AREVA NP Inc.,

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Engineering Information Record

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NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration

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AREVA

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Safety Related? ☐ YES ☒ NO

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

Signature Block

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Note: P/LP designates Preparer (P), Lead Preparer (LP)
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A/A-CRF designates Approver (A), Approver of Customer Requested Format A-CRF

Record of Revision

Revision No.	Date	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	3/4/2009	All	Initial Issue.
001	3/20/2009	Table 1	Added Note 2 to provide a description of the normal operation and accident configurations of the Reactor Cavity Cooling System. This Note includes a new figure, Figure-1. The original Notes 2 and 3 for Table 1 were renumbered to Notes 3 and 4. The original Figures 1 and 2 were renumbered to Figures 2 and 3.
001	3/20/2009	Figure 2	Figure 2 was updated to reflect the ability of the proposed design to operate in either 100% electricity generation or 100% process heat modes, as well as combinations between these extremes. The figure was further updated to depict its potential operation as one of several reactor modules.
001	3/20/2009	Table 2	Updated point design parameters as noted based on data contained within Reference 5.
001	3/20/2009	Table 3	Replaced the contents of Table 3 with the updated Plant Design Duty Cycle information provided in Reference 6, which was also added.
001	3/20/2009	Section 3.6	Added References 5 and 6 as accepted design baseline documents.
002	4/24/2009	Table of Acronyms	Added Table of Acronyms
002	4/24/2009	Table 1	Clarified "partially insulated for reactor vessel and cross vessel.
002	4/24/2009	Tables 1 and 2	Clarified applicability of Notes.
002	4/24/2009	Table 2	Changed the source for several table entries from Note 1 to Reference 5. Updated the RCCS normal heat load from 1.0 to 1.4 MWth.
002	4/24/2009	Figure 1	Added label for water-to-air heat exchanger.
002	4/24/2009	Figure 2	Updated Figure to reflect 625 MWth Reactor Power
002	4/24/2009	Table 3	Removed the Table and provided reference to the Design Duty Cycle document to elminiate duplication of information.
002	4/24/2009	Reference 2	Changed reference from meeting minutes to NGNP Plant Design Requirements Document
002	4/24/2009	References	Updated References 5 and 6 to reflect the current revisions of these documents.

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Table of Acronyms

DCC	Depressurized Conduction Cooldown
LWR	Light Water Reactor
NGNP	Next Generation Nuclear Plant
PCS	Power Conversion System
PH	Process Heat
PWR	Pressurized Water Reactor
SG	Steam Generator
SSC	Systems, Structures, and Components
TBD	To Be Determined

1.0 INTRODUCTION AND PURPOSE OF THE DESIGN BASELINE

This document is the conceptual design baseline document that includes plant technical configuration and operational information for the prismatic Next Generation Nuclear Plant (NGNP) conventional steam cycle plant. This document is prepared as an Engineering Information Record under AREVA WI-13 procedure. It represents a plant Technical Requirements Document. As such it specifies plant parameters necessary to guide conceptual design activities being conducted by the AREVA NGNP design team.

The baseline document is created for use by the entire AREVA NGNP design team as the latest agreed upon listing of plant design parameters, configuration, operation and performance requirements/characteristics. The contents of this document guides plant design and special studies being performed.

The NGNP is a modular high temperature gas-cooled reactor prototype plant. The role of the design baseline document at the beginning of the conceptual design phase is to serve as a single document that specifies the reference plant configuration and parameters. This document will be updated as needed when choices concerning the NGNP plant design, configuration and operation are updated and applied to the reference design.

Please note that the data being provided are provisional and are intended for use and reference by the AREVA design team. Data provided in this document shall be used as follows:

- The design team members that are involved in studies to determine certain plant parameters and configuration should consider the data in this document as initial estimates or the starting point for their investigation.
- The design team members that are not directly involved with the development of certain design feature or parameter should use the data as the best data available at the time this document is issued.
- Others may use the data for information only.

The NGNP project is in <u>conceptual</u> design phase. The information in this document will be validated by formal design calculations in this and subsequent phases of the design. As the design progresses and references become available the values in the design baseline will be referenced to design calculations.

All baseline values and text have been defined by the NGNP System Integration function and shall be used "as-is". Certain values and textual requirements are placed in brackets [ ]. These are best estimates and are subject to change as a result of normal design evolution. Once these values are adopted for NGNP and verified by initial analyses; the brackets will removed in the next revision of the document.

2.0 PLANT DESCRIPTION

2.1 Statement of Plant Functions

The Conventional Steam Cycle NGNP plant is a high temperature gas-cooled 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.

2.2 Description of Plant Concept

The Conventional Steam Cycle as defined for this baseline consists of two helium loops in parallel, each with a gas-to-water steam generator unit in the primary loop. 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.

3.0 PLANT DEFINITION

3.1 Main Plant Characteristics and Physical Configuration

In this section a listing of major plant design characteristics is provided.

Table 1 – Main Plant Characteristics and Physical Configuration

Description	Baseline Value	Source
Nuclear Island		
Reactor	Prismatic Blocks	Reference 2
Construction	[Below Grade – Silo]	* Note 1
Reactor building	[Vented & Filtered]	Note 1
Primary coolant	Helium	Reference 2
Vessel System		
Reactor Vessel	SA-508/533 [Partially insulated – core adjacent cylindrical section is not insulated]	Note 1
Cross Vessels	Metallic Vessel w/center hot duct [Partially insulated – not insulated near reactor vessel]	Note 1
SG Vessels	Metallic Vessel with Top Mounted Circulator Fully insulated	Note 1
Reactor Core		
Fuel Form	Prismatic Blocks	Reference 2
Configuration	Annular core 102 column 10 blocks/column	Note 1
Moderator	Graphite	Note 1

Description	Baseline Value	Source
Reflector (inner and outer)	Graphite Blocks	Note 1
Fuel		
Fuel Design	TRISO Coated Particles	Note 1
Fuel Kernel	UCO	Note 1
Coating	TRISO	Note 1
Fuel Enrichment	<20%	Note 1
Fuel Compact	Particle Fuel and Graphite Matrix Compacted in a Cylindrical Shape	Note 1
Fuel Block	Hexagonal Graphite Block	Note 1
System Configuration	Conventional Steam Cycle	Reference 2
Loop Configuration		
No. of Loops (# of cross vessels)	Two Parallel Loops	Note 1
No. of cross vessels	Two	Note 1
No. of Steam Generators	Two	Note 1
No. of Circulators	Two	Note 1
Heat Transport System		
Primary Fluid	Helium	Reference 2
Steam Generator Unit to PCS or Process Heat Plant		
Steam Generator Type	Once-through helical coil [with reheat]	Note 1
Heat Transfer Medium	He to Water/Steam	Reference 2
Shutdown Cooling System		
Thermal Capacity	TBD MWth	
Circulator	TBD MWe	
Heat Exchanger	Tube-type (He to Water)	Note 1
Reactor Cavity Cooling System		
Type	Active (normal ops.)/ Passive (accident) – Water Based	* Note 2
Configuration	Water Tube Panel	Note 1
No of Loops	2	Note 1
Refueling System		
Refueling Cycle	[18 months] Periodic –Remote Access	Note 1

Description	Baseline Value	Source
Power Conversion System		
Configuration	Multi Stage Steam Turbine [with Reheat Cycle]	Note 1
Steam reheat cycle	[Yes]	Note 1
Steam turbine	Multi Stage	Note 1
Feedwater system	TBD	

* Notes pertaining to this Table are included after Table 2.

3.2 Plant Heat Balance and Point Design

The plant Point Design parameters are presented here. These parameters represent an operating point at steady state plant conditions.

Table 2 – Plant Heat Balance and Point Design

Description	Baseline Value	Source
Nuclear Island		
Power level	[625 MWth]	Reference 2, Note 3
Reactor Core		
Core inlet temperature	[325°C]	Note 1, Note 4
Core outlet temperature	750°C	Reference 2
Core pressure drop	[66 kPa]	Reference 5
Primary Heat Transport System		
Primary Pressure	[6 MPa]	Reference 5
Mass Flow	[281.9 kg/s]	Reference 5
Primary Circulator Power (each)	[4 MWe]	Reference 5
Steam Generator Unit		
SG Heat Transfer (each)	[315 MWth]	Reference 5
Gas Side Inlet Temperature	[750°C]	Reference 2
Gas Side Outlet Temperature	[320°C]	Reference 5
Steam-Water Side Inlet Temperature	[281.5°C]	Reference 5
Steam-Water Side Outlet Temperature	[566°C]	Reference 5
Steam Pressure (Outlet)	[16.7MPa]	Reference 5
Pressure Drop (shell side) Helium side	30 kPa]	Reference 5
Pressure Drop (tube side) Steam/Water side	[7.6 MPa]	Reference 5

Description	Baseline Value	Source
Power Conversion System (100% electrical generation)		
Total Power (gross)	[296 MWe]	Reference 5
Gross cycle efficiency	[47%]	Reference 5
House load	[13 MWe]	Note 1
Net module generation	[283 MWe]	Note 1
Net plant efficiency	[46%]	Note 1
Process Heat System (100% process heat utilization)		
Energy Input	[630 MWth]	Reference 5
Reactor Cavity Cooling System		
Normal operating heat load	[1.4 MWth]	Reference 5
Heat load during accident	[2.5 MWth]	Note 1
Power Conversion System		
Main Steam		
Temperature	[566°C]	Reference 5
Pressure	[16.7 MPa]	Reference 5
Flow	[140.7 kg/s]	Reference 5
Reheat Steam		
Temperature	[538°C]	Note 1
Pressure	TBD	
Flow	TBD	
Circulating Water Temperature	[25 °C]	Note 1
Condenser Pressure	TBD	

Note 1: These parameters are presented as initial baseline design values based on AREVA's preliminary studies of the NGNP reactor and experience with similar reactor types. These values will be refined and updated as the conceptual design process evolves based on the results of specific trade studies.

Note 2: The Reactor Cavity Cooling System is designed to operate with an active, forced cooling system for the primary fluid inventory tank during periods of normal reactor operations. The system is designed to function without the forced cooling loop during accident conditions. That is, the primary fluid inventory tank can be adequately cooled via natural circulation under accident conditions. This system is shown in Figure 1.

Note 3: It is proposed to change the baseline Reactor Power for the NGNP plant from 600 MWth to 625 MWth. This change is based on observing that:

1. The design considered in the AREVA NGNP PCDSR, Reference 3, demonstrated acceptable DCC performance with inlet/outlet temperatures of 500/900C at a power level of 565 MWth.
2. The original ANTARES design, Reference 4, demonstrated acceptable DCC performance with inlet/outlet temperatures of 400/850 at a power level of 600 MWth.
3. This shows a -35 MWth power level change resulting from a +100/+50 inlet/outlet temperature change.
4. Using our new proposed temperatures of 325/750 results in a -75/-100 temperature change.
5. Considering these changes in temperature and temperature difference, and assuming basic linear behavior, we might expect a change in magnitude of from one half to three quarters the magnitude of the above change, in the positive direction.
6. A proposed change of +25MWth seems a good compromise, and should be used until such time that detailed DCC calculations are run during the upcoming NGNP Power Level Study.

Note 4: It is proposed to change the baseline Core Inlet Temperature for the NGNP plant from 350°C to 325°C. This change will provide additional margin to the upper limit of the negligible creep regime for the PWR steel reactor vessel, which is 371°C as defined by Section 3 of the AMSE Boiler and Pressure Vessel Code. This change will also bring the Core Inlet Temperature within the experience base developed by the LWR fleet, some of which operate with core exit temperatures of approximately 328°C.

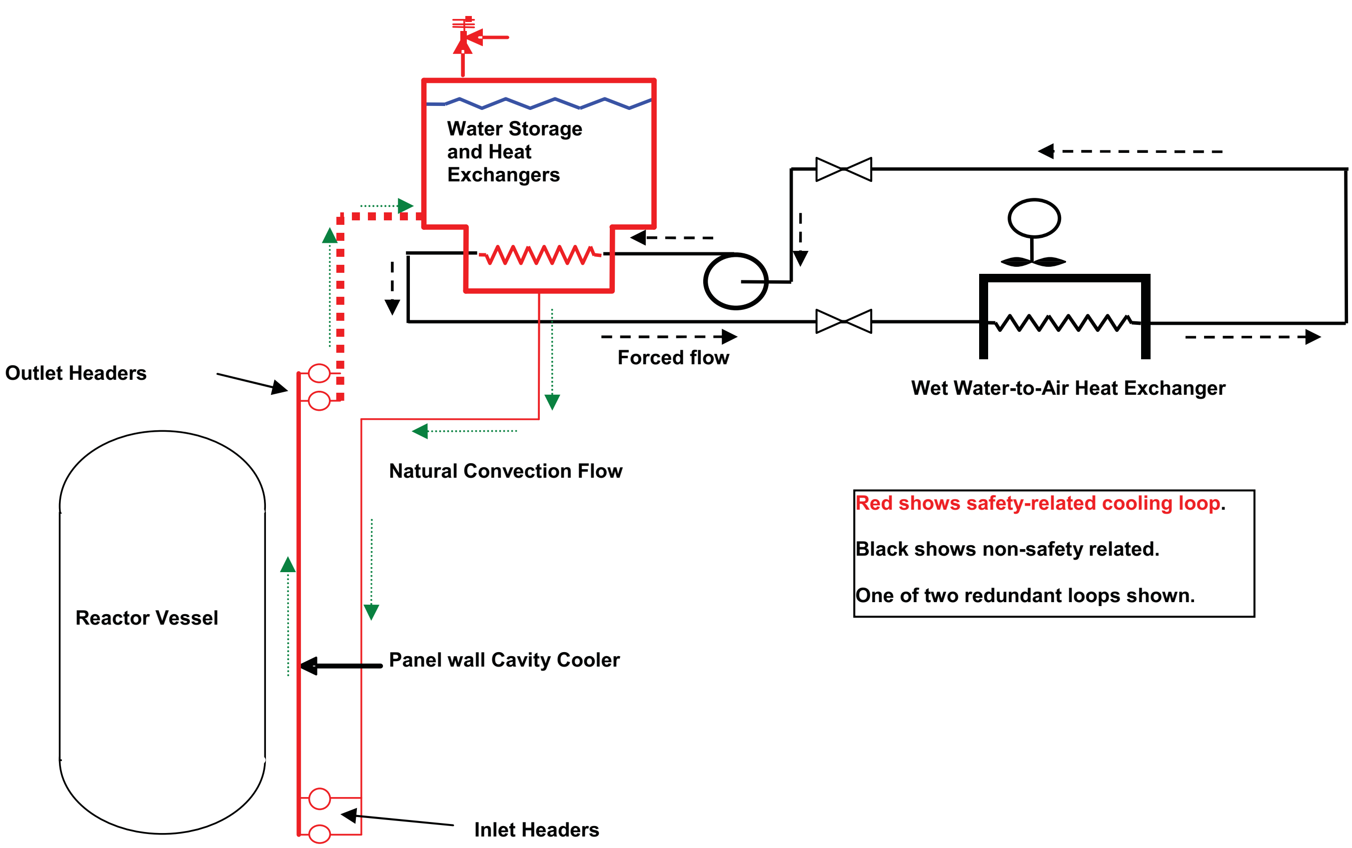

Figure 1 – NGNP Reactor Cavity Cooling System Schematic Representation

3.3 Plant Design Duty Cycle

The Plant Design Duty Cycles for which the designers should allow operations of the SSCs are fully defined in Reference 6. If the designer determines it to be preferable to restrict the duty cycle to less than these values, these limits will be reevaluated.

Note - The number of duty cycles is not a prediction of how many of these cycles will occur. It is the basis for applicable design analyses, as such, it is mandatory that the plant operate in a manner which results in fewer duty cycles.

3.4 Plant System Schematic Representation

This plant schematic representation is based on the information contained in Reference 2.

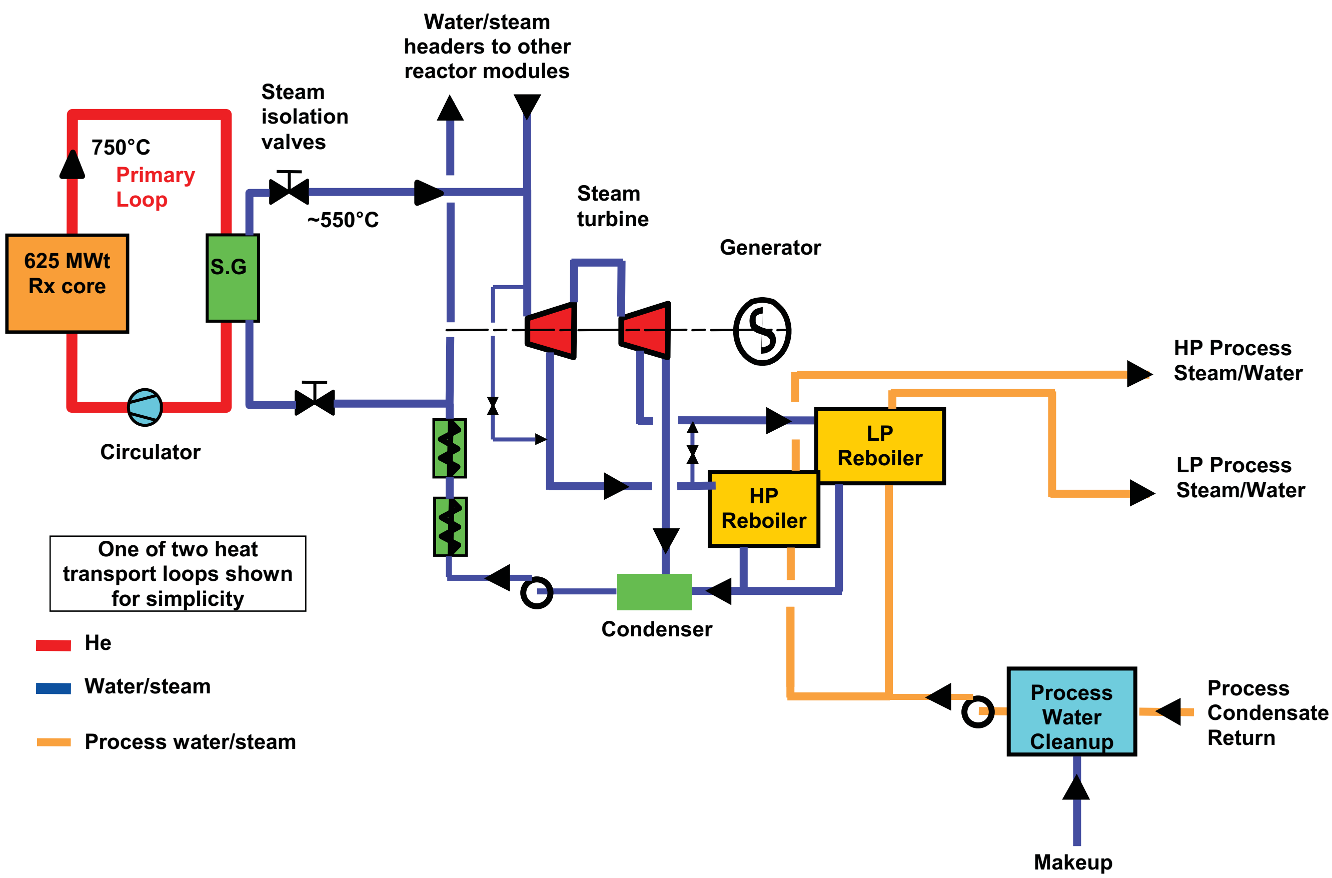

Figure 2 – NGNP Plant System Schematic Representation

3.5 Plant Primary System Layout

This plant primary system layout is taken from Reference 2.

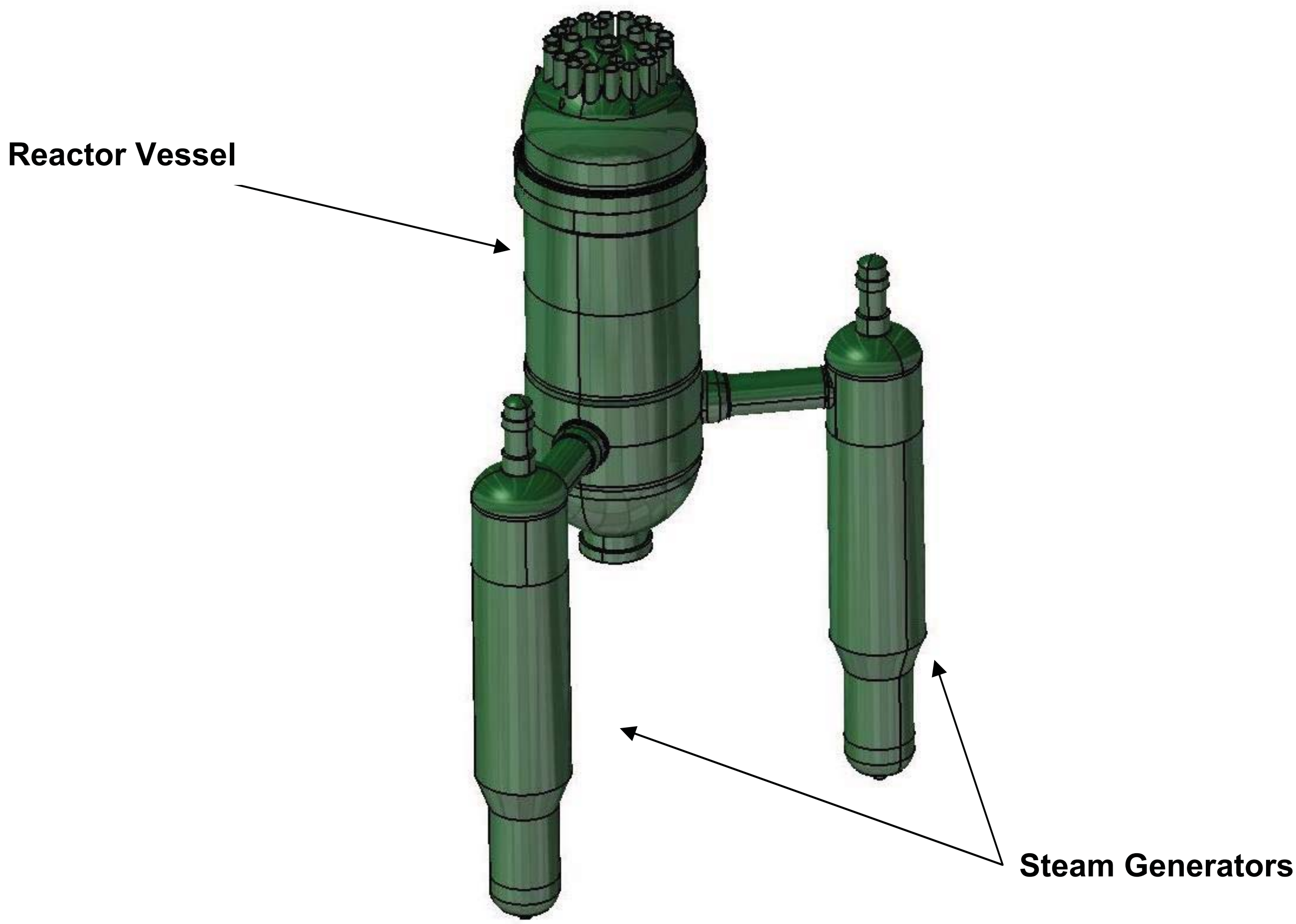

Figure 3 – NGNP Plant Primary System Layout

3.6 Accepted Design Documents

The following documents have been accepted as part of the NGNP design baseline at this time.

1. AREVA Report 51-9106211-001, “NGNP Conceptual Design – Point Design”, April 2009 (Reference 5).
2. AREVA Report 51-9105791-001, “NGNP Conceptual Design – Plant Design Duty Cycle”, April 2009 (Reference 6).

4.0 REFERENCES

1. AREVA Report 51-9086344-000, “NGNP Conceptual Design Studies Baseline Document for Conventional Steam Cycle Configuration”, July, 2008.
2. AREVA Report 51-9106032-000, “NGNP Plant Design Requirements Document”, April 2009.
3. AREVA Report 12-9051191-001, “NGNP with Hydrogen Production Preconceptual Design Studies Report”, June 2007.
4. AREVA Internal Reference.
5. AREVA Report 51-9106211-001, “NGNP Conceptual Design – Point Design”, April 2009.
6. AREVA Report 51-9105791-001, “NGNP Conceptual Design – Plant Design Duty Cycle”, April 2009.