shall consider potential decommissioning strategies and roadblocks and shall, to the extent practicable, minimize potential decommissioning issues.***

6.14 Environmental Requirements

Environmental requirements are as follows:

PR-ENV-001	***The NGNP shall identify all waste streams generated by type and estimated quantity, providing a disposition pathway within the applicable regulatory framework.***
PR-ENV-002	***The NGNP project shall minimize the generation of all waste, including radioactive, non-radioactive and mixed waste, and it shall comply with applicable DOE orders, NRC regulations, and EPA regulations in the treatment of these wastes.***
PR-ENV-003	***The design of the NGNP shall incorporate features consistent with decommissioning and decontamination best practices.***

PR-ENV-004	***The NGNP and NOAK plant will be capable of controlling the transport of radionuclides to the end products at levels below the concentration of exposure requirements for the product (e.g., tritium in steam). (Initial acceptable tritium levels will be set at a fraction of the EPA limits for drinking water and air).***
PR-ENV-005	***An Environmental Impact Statement shall be prepared for the NGNP. NRC regulations implementing the National Environmental Policy Act are contained in 10 CFR 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions, with 10 CFR 51.45, Environmental Report, providing general requirements for the contents of the environmental reports, including consideration of alternatives to proposed actions.***
PR-ENV-006	***Emissions from the NGNP and process heat facilities shall comply with all the applicable requirements of the Clean Air Act/Air Programs. Applicable federal regulations include 40 CFR 50 - 99, Clean Air Act.***
PR-ENV-007	***For the use and release of water, the NGNP and process heat facilities shall comply with all applicable requirements of the Clean Water Act/Water Programs. Applicable federal regulations include 40 CFR 100–149, Clean Water Act.***
PR-ENV-008	***Off-site radioactive releases from the NGNP shall comply with all NRC, EPA and associated DOE requirements including dose limits specified in 10 CFR 20, 10 CFR 50 Appendix I, and 40 CFR 190 for normal operation and 10 CFR 100 for DBAs.***
PR-ENV-009	***Nuclear waste streams' disposal cost shall be minimized.***
PR-ENV-010	***The PHTS design shall be such that there is a disposal path for all waste. Hazardous waste streams identified in 40 CFR 261.3 shall be disposed of accordingly.***

6.15 Spent Nuclear Fuel

Provision for temporary storage of discharged spent fuel shall be provided in the design of the NGNP facility. Facilities shall be provided to package and ship discharged spent fuel to appropriate federal facilities as permitted by future regulations.

PR-SNF-001	***The NGNP shall have the storage capacity to store all of the spent fuel generated during its expected design life plus a marginal capacity of [TBD] fuel elements. Such storage may be a mix of accessible storage within the reactor or fuel building and storage in a separate, on-site or near-site storage facility.***
PR-SNF-002	***The NGNP shall have the facilities required to package and ship spent fuel, either to an off-site facility or an on-site long term storage facility.***

6.16 Hazardous Waste Requirements

TBD

6.17 Construction Requirements

Construction requirements are as follows:

PR-CON-001	***Advanced techniques, such as the use of factory or field-fabricated and assembled modules containing portions of systems and/or structures, shall be used (as appropriate) to reduce erection costs and schedule risks and to enhance quality control.***
PR-CON-002	***The design of buildings and equipment shall facilitate plant construction and the installation, repair, and replacement of equipment.***

6.18 Availability Assurance Requirements

The SAG has proposed a target availability factor of greater than or equal to 90% for the NGNP. Specific availability requirements will be determined by the process heat end-user and will include the following:

PR-AVL-001	***Excluding NGNP mission-specific outages for inspection and testing, the NGNP design capacity factor for supplying process heat over the plant lifetime shall be at least [90 %] when modeled with equipment mean time to failure and mean time to repair data for the same or similar systems and components.***
PR-AVL-002	***Excluding NGNP mission-specific outages for inspection and testing, the capacity factor loss due to NGNP planned outages averaged over the lifetime of the plant shall not exceed [TBD %], including all planned inspection and maintenance activities which must be accomplished with the reactor shut down.***
PR-AVL-003	***Excluding NGNP mission-specific outages for inspection and testing, the calculated capacity factor loss due to unplanned outages averaged over the lifetime of the plant shall not exceed [TBD %].***

The following is the requirement for the PHTS capacity factor:

PR-AVL-004	***Excluding NGNP mission-specific outages for inspection and testing, the PHTS design capacity factor for process heat averaged over the plant lifetime shall be at least [TBD%] when modeled with equipment mean time to failure and mean time to repair data for the same or similar systems and/or components.***

The following is the requirement for the process heat plant planned outages:

PR-AVL-005	***Excluding NGNP mission-specific outages for inspection and testing, the capacity factor loss due to PHTS planned outages averaged over the plant lifetime shall be no greater than [TBD %], including all planned inspection and maintenance activities that must be accomplished with the PHTS shutdown.***

7.0 SYSTEM FUNCTIONS AND DESIGN REQUIREMENTS

In the sections below are presented a preliminary set of required functions and design requirements for most of the NGNP systems. It is anticipated that, as the NGNP conceptual design evolves and these systems become better defined, these functions and requirements will be updated and refined.

7.1 Reactor System

The following are the required functions of the Reactor System (RS):

1. Generate and control the generation of heat and transfer it to the primary coolant.
2. Control the nuclear chain reaction in the reactor core by absorbing neutrons in required operational modes.
3. Shut down the nuclear chain reaction within the designated time interval in any operational mode.
4. Have the capability to maintain reactor shutdown as required under normal operating, abnormal operating, and accident conditions.
5. Provide a controllable fuel geometry.
6. Provide core support and maintain its relative position to the control rods.
7. Provide heat transfer during conduction cooldown.
8. Conserve neutrons in the reactor core and provide shielding.
9. Control chemical attack of the fuel and graphite components within the core.

The RS shall be designed with the following requirements:

1. The decay heat removal shall be possible by passive heat transfer means (conduction, convection, and radiation) from the fuel to the reactor internals without reaching unacceptable fuel temperatures during all DBA conditions.
2. 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 conditions.
3. Provide core support.
4. Maintain the relative position of the core and the control rods.
5. The RS shall be designed for an operational lifetime of 60 years (calendar) excluding those portions of the system that can be replaced.
6. The core shall use forced circulation helium as the heat transport fluid.

7. Non-replaceable structural materials in contact with helium shall resist corrosion and erosion during plant life so as to avoid failure and or need for replacement.

8. The fuel shall be designed with the following requirements:

   a. As-manufactured quality requirements, at a [95%] confidence level:

      i. Heavy metal contamination: [$\leq 2 \times 10^{-5}$] (prismatic block).

      ii. SiC defect fraction: [$\leq 1 \times 10^{-4}$] (prismatic block).

   b. In-service fuel performances requirements, at a [95%] confidence level:

      i. Fuel failure during normal operations: [$\leq 2 \times 10^{-4}$] (prismatic block).

      ii. Incremental fuel failures during accident conditions: [$\leq 6.0 \times 10^{-4}$] (prismatic block).

9. The core shall utilize thermal neutron energy spectrum.

10. The core shall be moderated with graphite.

11. The active core height shall ensure the axial stability of the neutron flux and preclude the risk of uncontrolled xenon oscillations.

12. The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

13. Reference fuel shall be LEU-based (UCO or UO_2) with an enrichment limited to [<20.0%] (in mass) and with a peak burnup limited to [25%] fissions per initial metal atom (FIMA).

14. The reactivity temperature coefficient shall be sufficiently negative to shut down the nuclear chain reaction before an unacceptable fuel temperature is reached and maintain the core in a safe state for a time offering the ability to reliably introduce absorber elements.

15. The reactor core and associated coolant systems shall be designed so that in the power operating range the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity.

16. The reactor internals shall be designed to channel primary coolant to and from the reactor core for transfer of heat to the Main Heat Transport System (MHTS).

17. The reactor internals shall be designed to provide radiological shielding to limit neutron fluence to the reactor vessel.

18. The reactor internals shall be designed to limit gamma radiation exposure to the plant personnel and equipment.

19. The reactor internals shall be designed to limit damage to plant components during design basis conduction cooldown events.

20. The neutron control elements shall be designed to provide sufficient negative reactivity to shut down the reactor and maintain it in a subcritical condition, for anticipated events where these elements are assumed operational in the safety analysis, by compensating the worst positive reactivity insertion.

21. The appropriate neutron control elements shall be able to be reliably inserted into the appropriate locations in the core and/or reflector under all operational conditions.

7.2 Vessel System

The following are the required functions of the Vessel System (VS):

1. Contain and support the components of the reactor core, reactor internal supports and structures, and the nuclear heat transport components.

2. Maintain the relative position of the core and the control rods.

3. Provide decay heat and residual heat removal path by radial conduction during conduction cooldown.

4. Maintain primary pressure boundary integrity and containment of primary fluids and radionuclides.

5. Provide a primary heat transport path to/from the reactor vessel and Steam Generator (SG) vessels.

6. Support the SG tube bundle elements and associated piping.

7. Provide the primary coolant vessel's overpressure protection as required by ASME code.

The VS shall be designed with the following requirements:

1. The vessel supports shall support the vertical load.

2. The vessel supports shall include keying for lateral support.

3. The vessel supports shall accommodate thermal expansion.

4. The vessel supports shall accommodate duty cycle events.

5. The vessel supports shall withstand coupled vibration from the circulator.

6. The duration of maintenance, ISI, and repair/replacement operations of the VS shall be minimized.

7. All major parts of the VS shall be designed for an operating lifetime of 60 years.

8. Lifetime of piping, cross-vessels (where applicable), and other components of the VS shall be optimized according to the investment cost and replacement duration.

9. The VS shall be designed for design basis duty cycle events.

10. 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.

11. Maintain the primary pressure boundary integrity.

12. In normal operation, the creep effects on the reactor vessel shall be avoided (negligible creep).

13. No significant [TBD %] increase in leakage shall result from anticipated operating occurrences (AOO).

14. For AOOs and DBEs, the reactor vessel shall not prevent restarting of the plant.

15. The reactor vessel shall have a drain mechanism in case of water buildup in the vessel.

16. The cross vessels shall provide the primary heat transport path to/from the reactor vessel and SG vessels.

17. The SG vessels shall have a drain mechanism in case of water buildup in the vessel.

18. The pressure relief system shall be designed to eliminate overpressure in the primary system in the following conditions:

    a. In case of primary overpressure, the relief valves shall open to eliminate the overpressure and reclose once the overpressure condition terminates.

    b. Redundancy of the primary pressure relief system shall be required.

7.3 Main Heat Transport System

The following are the required functions of the Main Heat Transport System (MHTS):

1. Transfer heat from the reactor core to the SG.

2. Control the flow of helium to match the heat generation of the reactor core with the heat removal of the SGs.

3. Channel high-temperature helium from the reactor core outlet plenum to the SG inlet.

4. Transfer heat from the primary loop to the secondary loop during all normal conditions, at various power levels, and during accident conditions where such heat transfer is assumed.

5. Separate the primary loop from the secondary loop.

The MHTS shall be designed with the following requirements:

1. Helium shall be used as the heat transfer medium in the MHTS.

2. The MHTS shall be capable of decay heat removal under depressurized conditions with the primary coolant loop filled with any mixture of air and helium.

3. All parts of the MHTS shall be replaceable.

4. The main helium circulator (MHC) shall be driven by electrical motors capable of rated and variable speeds.

5. Bearing design shall preclude contaminant (e.g., lubricating product) ingress in the primary circuit.

6. Thermal insulation shall be required to protect the internal components by reducing heat migration due to primary system temperatures.

7. The MHC shall be designed with a minimum lifetime of 10 years.

8. The MHC shall be designed with stable hydraulic characteristics over the required speed range, without distinctive reversal points and a pronounced peak that would impact the operation of the unit and the MHTS.

9. The MHC shall maintain primary pressure boundary integrity.

10. Radial keys shall be provided to support the Hot Duct Assembly during operating and seismic conditions.

11. The Hot Duct Assembly shall provide helium leak tightness at each end (with core barrel and SG).

12. The primary helium shall flow on the shell side of the SG.

7.4 Shutdown Cooling System

The following are the required functions of the Shutdown Cooling System (SCS):

1. Transport core residual and decay heat from the RS to the environment when the RS is shut down and the MHTS is not operational. The helium primary coolant may be pressurized or depressurized.

2. Transport core residual and decay heat from the RS to the environment when the helium primary coolant is depressurized during reactor core refueling operations.

3. Provide residual heat and decay heat removal during recovery from conduction cooldown events.

4. Limit core bypass flow through its components during MHTS operation.

5. Retain helium and radionuclides within the parts of the SCS comprising the primary Helium Pressure Boundary (HPB).

6. Limit the ingress of potential contaminants into the primary helium circuit from components of the SCS external to the primary HPB.

The SCS shall be designed with the following requirements:

1. The SCS shall retain helium and radionuclides within the parts of the SCS comprising the primary HPB.

2. The SCS shall limit the ingress of potential contaminants into the primary helium circuit from components of the SCS external to the primary HPB.

3. All parts of the SCS shall be replaceable.

4. The SCS shall be able to cool the reactor down from normal operating temperature in [TBD hrs] under pressurized conditions.

5. The SCS shall be able to cool the reactor down from normal operating temperature in [TBD hrs] under depressurized conditions.

6. The SCS shall be able to accept hot inlet gas from the reactor outlet plenum under pressurized conditions at the peak temperature observed during pressurized conduction cooldown.

7. The SCS shall be able to accept hot inlet gas from the reactor outlet plenum under depressurized conditions at the peak temperature observed during depressurized conduction cooldown.

8. The SCS shall be capable of decay heat removal under depressurized conditions with the primary coolant loop filled with any mixture of air and helium.

7.5 Reactor Cavity Cooling System

The following are the required functions of the Reactor Cavity Cooling System (RCCS):

1. Protect the reactor cavity concrete structure, including the support structures of the reactor pressure vessel, from overheating during all modes of operation.

2. Provide an alternate means of reactor core heat removal from the RS to the environment when neither the MHTS nor the SCS is available.

The RCCS shall be designed with the following requirements:

1. The RCCS shall operate continuously and maintain reactor cavity concrete temperatures less than [90°C] during normal operations and less than [150°C] for off-normal events (short term).

2. 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 even combinations determined to be required by plant transient analysis.

3. Inaccessible parts of the RCCS shall be designed for an operating life of 60 years.

4. The need for access to individual components during normal plant operation and under accident conditions shall be considered in developing building and component arrangements.

5. The RCCS shall be designed to meet availability/investment protection requirements.

6. The RCCS shall be designed to accommodate continuous operation at any power level up to [100%] of rated power.

7. Where cost effective, the design of the RCCS shall incorporate features required to implement online surveillance and performance monitoring.

8. The design of 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.

9. The RCCS shall be required to operate continuously in all plant states, including shutdown following loss of forced reactor cooling by the MHTS and SCS with simultaneous loss of pumped circulation of RCCS cooling water, where applicable, and an SSE.

10. All components and piping of the RCCS shall be designed against seismic loads.

11. 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).

7.6 Fuel Handling and Storage System

The following are the required functions of the Fuel Handling and Storage System (FHSS):

1. Remove and replace fuel from the reactor core.

2. Prepare and stage new and used fuel and reflector blocks in a location which facilitates efficient refueling of the reactor core.

3. Transfer spent fuel to storage.

4. Minimize possibility of special nuclear materials (SNM) diversion and facilitate appropriate inspections.

5. Provide efficient and reliable fuel transportation both within the reactor buildings and between the power block and the long-term storage facility.

6. Provide temporary storage of spent fuel necessary to facilitate the refueling process.

The FHSS shall be designed with the following requirements:

1. During reactor shutdown, the FHSS shall physically replace and restack the core with new and irradiated fuel, reflector blocks, and other core elements, including fuel from the spent fuel storage system.

2. The FHSS shall provide shielding to protect workers from radiation during fuel handling operations.

3. The FHSS shall limit the ingress of potential contaminants into the primary helium circuit from components of the FHSS external to the primary HPB.

4. The FHSS shall be designed to accomplish plant refueling within a time interval specified in planned outage allocations.

7.7 Spent Fuel Cooling System

The following is the required function of the Spent Fuel Cooling System (SFCS):

1. Remove decay heat from the spent fuel elements within their storage locations and transfer the heat to a secondary coolant.

The SFCS shall be designed with the following requirements:

1. The SFCS shall be designed to continuously remove and transfer [TBD MWt] of heat at ambient atmospheric conditions.

2. The SFCS shall be designed to operate continuously whenever spent fuel is located in storage.

7.8 Component Handling System

The following is the required function of the Component Handling System (CHS):

1. Provide a means of removing and replacing reactor internals components not normally moved during a refueling outage, that is, those reactor internals components not able to be handled by the fuel handling machine in its normal configuration.

The CHS shall be designed with the following requirement:

1. TBD

7.9 Intermediate and Long Term Spent Fuel Storage System

The following are the required functions of the Intermediate and Long Term Spent Fuel Storage System (SFSS):

1. Store used NGNP fuel following discharge from the reactor for [10 years] within the reactor building or fuel building.

2. Provide the capability to store all used NGNP fuel generated during the anticipated 60 year plant lifetime, including [TBD%] margin, in an on-site or near-site Independent Spent Fuel Storage Installation (ISFSI).

3. Passive removal of decay heat from the spent fuel elements within the long term storage system and transfer heat to the environment.

4. Prevent damage to the fuel element from external hazards.

The SFSS shall be designed with the following requirements:

1. Designed with passive heat removal capability.

2. Shall have radiation leakage monitoring capability.

3. Shall prevent damage to fuel elements and subsequent release of radioactivity to the environment, due to external hazards.

7.10 Helium Service System

The following are the required functions of the Helium Service System (HSS):

1. Remove chemical and particulate contaminants from the primary coolant to maintain specified values.

2. Supply purified helium to systems filled with helium.

3. Remove helium from the primary system and the helium-filled supporting systems, and store in a gas store for purified helium.

4. Accept helium from helium-filled auxiliary and supporting systems during depressurization activities, and possibly, store radioactively contaminated helium.

5. Evacuate primary systems and helium supporting systems.

6. Maintain chemical contaminants within required concentration bands.

7. Provide storage for excess/reserve helium.

The HSS shall be designed with the following requirement:

1. TBD

7.11 Radioactive Waste and Decontamination System

The following are the required functions of the Radioactive Waste and Decontamination System (RWDS):

1. Provide for collecting, storing, processing, and monitoring radioactive (or potentially radioactive) solid, liquid, and gaseous waste.

2. Provide equipment and procedures 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.

The RWDS shall be designed with the following requirements:

1. The RWDS shall collect radioactive and potentially radioactive floor and equipment liquid runoff. These waste streams shall be routed to the liquid radioactive waste subsystem.

2. Provisions shall be included to reduce activity levels contained in liquid effluent.

3. Radioactive liquid waste system components shall be redundant to provide for both system reliability and online maintenance.

4. The gas waste portion of the RWDS shall have sufficient storage capacity to allow for radioactive decay prior to release.

5. Decontamination equipment shall provide steam, wash water (including detergent and/or additives), rinse water, drying air, and vacuuming service.

6. Decontamination system waste shall be collected locally and routed to the appropriate radioactive waste systems.

7. All radioactive waste generated within the facility shall be collected, monitored, treated, and processed on-site prior to shipment off-site.

7.12 Reactor Protection System

The following is the required function of the Reactor Protection System (RPS):

1. Maintain plant safety parameters within acceptable limits established for Design Basis Events (DBEs).

The RPS shall be designed with the following requirements:

1. The RPS shall be designed to initiate automatically the operation of appropriate systems, including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences.

2. The RPS shall be designed to sense accident conditions and to initiate the operation of systems and components important to safety.

3. The RPS shall be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection or dropout) of control rods.

4. The reactivity control systems shall be designed to have a combined capability of reliably controlling reactivity changes to assure that, under postulated accident conditions and with appropriate margin for stuck rods, the capability to cool the core is maintained.

5. The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor coolant pressure boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures, or other reactor pressure vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents shall include consideration of rod ejection (unless prevented by positive means), rod dropout, steam line rupture, and changes in reactor coolant temperature and pressure.

6. The RPS shall implement the relevant monitoring, analysis, and actuation functions necessary to reach the controlled state in case of abnormal events.

7. The RPS shall provide redundant, fail-safe protective functions.

8. The RPS shall remain operable or fail-safe during credible external events.

9. Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety; including those variables and systems that can affect the fission process, the integrity of the reactor core, the reactor coolant pressure boundary, and the reactor building and its associated systems. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges.

10. Two independent reactivity control systems of different design principles shall be provided.

    a. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded.

    b. The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions.

11. 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.

12. TBD requirements for local control of systems and safe shutdown from locations outside the control room.

13. The control room shall remain operable and capable of occupation during credible external events.

14. TBD for additional control room and operator interface requirements, such as human factors, protection in DBAs, etc.

7.13 Plant Investment Protection System

The following is the required function of the Plant Investment Protection System (PIPS):

1. Maintain plant parameters within pre-specified limits which have been determined to preclude damage to plant system components.

The PIPS shall be designed with the following requirements:

1. The PIPS shall prevent plant operations outside of the pre-specified set of plant operating limits.

2. The PIPS shall remain operable during adverse environmental operating conditions.

3. Failure of the PIPS during normal operation shall not cause degraded plant conditions.

7.14 Turbine Generator System

The following is the required function of the Turbine Generator System (TGS):

1. Convert energy from the Main Steam System (MSS) into electricity for distribution on the commercial grid.

The TGS shall be designed with the following requirements:

1. The NGNP TGS shall be connected to the Plant Electrical System (PES) for external distribution and sale of [250-300] MWe.

2. The NGNP TGS shall produce electricity at 60 Hz.

3. The NGNP TGS shall be designed and sized to produce electricity at commercial scale using up to100% of the thermal energy from the NGNP reactor.

4. The NGNP electrical output shall be delivered to the operating utility at [TBD].

5. The steam turbine and generator shall be designed for superheated steam at a pressure of [TBD] and temperature of [TBD] at the turbine throttle.

6. The turbine shall be designed for main steam temperature variations of up to [TBD].

7. The steam turbine generator rating shall be [TBD].

7.15 Main Feedwater System

The following are the required functions of the Main Feedwater System (MFS):

1. Deliver feedwater to the SG at the specified temperature, pressure, flow rate, and water chemistry.

2. Provide storage to accommodate secondary coolant surge and volume fluctuations.

3. Provide isolation of the feed water to prevent water inflow to a failed SG.

The MFS shall be designed with the following requirement:

1. TBD

7.16 Main Steam System

The following is the required function of the Main Steam System (MSS):

1. Convey steam from the SG to the inlet of the high pressure turbines.

The MSS shall be designed with the following requirement:

1. TBD

7.17 Extraction Steam System

The following are the required functions of the Extraction Steam System (ESS):

1. Divert steam from the high pressure turbines to the high pressure reboiler.
2. Divert steam from low pressure turbine to the low pressure reboiler.
3. Provide steam for feedwater heating and dearating.

The ESS shall be designed with the following requirement:

1. TBD

7.18 Main Condensate System

The following is the required function of the Main Condensate System (MCS):

1. TBD

The MCS shall be designed with the following requirement:

1. TBD

7.19 Process Heat Transport System

The following is the required function of the Process Heat Transport System (PHTS):

1. TBD

The PHTS shall be designed with the following requirement:

1. TBD

7.20 Circulating Water System

The following is the required function of the Circulating Water System (CWS):

1. TBD

The CWS shall be designed with the following requirement:

1. TBD

7.21 Nuclear Island Cooling Water System

The following is the required function of the Nuclear Island Cooling Water System (NICS):

1. Remove heat from the reactor plant components and transfer heat to an ultimate heat sink.

The NICS shall be designed with the following requirements:

1. The NICS shall serve the needs of the reactor and its associated components at all times under full power operating conditions.

2. System makeup shall be provided from the plant water supply treatment system.

3. Redundant components shall be provided for the NICS, as needed, to support continuous operation of the reactor and to provide for online maintenance of the cooling system components.

7.22 Balance of Plant Component Cooling Water System

The following is the required function of the Balance of Plant Component Cooling Water System (BCCS):

1. TBD

The BCCS shall be designed with the following requirement:

1. TBD

7.23 Steam Water Dump System

The following are the required functions of the Steam Water Dump System (SWDS):

1. Drain the water inventory from a SG with a leaking tube to minimize water ingress.

2. Contain the SG inventory following SG dump.

3. Prevent sustained escape of primary coolant from the primary loop.

The SWDS shall be designed with the following requirement:

1. TBD

7.24 Plant Electrical Systems

The following are the required functions of the Plant Electrical System (PES):

1. Deliver power generated by the plant to the off-site transmission network.

2. Take power from the off-site transmission network for various plant operations, including startup.

3. Provide backup power to select auxiliaries when the plant power units and off-site power are not available.
4. Deliver primary and backup power to the process heat process.
5. Distribute stable electrical power to plant components at required voltages, amperages, and frequencies.
6. Provide a stored energy source for all safety-related direct current loads.
7. Protect personnel and equipment from system faults and lightning strikes.
8. Minimize electrical noise in signal cables.
9. Provide cathodic protection.

The PES shall be designed with the following requirement:

1. TBD

7.25 Nuclear Island HVAC System

The following is the required function of the Nuclear Island HVAC System (NIHS):

1. Maintain appropriate temperatures for plant personnel and equipment including the Neutron Control Assemblies.

The NIHS shall be designed with the following requirement:

1. TBD

7.26 Plant Mechanical Services System

The following is the required function of the Plant Mechanical Services System (PMSS):

1. Provide HVAC services for all plant buildings and structures except those serviced by the NIHS.

The PMSS shall be designed with the following requirement:

1. TBD

7.27 Fire Detection and Suppression System

The following are the required functions of the Fire Detection and Suppression System (FDSS):

1. Rapidly detect and annunciate the presence and location of combustion by-products or the presence of fire within the nuclear plant and the process heat distribution system.
2. Control and extinguish fires.

3. Provide protection for SSCs such that the performance of safety functions is not prevented.

The FDSS shall be designed with the following requirement:

1. TBD

7.28 Plant Communications System

The following are the required functions of the Plant Communication System (PLCS):

1. Provide intra-plant communications.
2. Provide communications from plant to off-site locations (as specified).

The PLCS shall be designed with the following requirement:

1. TBD

7.29 Safeguards and Security System

The following are the required functions of the Safeguards and Security System (SSS):

1. Provide physical protection of the plant.
2. Provide for storage and inventory control of SNM.

The SSS shall be designed with the following requirement:

1. TBD

7.30 Plant Instrumentation and Control System

The following are the required functions of the Plant Instrumentation and Control System (ICS):

1. Provide an interface between plant operators and each of the necessary systems within the plant.
2. Provide supervisory control of the integrated NHS, power conversion system, and process heat supply system.

The ICS shall be designed with the following requirement:

1. Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation and for anticipated operational occurrences, and for accident conditions as appropriate.

7.31 Switchyard System

The following are the required functions of the Switchyard System (SWS):

1. Provide an on-site electrical facility to transmit electrical power to the external high voltage distribution system.

2. Distribute off-site power to the plant electrical system when on-site generated power is not available.

The SWS shall be designed with the following requirement:

1. TBD

7.32 Helium Storage Area

The following is the required function of the Helium Storage Area (HSA):

1. Provide receiving and unloading of helium.

The HSA shall be designed with the following requirement:

1. TBD

7.33 Reactor Building

The following is the required function of the Reactor Building (RB):

1. TBD

The RB shall be designed with the following requirement:

1. TBD

7.34 Fuel Building

The following is the required function of the Fuel Building (FB):

1. TBD

The FB shall be designed with the following requirement:

1. TBD

7.35 Reactor Auxiliary Building

The following is the required function of the Reactor Auxiliary Building (RAB):

1. TBD

The RAB shall be designed with the following requirement:

1. TBD

7.36 Other Nuclear Island Buildings

The following is the required function of the other nuclear island buildings:

1. TBD

The other nuclear island buildings shall be designed with the following requirement:

1. TBD

7.37 Power Conversion System Buildings

The following is the required function of the Power Conversion System (PCS) buildings:

1. TBD

The PCS buildings shall be designed with the following requirement:

1. TBD

7.38 Other Site Buildings

The following are the required functions of the other site buildings:

1. Provide protection from outdoor conditions.
2. Provide a controlled environment.
3. Provide internal and external lighting.

The other site buildings shall be designed with the following requirement:

1. TBD

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