AREVA

Doc. No. TDR-3001463-000

NGNP Technology Readiness Levels for 750°C Conventional Steam Cycle Configuration

March 31, 2009

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1.0 Purpose

This technical data record provides Technology Readiness Levels (TRLs) for the Next Generation Nuclear Plant (NGNP), a prototype of the modular high temperature gas-cooled reactor plant now in the early conceptual design studies phase.

This NGNP conceptual design has a different heat transport system configuration and a lower reactor operating temperature than the earlier pre-conceptual design concept. This new configuration has been selected to reduce project risk as described in AREVA document 51-9103803, *NGNP Conceptual Design Baseline Document for Conventional Steam Cycle* **[1]**.

The Conventional Steam Cycle NGNP plant, as defined for this baseline, has two helium gas-to-water steam generator units in the primary loop. The conventional multi-stage steam turbines generate electricity by using steam produced by the steam generators. This same steam also provides energy to one or more steam reboilers, which then supply process steam to industrial processes through a tertiary steam loop. AREVA envisions the NGNP as collocated with and providing energy to a commercial industrial facility. Given the commercial nature of this cogeneration configuration, no consideration is given to an independent parallel heat transfer loop to an experimental hydrogen production loop, nor is consideration given to limited plant operation at higher temperatures with low reactor powers.

These changes affect design data needs (DDNs) and technology development needs (TDNs) for the NGNP. AREVA document 12-9102279, *NGNP Conceptual Design DDN/PIRT Reconciliation* **[2]**, identifies DDNs for the conventional steam cycle. This document updates the NGNP TRLs originally identified in TDR-3001031, *NGNP Technology Development Road Mapping Report* **[3]** for the very high temperature NGNP with an indirect steam cycle reactor configuration. The NGNP TDRM report identifies critical plant, area, systems, structures, or components (PASSCs), which require additional technology development and testing to achieve acceptable project risk, and includes technology development roadmaps (TDRMs) and test plans for technologies that have not been adequately demonstrated at an engineering scale as part of an integrated system in a relevant environment and configuration. This document, (TDR-3001463) updates that information based on an assessment of the technology readiness of the current NGNP baseline **[1]**. This technology readiness assessment and the associated TDRMs and test plans should be revised as the NGNP plant design baseline changes, as the detail of the design information increases, and as technology development activities are completed.

2.0 Methodology

The NGNP TDRM report **[3]** describes the methodology for assigning TRLs. That report identifies the following:

- critical plant, area, systems, structures, and components (PASSCs) in the indirect steam cycle configuration
- baseline TRL score for each PASSC in the indirect steam cycle configuration
- basis for each PASSC TRL score in the indirect steam cycle configuration
- test plans to achieve a TRL of 7, i.e., System Demonstration at Engineering Scale

The critical PASSCs were established by assessing whether technology development or testing was required before systems or components in the Nuclear Heat Supply System (NHSS), Heat Transport System (HTS), Power Conversion System (PCS), or Balance of Plant (BOP) were ready for integration into the NGNP. Only PASSCs requiring development are considered critical PASSCs. The TDRM report **[3]** included TRL rating sheets that include brief system descriptions and the basis for the TRL score. Interfacing systems were only identified if they were considered during the review of potential development needs. For example, the Vessel Support is not included in the PASSC list but is identified in the TRL rating sheet as an interface with the Vessel. The technology issue - differential thermal expansion – was evaluated and it was concluded that additional testing and development work was not required.

The critical PASSCs and TRL ratings for the conventional steam cycle design were developed by reviewing the above information and then revising the list of PASSCs and the TRL score based on the following:

- Operating configuration and design parameters in the NGNP Design Baseline **[1]**
- Recommendations in the NGNP DDN/PIRT Reconciliation document **[2]**
- Revising the technical basis for the original TRL score based on current design information
- Technical review by the NGNP subject mater experts

The preliminary list of critical SSCs for the conventional steam cycle was revised based on the new system configuration **[1]**, shown in Figure 2-1. The changes are:

- Added High Pressure Reboiler and Low Pressure Reboiler for generating process steam
- Removed the compact IHX, the tubular IHX, the IHX Vessel (part of the vessel system), the Secondary Gas Circulator (part of the secondary heat transfer loop), the High Temperature Isolation Valve (part of the Hydrogen Production Heat Transfer Loop), and the Startup and Decay Heat Removal System.

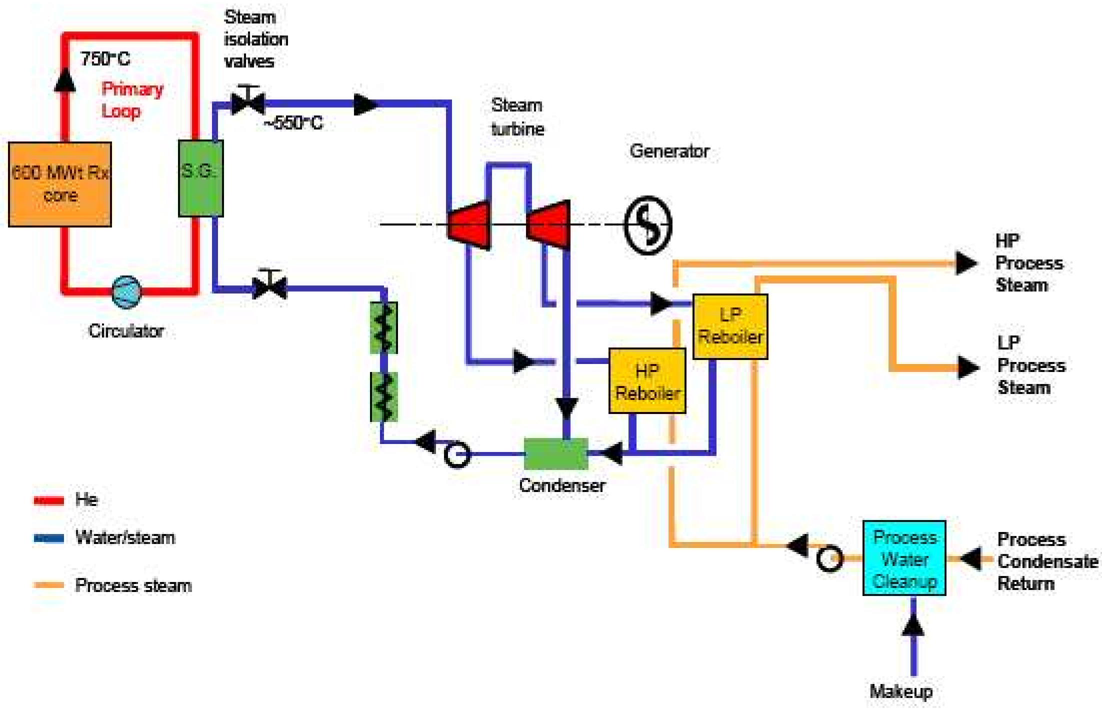

Figure 2-1. NGNP Conceptual Design System Configuration

The TRL ratings for critical SSCs were revised based on the following considerations:

- Vessel, Vessel Internals, Cross Vessel, and SG Vessel (material selection and temperature limits)
- Steam Generator internals (material temperature limits)
- Circulator (material temperature limits and stress levels)
- Reboilers (industrial experience)
- Reactor Core (added work being performed under the graphite fuel program)

Key parameters for the reference design **[1]** are listed in Table 2-1.

Table 2-1. Parameters for NGNP Conceptual Design

Reactor Core Configuration	Prismatic Annular, 102 column, 10 blocks/column
Reactor Core Power Level	625 MWt
Reactor Core Outlet Temperature	750°C
Reactor Core Inlet Temperature	325°C
Steam Supply Temperature	566°C
Type of Power Conversion Cycle	Conventional Steam Cycle
Power Conversion System Configuration	Steam Generator in primary gas loop Steam Turbine uses secondary steam from SG Extraction steam available for cogeneration
Number of Main Loops	2
Number of Side Loops	0
Direct Process Steam Supply	Steam/Steam Reboiler

The design of the NGNP reactor is in the early phase of conceptual design. As such, many of the plant configuration and detailed component design decisions have yet to be made. As described in the TDRM report **[3]**, now is the ideal time to create technology development plans, but it is essential that the process be reviewed and updated periodically as the design matures.

The change in NGNP configuration to a conventional steam cycle eliminates the complexity of the secondary heat transfer loops and the need to develop IHX technology and coatings. Of the 15 critical PASSCs identified in the indirect steam cycle configuration, 12 are included in the conventional steam cycle configuration. One new PASSC, the steam reboiler system, is used to generate process steam in the conventional steam cycle **[1]**. This system includes two components, the high pressure and low pressure reboilers, as shown on Figure 2-1. The nomenclature used in AREVA's plant breakdown structure for some system names has changed. This document has adopted the new nomenclature but also identifies the nomenclature used in the TDRM report (in parentheses) to enhance traceability.

The 13 PASSCs whose technology readiness was assessed for the conventional steam duty cycle are follows:

- Nuclear Heat Supply System
  - Vessel System
  - Reactor Internals (formerly Reactor Vessel Internals)
  - Reactor Core (formerly part of Reactor Core Design Features)
  - Control Rod Drives (formerly Neutron Control System)
  - Nuclear Instrumentation
  - Reactor Cavity Control System
- Heat Transport System
  - Main Helium Circulator (formerly the Primary Gas Circulator)
  - Circulator Shutoff Valve
  - Hot Duct (formerly the Primary Hot Gas Duct)
- Power Conversion System
  - Steam Generator
- Other reactor support systems (formerly identified as auxiliary systems)
  - Primary Loop Instrumentation
  - Fuel Handling System
- Process Heat Transport System
  - Steam Reboiler System (new system)

The technology readiness of each of these 13 systems was evaluated by reviewing the previous TRL rating sheets **[3]** and updating them based on the revised NGNP design baseline **[1]** and DDN/PIRT reconciliation report **[2]**. New TRL rating sheets were prepared for the reboilers based on open literature sources **[8, 9]** and professional judgment. All of the TRL Ratings were reviewed by subject matter experts. The following individuals reviewed the ratings: Lew Lommers (project engineer), Farshid Shahroki (design requirements and safety protection), Kevin McCoy (materials), Duane Spencer (interfaces, design codes) Elisa Herd (DDNs and duty cycles), John Mayer (core design and design basis), Dominique Hittner (AREVA SAS senior technical advisor), Eric Breuil (AREVA SAS advanced reactor components, helium circulator technology development program).

3.0 Key Assumptions

The following key assumptions are made in the TRL evaluations:

- It is assumed that the preferred material for the hot duct liner is Alloy 800H pending transient thermal hydraulic analysis of the reactor cooling loop. Composite materials, which were needed for the indirect steam cycle configuration, are considered an alternative material.
- It is assumed that the SG design will include a reheater, similar to the configuration shown in **[3, Figure 6-18]**. The following operating temperatures are assumed:
    - 325°C for the SG vessel,
    - 550 - 600°C for the hot end of the SG tubes (the nominal temperature range is 250-600°C)
    - ~725°C for the support plates and shrouds
- It is assumed that the materials are the same as those selected for the indirect steam cycle SG, i.e.:
    - 800H tubes for reheater and super heater
    - 2.25Cr-1Mo tubes for the evaporator zone
- During normal operating conditions the vessel is expected to operate at approximately 340°C, which is below the ASME Boiler and Pressure Vessel Code, Section III **[10]** allowable temperature limit for Class 1 components for SA508.
- The temperatures of the reactor core and vessel internals are based on preliminary design calculations. It is assumed that the results of more detailed analysis of normal, off normal and accident transients will be used to define the demonstration and qualification test requirements.

4.0 TRL Rankings

The TRL definitions used in this report are shown in Table 4-1 and are the same as those used in the previous report.

Table 4-2 summarizes the TRL ratings for each of the PASSCs whose technology readiness was assessed in this report for the operating conditions for the NGNP conventional steam cycle for process heat and cogeneration **[1]**. Appendix A provides the TRL rating sheets for each NGNP component. The rating sheets include the basis for the technology rating.

Table 4-1. TRL Rating Level Definitions

Rating Level	Definition	Abbreviated Definition
1	Basic principles observed and reported in white papers, industry literature, lab reports, etc. Scientific research without well defined application.	Basic principles observed
2	Technology concept and application formulated. Issues related to performance identified. Issues related to technology concept have been identified. Paper studies indicate potentially viable system operation.	Application formulated
3	Proof of concept: Analytical and experimental critical functions and/or characteristic proven in laboratory. Technology or component tested at laboratory scale to identify/screen potential viability in anticipated service.	Proof of concept
4	Technology or component is tested at bench scale to demonstrate technical feasibility and functionality. For analytical modeling, use generally recognized benchmarked computational methods and traceable material properties.	Bench scale testing
5	Component demonstrated at experimental scale in relevant environment. Components have been defined, acceptable technologies identified and technology issues quantified for the relevant environment. Demonstration methods include analyses, verification, tests, and inspection.	Component verified at experimental scale
6	Components have been integrated into a subsystem and demonstrated at a pilot scale in a relevant environment	Subsystem verified at pilot scale
7	Subsystem integrated into a system for integrated engineering scale demonstration in a relevant environment.	System demonstration at engineering scale
8	Integrated prototype of the system is demonstrated in its operational environment with the appropriate number and duration of tests and at the required levels of test rigor and quality assurance. Analyses, if used, support extension of demonstration to all design conditions. Analysis methods verified and validated. Technology issues resolved pending qualification (for nuclear application, if required). Demonstrated readiness for hot startup.	Integrated prototype tested and qualified
9	The project is in final configuration, tested and demonstrated in operational environment.	Plant operational
10	Commercial-scale demonstration is achieved. Technological risks minimized by multiple units built and running through several years of service cycles.	Commercial scale – multiple units

Table 4-2. TRL Ratings

PASSC	TRL
• Nuclear Heat Source	
o Vessel System	7
o Reactor Internals	4
o Reactor Core	4
o Control Rod Drives	4
o Nuclear Instrumentation	7
• Main Heat Transport System	
o Main Helium Circulator	6
o Circulator Shutoff Valve	6
o Hot Duct	5
• Power Conversion System	
o Steam Generator	6
• Other Reactor Support Systems	
o Primary Loop Instrumentation	6
o Fuel Handling System	6
o Reactor Cavity Control System	5
• Process Heat Transport System	
o Steam Reboiler System	8

5.0 Summary

This report updates the assessment of NGNP technology readiness levels based on changes to the design baseline. The critical PASSCs for the 750° NGNP Reactor with a conventional steam cycle are identified on Table 5-1. The most significant changes are to the assessment of the Primary Gas Circulator and to the Vessel System (Reactor Vessel, Cross Vessel, and Steam Generator Vessel).

Helium gas circulator technology has the mass flow rate and power required for the conventional steam cycle configuration **[1]** and is within the state-of-the-art **[5]**. The technology readiness level was revised to TRL 6 based on the lower operating temperature, impeller stress levels, and electrical voltage. Vendor testing is required to confirm the performance of the circulator impeller and the rotor/bearing/motor assembly and to demonstrate integrated performance of the gas circulator and circulator shut-off valve in a relevant environment **[2]** to achieve TRL 7. The technology development roadmap and test plan for the Primary Gas Circulator are being updated to reflect the revised TRL assessment. The timeline for implementation in the NGNP will be reduced by the decision to select a circulator that does not require additional materials testing and component development.

The lower reactor outlet temperature of 750°C allows the use of LWR steel (SA508/533) for the reactor vessel, greatly reducing the design data needs and simplifying reactor vessel qualification **[2, Section 5]**. The previous design with the higher outlet temperature of 900°C required the reactor vessel be comprised of modified 9Cr1Mo steel, which required materials testing to fill gaps in data from the European program and extend the code case for ASME Section III Subsection, Division 1, NH **[3, Section 6.1.1]**. The technology readiness level for the vessel system is TRL 7 based on the lower operating temperature, manufacturability, and extensive industry experience with this material in commercial light water reactors. To achieve TRL 8 will require studying: (1) effects of irradiation on low temperature materials, (2) long term creep, (3) corrosion in helium environment , (4) emissivity in air and helium (including consideration of emissivity degradation), and (5) field fabrication **[2, Table 4-9, Section 2.2.4]**. These are design data needs, not technology development issues. A Considerable amount of materials data is available to support this activity **[11]**.

Table 5-1 Critical PASSCs for NGNP Conventional Steam Cycle

o Reactor Core
o Reactor Internals
o Control Rod Drives
o Main Helium Circulator
o Circulator Shutoff Valve
o Hot Duct
o Steam Generator
o Primary Loop Instrumentation
o Fuel Handling System
o Reactor Cavity Control System

6.0 References

1. AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle
2. AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation
3. AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report
4. INL/BEA Amendment No. 01 to Release No. 3 under Blanket Master Contract No. 00075310, Dated 11/4/2008
5. AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components
6. AREVA 12-9076324-001, NGNP RPV and IHX Pressure Vessel Alternatives
7. AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study
8. McGraw Hill, Perry's Chemical Engineering Handbook, 8^{th} Edition, 2007
9. Thomas Publishing Company, ThomasNet® internet site updated daily
10. ASME Boiler & Pressure Vessel Code, Section III, Class 1, Subsection NH, 2007
11. Argonne National Laboratory ANL/EXT-06/46, Preliminary Issues Associated with the Next Generation Nuclear Plant Intermediate Heat Exchanger Design, September 2006

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APPENDIX A: TRL Rating Sheets

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Reactor Internals

Description:

Reactor Internals include those components which provide the structural interface between the Reactor Core System and the Vessel System and those components which provide for routing of helium between the reactor Core and the Main Heat Transport System and Shutdown Cooling Systems. In addition to providing structural support and directing the flow of helium, major functions of the Reactor Internals include thermal and radiological shielding of the reactor vessel, conservation of neutrons during power production and serving as a key link in the Reactor Cavity Cooling System heat transport path.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.T001 | **Parent:** 1.1.1 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

This structure is assigned a TRL 4 based on the development needs of its contained graphite and composite components, as detailed on the TRL rating sheets for those components.

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for the selected graphites and composite materials will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. The composite material will also need to be codified prior to use. Details of the tests required to obtain this data and the actions necessary for codification are provided in the Test Plan.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.2.1, AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.2.2, AREVA 4.1.4.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Upper Core Restraint

Description:

The Upper Core Restraint limits the movement of the replaceable reflector/fuel columns at the upper end of the reactor core, while providing for the flow of primary coolant into the active core. It comprises an assembly of interlocking pieces arranged such that each hexagonally shaped component of the UCR interfaces with the dowels provided on the upper surfaces of three adjacent reflector elements, effectively fixing their positions relative to each other at the top end. The UCR components also interlock with each other to form a semi-rigid structure over the top of the Reactor Core components. The hexagonal UCR components include through-thickness holes to channel helium coolant flow from the upper core inlet plenum to the replaceable reflector elements above the active core. Two material options are being considered for the UCR blocks: Alloy 800H and C/C composites. A decision will be required based on performance, cost, and licensing considerations, under both normal and off-normal accident conditions.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.1.T001 | **Parent:** 1.1.1.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The use of similar devices in past HTR designs, coupled with the fairly straight-forward mechanical design of this component would support a high TRL for UCR blocks based on Alloy 800H. However, temperatures expected during a PCC accident will likely exceed the maximum use temperature of Alloy 800H. Hence, there is a need to consider the need for inspection, inservice inspection, and repair as well as consider alternative materials. AREVA is considering the need to develop and qualify a C/C composite material to fabricate this component. Consequently, design evaluations of Alloy 800H and material development of C/C composite materials drives the TRL for this component to a 4. The selected material is required to meet specified mechanical performance requirements at the elevated temperatures and neutron fluences experienced by this component during both normal operation and accident conditions.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Conceptual design studies of the Upper Core Restraint will be performed to determine the preferred material option. Details of the activities required for each option are provided in the individual TRL rating sheets for each option. - Material properties for Alloy 800H are available. Detailed design analysis is required to determine the constraints on the reactor design and safety margins. - Material properties values for the selected C/C composite material will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. The material will also need to be codified prior to use.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.2.1, AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.4.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Upper Core Restraint- Alloy 800H

Description:

The Upper Core Restraint limits the movement of the replaceable reflector and fuel columns at the upper end of the reactor core, while providing for the flow of primary coolant into the active core. It comprises an assembly of interlocking pieces arranged such that each hexagonally shaped component of the UCR interfaces with the dowels provided on the upper surfaces of three adjacent reflector elements, effectively fixing their positions relative to each other at the top end. The UCR components also interlock with each other to form a semi-rigid structure over the top of the Reactor Core components. The hexagonal UCR components include through-thickness holes to channel helium coolant flow from the upper core inlet plenum to the replaceable reflector elements above the active core. UCR blocks based on Alloy 800H have been used for prior HTR designs.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.1.1.T001 | **Parent:** 1.1.1.1.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

The use of similar upper core restraints in past HTR designs, coupled with a fairly straightforward mechanical design would support a high TRL for the UCR blocks. Alloy 800H was used in the Ft. St. Vrain reactor and in the HTTR in Japan. There are concerns about the loss of ductility above 400℃ and interstitial He produced upon irradiation. This results in a reduction in ductility, which can be controlled by proper heat treatment during manufacturing, but the effect is not a major obstacle. Under normal operating conditions (maximum temperature of approximately 350℃), there are no problems with the ASME code, which allows a maximum use temperature of 760℃. However, during a PCC accident, it is estimated that temperatures may be in excess of 1100℃. Such temperatures would lead to significant damage to Alloy 800H components. Consequently, the use of Alloy 800H UCR blocks requires further evaluation of the maximum off-normal temperatures, and the likely impact on performance and cost in the event of such a condition, which would require replacement of the blocks before re-start of the reactor.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Advancement to the next TRL level requires installation into the NGNP reactor.	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.2.1, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Upper Core Restraint- C/C Composite

Description:

The Upper Core Restraint limits the movement of the replaceable reflector/fuel columns at the upper end of the reactor core, while providing for the flow of primary coolant into the active core. It comprises an assembly of interlocking pieces arranged such that each hexagonally shaped component of the UCR interfaces with the dowels provided on the upper surfaces of three adjacent reflector elements, effectively fixing their positions relative to each other at the top end. The UCR components also interlock with each other to form a semi-rigid structure over the top of the Reactor Core components. The hexagonal UCR components include through-thickness holes to channel helium coolant flow from the upper core inlet plenum to the replaceable reflector elements above the active core. One material option for the UCR blocks is C/C composites. This material is not as mature as Alloy 800H, but has the potential to provide superior high-temperature properties, at the expense of a more lengthy development and licensing process. A decision to use C/C composites will be required based on performance, cost, and licensing considerations, under both normal and off-normal accident conditions.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.1.2.T001 | **Parent:** 1.1.1.1.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Two material options are being considered for the upper core restraint blocks: a) Alloy 800H, and b) C/C composites. Temperatures in excess of 1100℃ may be present in the top of the c ore during a pressurized conduction cooldown. Such high temperatures may require the use of C/C composites to avoid damage to the restraint blocks during a PCC. C/C composite materials are a relatively mature technology, but they have not been used in nuclear applications. Moreover, the ability to manufacture hexagonal box-like structures with integrated keys using 3-D composites needs to be developed. However, based on available data for high-temperature physical and mechanical properties and relatively good irradiation stability, it appears that should provide acceptable performance.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
A decision must be made between Alloy 800H and C/C composites for UCR blocks. To support this decision, the following activities are required: - Perform modeling to more accurately define the maximum temperature conditions during a PCC; - Further develop and test C/C composites to better define cost and performance characteristics. - Make a decision between the two options based on performance, cost, safety and licensing considerations. - If C/C composites are selected, further development will require: preliminary design; fabrication and testing of hexagonal box-like structures; development of the integrated keys; development of forming methods for holes and other features; and then design, fabrication and laboratory testing of complete UCR blocks.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.2.1, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Permanent Side Reflector

Description:

The Permanent Side Reflector system serves as the radial transition interface between the exterior of the hexagonal Reactor Core System components (fuel elements and replaceable reflectors) and the interior of the circular core barrel. Axially, the PSR extends from the lower side of the UCR to the top of the underlying components of the graphite core support. The PSR design comprises an array of graphite blocks of varying size and shape. The blocks are keyed vertically with dowels and are overlapped to minimize helium bypass flow. The PSR limits movement of the reactor core and transfers structural loads (notably seismic) between the replaceable reflector elements that surround the active core and the core barrel. Another key function of the PSR is to reflect and conserve neutrons in order to facilitate the nuclear reaction for heat generation. The PSR in conjunction with the core barrel is designed to minimize helium bypass of the reactor core. It also provides radiological shielding. A subset of the graphite blocks contains B4C materials for shielding purposes to limit neutron fluence seen by the reactor vessel.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.2.T001 **Parent:** 1.1.1.2 **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Similar components, serving similar functions, under similar conditions have been demonstrated in many HTRs to date. These components were typically fabricated from a particular grade of graphite that is no longer commercially available. Therefore, new graphite materials must be identified and qualified for service in the HTR environment. The need for this selection and qualification activity leads to a TRL rating of 4 for this component. Unlike many other components, it may be advantageous to qualify and carry two or more types of graphite through the HTR design and manufacturing process, (i.e.: no down select) to provide supply redundancy for future reactors.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for each selected grade of graphite will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. Details of the tests required to obtain this data are provided in the Test Plan.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.4.2, AREVA 4.2.2.2

SME Name:	H. L. Massie	**Tech. Case File:**	(enter case file #)
Date: 03/26/09		**Originator:**	AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Permanent Bottom Reflector

Description:

The Permanent Bottom Reflectors are part of the Graphite Core Support Structure and constitute a transition region below the PSR and the bottom replaceable reflector elements that collects and channels the helium exiting the core to the core outlet plenum. Protection against neutron exposure will be ensured by inserting B4C rods inside one row of the blocks.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.3.T001 | **Parent:** 1.1.1.3 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Similar components, serving similar functions, under similar conditions have been demonstrated in many HTRs to date. These components were typically fabricated from a particular grade of graphite that is no longer commercially available. Therefore, new graphite materials must be identified and qualified for service in the HTR environment. The need for this selection and qualification activity leads to a TRL rating of 4 for this component. Unlike many other components, it may be advantageous to qualify and carry two or more types of graphite through the HTR design and manufacturing process, (i.e.: no down select) to provide supply redundancy for future reactors.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for each selected grade of graphite will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. Details of the tests required to obtain this data are provided in the Test Plan.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.4.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Core Outlet Plenum

Description:

The Core Outlet Plenum is the part of the Graphite Core Support Structure which transfers axial loads from the PSR and core assemblies above to the metallic core support structure below. The plenum is formed using an array of support posts between the upper transition floor and the lower insulating layer. The arrangement of the posts and transition blocks is such that the axial load from any given fuel/replaceable reflector column is shared by multiple posts.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.4.T001 | **Parent:** 1.1.1.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Similar components, serving similar functions, under similar conditions have been demonstrated in many HTRs to date. These components were typically fabricated from a particular grade of graphite that is no longer commercially available. Therefore, new graphite materials must be identified and qualified for service in the HTR environment. The need for this selection and qualification activity leads to a TRL rating of 4 for this component. Unlike many other components, it may be advantageous to qualify and carry two or more types of graphite through the HTR design and manufacturing process, (i.e.: no down select) to provide supply redundancy for future reactors.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for each selected grade of graphite will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. Details of the tests required to obtain this data are provided in the Test Plan.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Lower Floor Blocks

Description:

The Lower Floor is the part of the Graphite Core Support Structure which protects the metallic plate located below against neutron exposure and high temperature. The Lower Floor consists of a graphite layer thick enough to protect the metallic parts against neutron exposure. The thermal protection of the MCS is provided by a set of ceramic or composite material plates located below the graphite, generally referred to as the lower floor blocks (LFBs). The thickness of the LFBs is defined according to the thermal conductivity of the material selected. The lower floor blocks also provide a critical function of positioning the core through a combination of design features (dowels and keys). The metallic plate located below the lower floor is part of the Core Supports and provide structural support to the reactor core.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.5.T001 | **Parent:** 1.1.1.5 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

New graphite materials for the Graphite Core Support Structure must be identified and qualified for service in the HTR environment. The need for this selection and qualification activity leads to a TRL rating of 4.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for the selected graphites will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0, AREVA 4.1.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Metallic Core Supports

Description:

The Metallic Core Support serves both as an axial support structure and flow channeling device. The vertical shell of the support structure incorporates two concentric annular flow channels. The outer channel communicates with return (cold) helium flow from the cross vessel annulus surrounding the hot duct. This flow is directed to the lower plenum of the support structure. From there, the flow enters the upper plenum of the support structure via holes in the metal plate that separates the two plena and through an annular opening at the exterior of the vertical cylindrical shell that encloses the interface with the SCS Heat Exchanger. From the upper plenum, the flow enters the inner annular passage of the vertical shell, which communicates with the core barrel flow annulus above. The multi-plenum structure of the metallic core support is designed to provide uniform flow distribution of helium around the circumference of the structure at its interface with the core barrel at the upper end.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.6.T001 | **Parent:** 1.1.1.6 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Variations of this component have been successfully used in many different HTRs under a range of conditions, encompassing those anticipated for the NGNP. The material envisioned for the metallic components is Alloy 800H. This material is already codified at high temperature and provides design flexibility to cope with high temperature transients.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Advancement to the next TRL level requires installation into the NGNP and operation of the reactor.	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Core Barrel

Description:

The Core Barrel is a double-wall cylinder, open at the top (where it supports the top plenum structure) and attached to the metallic core support structure at the bottom. The inner cylinder serves as the principal structural member of the core barrel assembly. The outer cylinder is provided to establish an annular passage for helium flow. Flanges are incorporated at either end, which provide for stiffening, mounting of the outer cylinder shell and bolting of the four sections together in the field.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.7.T001	**Parent:** 1.1.1.7	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

Variations of this component have been successfully used in many different HTRs under a range of conditions, encompassing those anticipated for the NGNP. The material envisioned for the metallic components is Alloy 800H. This material is already codified at high temperature and provides design flexibility to cope with high temperature transients.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Advancement to the next TRL level requires installation into the NGNP and operation of the reactor.	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Top Plenum Shroud Structure

Description:

The Top Plenum Shroud (TPS) structure is connected to the top end of the MCS/Core Barrel to form the inlet plenum of the reactor. The TPS comprises an inner structural shell with external stiffening ribs. An outer shell is provided to contain the combined thermal and radiation shielding material that is included in the enclosed space within. Penetrations are provided for the neutron control assemblies during normal operation and/or refueling and fuel manipulation equipment and other maintenance equipment that is utilized during outages. During normal operation, the main helium flow exits the core barrel annular channel into the plenum formed by the MCS and the TPS. Flow outside the TPS is essentially stagnant to reduce parasitic heat losses.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.1.8.T001	**Parent:** 1.1.1.8	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Variations of this component have been successfully used in many different HTRs under a range of conditions, encompassing those anticipated for the NGNP. The material envisioned for the structural metallic components is Alloy 800H. This material is already codified at high temperature (up to 760℃), which is sufficient for maximum temperatures expected during normal operations (on the order of 350℃). However, during a pressurized conduction cooldown (PCC) it is possible that the inner structural shell will be exposed to He in excess of 1100℃. Although efforts are underway to extend th e ASME codified maximum use temperature toward 900°C, it is possible that the inner shell temperature will exceed this limit during a PCC. In this case, an alternate design of the Top Plenum Shroud would be required, using the outer shell as the primary structural member. Detailed design will be required for the inner shell, and the method of attachment to the outer shell, and selection of the thermal insulation and radiation shielding materials. This is a design issue, not a technology development issue.

References:

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, September 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, February 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Advancement to the next TRL level requires installation into the NGNP and operation of the reactor.	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: N/A

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	Document Number: TDR-3001463	Revision: 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Core

Description:

The prismatic blocks are hexagonal blocks that are used either as fuel or reflector elements. The structure is assigned a TRL 4 based on the development needs of its contained graphite and as detailed on the TRL rating sheets for those components.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.3.T001	Parent: 1.1.3	WBS:

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The prismatic block design is based upon the design that was successfully used in the Fort Saint Vrain gas reactor and has had further development in the GT-MHR design. The only development needs are considered to be testing that will be used to characterize some basic design parameters and validate design codes to be used in the design of the NGNP core.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
3) IAEA TECDOC 1249, " Critical Experiments and Reactor Physics Calculations for Low-Enriched High Temperature Gas Cooled Reactors"
4) Seismic behavior of gas cooled reactor components. Proceedings of a specialists' meeting held in Gif-sur-Yvette, France, 14-16 November 1989; International Atomic Energy Agency, Vienna (Austria). International Working Group on Gas-Cooled Reactors IWGGCR--22
5) Specialists' meeting on graphite component structural design, JAERI Tokai (Japan), September 8-11, 1986; International Atomic Energy Agency, Vienna
6) Uncertainties in physics calculations for gas cooled reactor cores. Proceedings of a specialist's meeting held in Villigen, Switzerland, 9-11 Ma
7) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	Actionee	Schedule	Cost ($K)
Material properties values for the selected graphites will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. The composite material will also need to be codified prior to use. - Obtain physical, thermal, and mechanical properties for the selected graphites as a function of temperature and neutron fluence over the ranges expected in the NGNP.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0

SME Name: H. L. Massie	Tech. Case File: (enter case file #)

Date: 03/26/09	Originator: AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Fuel Blocks

Description:

The prismatic fuel blocks are hexagonal blocks that contain compartments for fuel compacts as well as channels for the coolant. These blocks are stacked to form columns, which are placed in an annular hexagonal pattern between inner and outer reflector block columns to form the active region of the core.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.3.1.T001	**Parent:** 1.1.3.1	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The prismatic block design is based upon the design that was successfully used in the Fort Saint Vrain gas reactor and has had further development in the GT-MHR design. The graphite used in that core design is no longer available. The TRL score is based on the need to characterize basic graphite design parameters and validate design codes to be used in the design of the NGNP core. Mechanical performance data is required at elevated temperatures and neutron fluences during normal and accident conditions.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
3) IAEA TECDOC 1249, “ Critical Experiments and Reactor Physics Calculations for Low-Enriched High Temperature Gas Cooled Reactors”
4) Seismic behavior of gas cooled reactor components. Proceedings of a specialists' meeting held in Gif-sur-Yvette, France, 14-16 November 1989; International Atomic Energy Agency, Vienna (Austria). International Working Group on Gas-Cooled Reactors IWGGCR--22
5) Specialists' meeting on graphite component structural design, JAERI Tokai (Japan), September 8-11, 1986; International Atomic Energy Agency, Vienna
6) Uncertainties in physics calculations for gas cooled reactor cores. Proceedings of a specialist's meeting held in Villigen, Switzerland, 9-11 May 1990; International Atomic Energy Agency, Vienna (Austria). International Working Group on Gas-Cooled Reactors IWGGCR-24
7) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for the selected graphites will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. The composite material will also need to be codified prior to use. - Obtain physical, thermal, and mechanical properties for the selected graphites as a function of temperature and neutron fluence over the ranges expected in the NGNP.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Replaceable Reflector Blocks

Description:

The prismatic reflector blocks are hexagonal blocks that are stacked to form columns, which are used to form inner and outer reflectors within the permanent reflectors

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.3.2.T001	**Parent:** 1.1.3.2	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The prismatic block design is based upon the design that was successfully used in the Fort Saint Vrain gas reactor and has had further development in the GT-MHR design. The graphite used in that core design is no longer available. The TRL score is based on the need to characterize basic graphite design parameters and validate design codes to be used in the design of the NGNP core. Mechanical performance data is required at elevated temperatures and neutron fluences during normal and accident conditions.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
3) IAEA TECDOC 1249, “ Critical Experiments and Reactor Physics Calculations for Low-Enriched High Temperature Gas Cooled Reactors”
4) Seismic behavior of gas cooled reactor components. Proceedings of a specialists' meeting held in Gif-sur-Yvette, France, 14-16 November 1989; International Atomic Energy Agency, Vienna (Austria). International Working Group on Gas-Cooled Reactors IWGGCR--22
5) Specialists' meeting on graphite component structural design, JAERI Tokai (Japan), September 8-11, 1986; International Atomic Energy Agency, Vienna
6) Uncertainties in physics calculations for gas cooled reactor cores. Proceedings of a specialist's meeting held in Villigen, Switzerland, 9-11 May 1990; International Atomic Energy Agency, Vienna (Austria). International Working Group on Gas-Cooled Reactors IWGGCR-24
7) AREVA 12-9102279-001, "NGNP Conceptual Design DDN/PIRT Reconciliation", March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Material properties values for the selected graphites will be required to qualify for use in the NGNP. Physical, thermal, and mechanical properties will need to be determined as a function of temperature and neutron fluence over the ranges expected in the NGNP plant. The composite material will also need to be codified prior to use. - Obtain physical, thermal, and mechanical properties for the selected graphites as a function of temperature and neutron fluence over the ranges expected in the NGNP.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.4.1.0, AREVA 2.4.2.0

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☑ Subsystem/Structure ☐ Component ☐ Technology

Title: Nuclear Instrumentation

Description:

The nuclear instrumentation consists of ex-vessel neutron detectors, source range detectors, and in-core flux mapping units. These instruments include fission chambers and proportional neutron counters. The Nuclear Instrumentation is used in conjunction with Neutron Control Assemblies to control the neutron flux in the reactor core. During normal operation, the neutron flux levels are monitored by the ex-vessel neutron detectors, whose range overlaps with that of the source-range detectors. The ex-vessel detectors are located in the reactor cavity concrete which is under 60 ℃. During startu p and shutdown, the neutron flux levels are monitored using the source-range detectors. The detector assemblies are located inside the permanent reflector blocks which are under 400 ℃. The in-core flux mapping units are used to verify axial flux profiles and confirm power stability. These detectors can be installed near the centerline of the reactor or in the reflector blocks, or both locations. The temperatures at those location are approximately 350 ℃.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.6.T001 | **Parent:** 1.6 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

Nuclear Instrumentation is in common use in operating reactors and have been used in gas cooled reactors with similar design configurations as the NGNP reactor. Commercially available detectors are available that meet NGNP requirements for all three instruments at their respective design temperatures and neutron flux levels. Some qualification testing may be desirable to select detector technology and verify adequate sensitivity and lifetime. The maximum temperature for commercial detectors is 600 ℃, which precludes placing them in the active core region. Active core instruments are not part of the NGNP design requirements and are not used in commercial reactors. The NGNP will test and validate the monitoring strategy. The maximum temperatures that sensors will operate in is estimated at 325℃.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
R&D testing of candidate in-core sensor technology to demonstrate adequate sensitivity and lifetime	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Ex-Vessel Neutron Detectors

Description:

The ex-vessel neutron detectors enable monitoring power level in the core during operation. These instruments include fission chambers and proportional neutron counters. The proportional counters are highly sensitive to ensure detection of source neutrons at low power. They are located at source level in penetrations in the reactor cavity concrete which is at 60 ℃ under normal operating conditions.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.6.1.T001 | **Parent:** 1.6.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Commercially available detectors are available that meet anticipated requirements. These detectors are used in LWRs in similar operating environments. Additional testing is not required to qualify the sensor for NGNP selection. The design of the assembly and penetrations does require technology development.

References:
1) AREVA NDZ 2006-42, Original issued December 2006 (AREVA proprietary)*
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Source Range Detectors

Description:

The source range detector assemblies enable monitoring axial power distributions in the core. The detector assemblies are located inside the permanent reflector blocks. Each assembly includes fission chambers with cabling and support structure that is inserted into the reactor through reentrant penetrations in the bottom head of the reactor vessel. The reentrant penetration extends vertically into channels in the reflector blocks near the bottom of the core. The detectors measure both thermal and neutron flux. The reflector blocks are expected to be at approximately 325℃.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.6.2.T001 | **Parent:** 1.6.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Commercially available detectors are available that meet anticipated requirements. Some qualification testing may be desirable to select detector technology and verify acceptable sensitivity and lifetime. The design of the assembly and penetrations does require technology development.

References:
1) AREVA NDZ 2006-42, Original issued December 2006 (AREVA proprietary)*
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
R&D testing of candidate sensor technology to demonstrate adequate sensitivity and lifetime	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: In-Core Flux Mapping Units

Description:

The in-core flux mapping units are used during refueling when the neutron flux is very low. The in-core flux mapping units contain fission chambers, high sensitivity proportional detectors and thermocouples. Each detector assembly includes drive mechanism controls, and detector electronics. The detector assembly is composed of shielding cylinder topped by an instrument cylinder containing two independent fission chambers and two thermocouples. The shielding cylinders are used to protect the fission chambers from unnecessary radiation exposure when retracted up into the assembly. These detectors can be installed near the centerline of the reactor or in the reflector blocks, or both locations. The centerline assembly contains two mechanisms. One for retracting the detector guide tube to provide space for refueling operations, and the other for lowering and retracting the detector assembly in and out of the well in the central reflector block. They can also be installed in the reflector blocks during refueling using the same locations that are normally occupied by the source range detectors.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.6.2.T002 | **Parent:** 1.6.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Commercially available detectors are available that meet current NGNP requirements. Some qualification testing may be desirable to select sensor technology and verify adequate sensitivity and lifetime. The design of the assembly and penetrations does require technology development.

Commercially available detectors are limited to 600 ℃. AREVA's NGNP PCDR TRL's was based on having de tectors in the active core region, which would be over 1200 ℃. Active core instrument s are not part of the NGNP design requirements and are not used in commercial reactors. This analysis assumes that active core detectors are not required. They are not required as part of the NGNP PCDR safety basis. The NGNP reactor in-core neutron detectors will only be used during refueling when the neutron flux and core temperature are low.

References:
1) AREVA NDZ 2006-42, Original issued December 2006 (AREVA proprietary)*
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, February 2009
3) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
R&D testing of candidate sensor technology to demonstrate adequate sensitivity and lifetime	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☑ Subsystem/Structure ☐ Component ☐ Technology

Title: Reactor Cavity Cooling System

Description:

The RCCS is used to protect the reactor cavity walls from excess heat during normal operations and to provide a heat transport path for accident scenarios where both the HTS and SCS systems are unavailable.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.T001	**Parent:** 1.3	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Bench Scale Testing	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale
TRL	**4**	**5**	**6**

Basis for Rating *(Attach additional sheets as needed.)*

The operating principles and controlling physics of the system are simple and well understood. Although the use of an uninsulated reactor vessel coupled with a water cooled panel heat exchanger has not been demonstrated, a similar system was included in the NPR design. Some details of the Cavity Cooler Panel design are not fully developed, such as the need for emissivity enhancing coatings and surface treatments, and the final layout of the system. The design values for parameters such as the emissivity of the RPV and Cavity Cooler Panel materials have not been determined. Design studies of the heat transfer tradeoffs effecting cooling of the RPV during accident scenarios, while maintaining a minimum loss of energy during normal operation, is required. Special effects tests of the anticipated or proposed surface for the reactor vessel and the proposed heat exchanger will provide more precise information on critical design parameters (e.g., surface emissivity, particulates) and may provide adequate design margin. Large scale demonstration of the capability of the RCCS to release the decay heat from the reactor may be beneficial for: 1) qualifing the design codes and methods, and
2) providing convincing confirmation for licensing regulators.

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Characterize emissivity of RPV & panel materials Characterize effects of particulate on radiation heat transfer Characterize effects of particle plate-out on panel emissivity Large scale demonstration of RCCS capability	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Cavity Cooler Panels

Description:

The Cavity Cooler Panels surround the RPV within the reactor cavity. These panels are used to remove the heat from the RPV and protect the reactor cavity walls. The panels consist of a closed tube wall through which water flows via natural circulation.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.1.T001 | **Parent:** 1.3.1 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The concept of the Cavity Cooler Panels is essentially the same as an air-to-water heat exchanger. This technology was selected for the NPR reactor and is used in other applications. The operating principles and controlling physics are simple and well understood. However, some details of the design are not fully characterized, such as the emissivity of the RPV and Cavity Cooler Panel materials, the need for emissivity enhancing coatings, and the final layout of the system. All of these provide tradeoffs in the effective cooling of the RPV during accident scenarios, while maintaining a minimum loss of energy during normal operation.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Characterize emissivity of RPV & panel materials Characterize effects of particulate on radiation heat transfer Characterize effects of particle plate-out on panel emissivity A large scale demonstration of the capabilities of the RCCS to release the decay heat from the reactor may be beneficial.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Coolant Piping

Description:

The coolant piping directs the cooling water from the Cavity Cooler Panels to the Water Storage Tank.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.2.T001	**Parent:** 1.3.2	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

This is considered a basic piping configuration and operates at conditions similar to other industrial applications. The piping is considered to be commercially available.

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Water Storage Tank

Description:
The Water Storage Tank provides the heat sink for the natural convection flow through the Cavity Cooler Panels and Coolant Piping.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.3.T001 | **Parent:** 1.3.3 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

This is a simple water storage tank and requires no technological development prior to implementation in the NGNP

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	
☐ Area	☐ System	☐ Subsystem/Structure	☑ Component	☐ Technology	

Title: Water-to-Water Heat Exchanger

Description:

This heat exchanger is used to remove heat from the Water Storage Tank.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.4.T001	**Parent:** 1.3.4	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

This is a basic commercially available water-to-water heat exchanger and requires no technology development prior to implementation in the NGNP

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman		**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:** AREVA		

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Water Pump

Description:

This Water Pump circulates water through the water-to-water heat exchanger in the Water Storage Tank.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.5.T001 | **Parent:** 1.3.5 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

This is a basic commercially available water pump and requires no technology development prior to implementation in the NGNP

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Water-to-Air Heat Exchanger

Description:

This water-to-air heat exchanger is used to transfer the heat in the coolant system for the Water Storage Tank to the atmosphere.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.6.T001	**Parent:** 1.3.6	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

This is a basic commercially available water-to-air heat exchanger and requires no technology development prior to implementation in the NGNP

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Air Blower

Description:

This Air Blower is used for cooling of the air side of the water-to-air heat exchanger.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.3.7.T001 | **Parent:** 1.3.7 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

This is a basic commercially available air blower and requires no technology development prior to implementation in the NGNP

References:
1) AREVA 12-9051191-001, NGNP with Hydrogen Production Preconceptual Design Studies Report, June 2007
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Implement in NGNP reactor for hot testing	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.4.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Control Rod Drives

Description:

The Neutron Control System includes the Control Rod Equipment which, in turn, includes start-up control rods and operating control rods, the control rod drive mechanisms, and the control rod cable. Reactivity control is provided by the positioning of control rod assemblies relative to the active fuel such that neutrons are absorbed to regulate the reactivity rate. The system consists of control rods, control rod drive mechanisms, cables, drum drives, position indicators, and cable force sensors.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.T001 | **Parent:** 1.1.4 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The concept proposed for the NGNP reactor is similar to the neutron control system used in other gas reactors. The control rods may encounter some high temperatures during accident conditions, where traditional metal alloys would not have any useful strength. As a result, C/C composites and SiC/SiC composites are being considered for use in control rods. These materials will be able to withstand the anticipated temperatures, but will require significant effort to develop and qualify them for control rods. Similarly, Alloy 800H guide tubes may not be suitable for the NGNP reactor due to high temperatures expected during a pressurized conduction cooldown. C/C composites are being considered as an alternative material if detailed analyses show that it is necessary. A TRL = 4 has been assigned for the composite materials applied to both control rods and guide tubes.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Actions required to progress from TRL = 4 to TRL = 5 have been defined for the Control Rods and Guide Tubes.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.1.1, AREVA 2.3.1.2, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	
☐ Area	☐ System	☐ Subsystem/Structure	☐ Component	☑ Technology	
Title: Reserve Shutdown System					

Description:

The reserve shutdown system consists of spherical absorber elements that can be dropped into the core from a hopper in case an alternate source of negative reactivity is required to shutdown the core.

Area:	☑ NHSS	☐ HTS	☐ HPS	☐ PCS	☐ BOP
PASSC: 1.1.4.1.T001		**Parent:** 1.1.4.1		**WBS:**	

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The RSS was demonstrated at Fort Saint Vrain and is considered mature enough to be implemented in the NGNP with no development.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
N/A	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: N/A

SME Name: H. L. Massie		**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:** AREVA		

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Control Rods

Description:

The control rods are composed of a string of 18 annular canisters with articulating joints between adjacent canisters. The canisters are constructed with clad on the inside and outside to contain annular compacts of the B4C absorber material. The cladding is vented so that any helium that is generated by the neutron absorbing process is discharged into the helium coolant. Consequently, there is no pressure boundary in the control rod assembly. The articulating joint configuration allows the control rod assembly to act like a chain and allows the assembly to flex around bends within the columns of graphite blocks. A cable connected to the control rod drive runs through the center of the string of canisters, providing the primary axial support.

There are three candidate materials for the control rod cladding, end caps and articulating connectors: Alloy 800H, C/C composite, and SiC/SiC composite. A decision regarding the material to be used for the control rod canisters will be required.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.2.T001 | **Parent:** 1.1.4.2 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

There are three candidate materials for the control rod canisters: Alloy 800H, C/C composite, and SiC/SiC composite. Alloy 800H has been used as the control rod material for other HTR designs (TRL = 8) and may be suitable for use under normal operating conditions, provided that the maximum allowable use temperature per the ASME Code is extended to 850ºC or the control rod channels are cooled with by-pass flow. This material will not be acceptable for use under off-normal conditions, such as conduction cooldown accidents. C/C composites and SiC/SiC composites are much less mature and have not been used in nuclear applications (TRL = 4). These materials are capable of operating at even the most extreme temperatures envisioned within the core. C/C composites are a more mature technology than SiC/SiC composites. However, SiC/SiC composites appear to have superior oxidation resistance and stability upon exposure to neutron radiation.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Perform modeling to more accurately define the maximum temperatures (both normal and off-normal) for the control rods - Perform design analyses to determine the performance envelop for Alloy 800H control rods - Perform limited testing for C/C and SiC/SiC composites to generate the necessary data to support preliminary design analyses - Perform design analyses for each composite material and define the performance characteristics - For the selected composite material, further development will require: preliminary design; fabrication and testing of control rod elements; development and testing of the joint; and the design, fabrication and testing of a string of control rod elements.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.1.1, AREVA 2.3.1.2, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Control Rods-Alloy 800H

Description:

A complete description of the control rods is provided under item 1.1.4.2 Control Rods. This sheet is limited to discussion of Alloy 800H canisters and connectors.

Alloy 800H is an iron based alloy with a significant amount of nickel and chromium in its composition, as well as a small amount of boron. It has useful strength to high temperatures and is supported by the ASME Code for use up to 760ºC. It is proposed as a candidate material for the control rod canister (cladding and end caps) and connector, since it has been successfully used in other HTR designs. Alloy 800H may satisfy the temperature criteria for normal operation of the NGNP reactor, provided the maximum ASME use temperature is extended to 850ºC, or if control rod channels are cooled with by-pass flow. However, it has not been codified for the entire envelope of operating conditions for the NGNP reactor, particularly the temperatures projected for accident conditions.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.2.1.T001 | **Parent:** 1.1.4.2.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Alloy 800H has been used for control rods in other HTR designs, and thus is considered a mature technology. No further technology development is required. However, some analysis to precisely define the operating envelope of control rods manufactured from Alloy 800H is recommended. If this option is chosen, the control rods will require replacement following accident conditions that exceed the material temperature limits.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Perform modeling to more accurately define the maximum temperatures (both normal and off-normal) for the control rods - Perform design analyses to determine the performance envelop for Alloy 800H control rods - If Alloy 800H is selected, no further development will be required.	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	
☐ Area	☐ System	☐ Subsystem/Structure	☐ Component	☐ Technology	

Title: Control Rods- C/C Composite

Description:

A complete description of the control rods is provided under item 1.1.4.2 Control Rods. This sheet is limited to discussion of C/C composite canisters and connectors.

C/C composites have been identified as candidate materials for the control rod clad, end caps, and connector. These materials have been used in recent years for numerous aerospace applications where high-temperature strength and high thermal conductivity were needed. As a result, C/C composites are considered a relatively mature technology. For the NGNP reactor, C/C composites should be stable in the He coolant environment to any temperature envisioned within the core. Certain C/C composites have also been shown to exhibit structural stability to fast neutron irradiation to dose levels up to 6-8 dpa.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.2.2.T001	**Parent:** 1.1.4.2.2	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

C/C composites are used commercially in the aerospace industry and elsewhere. Thus, these materials are considered to be relatively mature. Furthermore, tubular components having dimensions similar to those envisioned for the control rod clad have been produced. However, C/C composites have not been used in nuclear applications. Significant effort will be required to develop control rod elements using C/C composites and qualify them for use in the NGNP reactor. Based on these factors, a TRL rating of 4 has been assigned.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Perform modeling to more accurately define the maximum temperatures (both normal and off-normal) for the control rods - Perform testing for C/C composites to generate the necessary data to support preliminary design analyses; this includes high-temperature properties and effects of irradiation - Perform design analyses and define the performance characteristics - If a C/C composite is selected, further development will require: preliminary design; fabrication and testing of control rod elements; development and testing of the joint; and the design, fabrication and testing of a string of control rod elements.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Control Rods- SiC/SiC Composite

Description:

A complete description of control rods is provided under item 1.1.4.2 Control Rods. This sheet is limited to discussion of SiC/SiC composite canisters and connectors.

SiC/SiC composites have been identified as candidate materials for the control rod clad, end caps, and connector, primarily because it is believed that this material may be suitable for long-term performance (up to 60 years) in the NGNP reactor. While SiC/SiC composites are commercially available, there is a limited amount of data available for the physical, thermal and mechanical properties, particularly at high temperatures. Furthermore, this material has not been used in nuclear applications. However, available data show that SiC/SiC composites exhibit excellent stability upon exposure to radiation. Small changes in mechanical properties have been measured, and volumetric swelling is limited to less than 1% at elevated temperatures.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.2.3.T001	**Parent:** 1.1.4.2.3	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	**3**	**4**	**5**

Basis for Rating *(Attach additional sheets as needed.)*

Although SiC/SiC composites are used commercially in the aerospace industry and elsewhere, they are not considered to be a mature technology. Tubular components having dimensions similar to those envisioned for the control rod clad have been produced. And, while SiC/SiC composites have not been used in nuclear applications, they have been the subject of considerable investigation for use in fusion reactors. Testing has shown that SiC/SiC composites have excellent radiation stability. Moreover, they exhibit superior oxidation resistance relative to C/C composites. However, significant effort will be required to develop control rod elements using SiC/SiC composites and qualify them for use in the NGNP reactor. Based on these factors, a TRL rating of 4 has been assigned.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Perform modeling to more accurately define the maximum temperatures (both normal and off-normal) for the control rods - Perform testing for SiC/SiC composites to generate the necessary data to support preliminary design analyses; this includes high-temperature properties and effects of irradiation - Perform design analyses and define the performance characteristics - If a SiC/SiC composite is selected, further development will require: preliminary design; fabrication and testing of control rod elements; development and testing of the joint; and the design, fabrication and testing of a string of control rod elements.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.1.1, AREVA 2.3.1.2, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Guide Tubes

Description:

The guide tubes are approximately 5-inch diameter tubes that will extend from the control rod drive in the stand-pipe to the top reflector block within the reactor core. The tubes will protect the control rod elements and guide them into channels within designated fuel and reflector blocks within the core. Two material options are being considered for the guide tubes: a) Alloy 800H, and b) C/C composites. A decision between these two materials will need to be made.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.3.T001	**Parent:** 1.1.4.3	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Alloy 800H guide tubes have been used in prior HTGR designs, and are considered to be a mature technology. However, while this material will perform well under nominal operating conditions (approximately 325ºC), He temperatures in excess of 1100ºC may be present in the top plenum during a pressurized conduction cooldown. Such high temperatures will exceed the maximum use temperature of Alloy 800H and will likely cause damage to the guide tubes. To avoid potential damage to the guide tubes during a PCC, C/C composite guide tubes are being considered. C/C composite materials are a relatively mature technology, but they have not been used in nuclear applications. Moreover, the ability to manufacture long tubes that can extend from the stand-pipe to the top reflector block must be developed.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
A decision must be made between Alloy 800H and C/C composites for guide tubes. To support this decision, the following activities are required: - Perform modeling to more accurately define the maximum temperature conditions during a PCC - Assess the performance envelop for Alloy 800H guide tubes and the impact of high-temperature exposure - Further develop and test C/C composites to better define performance characteristics of guide tubes - If C/C composites are selected, complete the development and qualification of guide tubes	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.1.1, AREVA 2.3.1.2, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name:	H. L. Massie	**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:** AREVA		

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Guide Tube- Alloy 800H

Description:

The guide tubes are approximately 5-inch diameter tubes that will extend from the control rod drive in the stand-pipe to the top reflector block within the reactor core. The tubes will protect the control rod elements and guide them into channels within designated fuel and reflector blocks within the core.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.3.1.T001 | **Parent:** 1.1.4.3.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Alloy 800H guide tubes have been used in prior HTGR designs, and are considered to be a mature technology. However, while this material will perform well under nominal operating conditions (approximately 325ºC), He temperatures in excess of 1100ºC may be present in the top plenum during a pressurized conduction cool down. Such high temperatures will exceed the maximum use temperature of Alloy 800H and will likely cause damage to the guide tubes. Some analysis will be conducted to precisely define the operating envelope for Alloy 800H guide tubes, but no technology development is required.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Alloy 800H guide tubes are considered to be a mature technology. However, this material may not be suitable for use at the high temperatures expected during a PCC. The following actions are required to address the Alloy 800H option: - Perform more accurate thermal analyses for a PCC to define maximum temperatures for guide tubes. - Assess the performance envelop for Alloy 800H guide tubes and the impact of high-temperature exposure	N/A	N/A	N/A

DDN(s) Supported: AREVA 2.2.3.1, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Guide Tubes- C/C Composite

Description:

The guide tubes are approximately 5-inch diameter tubes that will extend from the control rod drive in the stand-pipe to the top reflector block within the reactor core. The tubes will protect the control rod elements and guide them into channels within designated fuel and reflector blocks within the core.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.3.2.T001 | **Parent:** 1.1.4.3.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

Two material options are being considered for the guide tubes: a) Alloy 800H, and b) C/C composites. He temperatures in excess of 1100ºC may be present in the top plenum during a pressurized conduction cooldown. Such high temperatures may require the use of C/C composites to avoid damage to the guide tubes during a PCC. C/C composite materials are a relatively mature technology, but they have not been used in nuclear applications. Moreover, the ability to manufacture long tubes that can extend from the stand-pipe to the top reflector block must be developed. Given the long lengths (greater than 5 meters), it is likely that guide tubes will be comprised of shorter segments that are joined together. As such, a TRL rating of 4 has been assigned.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Perform modeling to more accurately define the maximum temperature conditions during a PCC - Further develop and test C/C composites to better define performance characteristics for guide tubes - If C/C composites are selected, further development will require: preliminary design; fabrication and testing of tubes; development of the joining method; and then design, fabrication and laboratory testing of full-length guide tubes.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.1.1, AREVA 2.3.1.2, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Control Rod Drive Mechanism

Description:

The Control Rod Drive Mechanism (CRDM) positions the control rods to regulate the rate of reactivity in the reactor. The proposed CRDM for the NGNP reactor is a motor driven drum and cable mechanism that is similar to mechanisms used for the Fort St. Vrain reactor and numerous other reactors. The CRDM is equipped with instrumentation to provide feedback to the reactor protection system and to the reactor operators on control rod position in the core. The principal sub-assemblies in the drive mechanism are a cable, drum drive, position indicator (PI) and cable force sensor.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.4.T001	**Parent:** 1.1.4.4	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The CRDM design proposed for the NGNP program is similar to drive mechanisms that have been in service on numerous other reactors. The design of this type of mechanism has been developed during its service life to satisfy performance and reliability criteria of the reactors on which it was installed. It is envisioned that the NGNP drive mechanism will be similar to existing cable and drum mechanism designs and will capitalize on the experience that has been acquired during their service lives. However, a TRL rating of 4 is assigned to the CRDM as a result of the TRL = 4 rating assigned to the cable. Depending on the design configuration for the control rod channels and the materials chosen for the cable, this system may only require final confirmatory testing in a integrated test of the CR and CRDM.

References:

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
The actions required to progress from TRL = 4 to 5 are the actions defined for the cable.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.1.1, AREVA 2.3.1.2

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Cable

Description:

The cable connects the column of control rod canisters to the control rod drive mechanism. It is anchored to the bottom of the control rod column and passes through the center of the canisters and the articulating connectors. The cable is loaded in tension to provide a means of retaining the entire column of the control rod canisters during reactor operation and to provide some level of control of the control rod assembly during rod repositioning. The upper end of the cable is attached to the cable drum section of the control rod drive mechanism. The cable is wrapped around the cable drum as a control rod is withdrawn from the core.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.4.1.T001 | **Parent:** 1.1.4.4.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Proof of Concept	Bench Scale Testing	Component Verified at Experimental Scale
TRL	3	4	5

Basis for Rating *(Attach additional sheets as needed.)*

The cable is made from a high temperature wire cable material. Since it passes through the center of the control rod column, it is subject to the same temperatures and environmental conditions as the control rod canisters. It may be necessary to provide a coating on the cable for thermal insulation and wear resistance during reactor accident conditions. Cable of this type should be available from commercial sources. However, testing will be required to select an appropriate cable material for the NGNP reactor. Since the material has not yet been defined, a TRL rating of 4 is assigned for the cable. If control rod channels are cooled and Alloy 800H canisters are used, the cable material and design are well known from application at numerous other reactors and no development will be required.

References:
1) Engineering judgment of subject matter experts and experience with similar systems

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
1) Develop design criteria and a test plan that addresses the NGNP reactor operating and radiation environment, strength, thermal relaxation, creep, and wear 2) Prepare a prototype design for a test fixture 3) Fabricate hardware and cable samples for testing in the test fixture. 4) Perform tests at reactor operating conditions (temperature and radiation level) to satisfy the cable design criteria. 5) Make a decision for the material to be used for the CRDM cable.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.3.1.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Drum Drive

Description:

The drum drive is the portion of the control rod drive mechanism that feeds the cable into the core to position the control rod assembly. It will be similar in configuration to the drum drive that has been used on a number of other reactors.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.4.2.T001 | **Parent:** 1.1.4.4.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The drum drive concept is proven technology that has been used on several reactors. The concept will need to be adapted to the space envelope available and to the thermal and environmental conditions of the NGNP reactor. Therefore, its operation will be validated as part of the integrated CRDM testing.

References:
1) Engineering judgment of subject matter experts and experience with similar systems

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Conduct tests of prototype CRDM, including a control rod assembly, at ambient conditions and reactor operating conditions to verify performance.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.3.1.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Control Rod Position Indicator

Description:

The control rod Position Indicator provides feedback to reactor operating personnel and to the reactivity control system on the actual position of the control rod assembly relative to the active core. The control rod Position Indicator is a readout device that provides a measurement of the total angle that the cable drum has rotated through. The proposed Position Indicator (PI) will provide an indication of the control rod position by measuring the total angle through which the cable drum has rotated.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.4.3.T001	**Parent:** 1.1.4.4.3	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	**5**	**6**	**7**

Basis for Rating *(Attach additional sheets as needed.)*

Position Indicators have been developed for all of the operating reactors that use a cable and drum type of CRDM. Commercial instrumentation can be employed for the Position Indicator after it has been adapted to the operating environment and design configuration of the NGNP reactor.

References:
1) Engineering judgment of subject matter experts and experience with similar systems

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Conduct tests for the prototype CRDM to confirm the performance, reliability, and durability of the Position Indicator. Final testing will be conducted at reactor operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.3.1.2

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Control Rod Force Sensor

Description:

The control rod force sensor provides feedback to the reactor control system and the reactor operator of the load on the CRDM cable. This sensor provides an indication of any hang ups or jamming that the control rod assembly may encounter during rod repositioning. In addition, the sensor will provide an indication of cable breakage.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.4.4.4.T001 | **Parent:** 1.1.4.4.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	**5**	**6**	**7**

Basis for Rating *(Attach additional sheets as needed.)*

The control rod force sensor uses commercial load sensing instrumentation in the form of a load cell or strain gage to measure the load in the cable. This type of instrumentation has been used in many applications in similar environments. It will need to be adapted to the design configuration and environment of the control rod drive mechanism for NGNP and therefore validation of operation is warranted as part of the integrated CRDM test.

References:
1) Engineering judgment of subject matter experts and experience with similar systems

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Conduct tests for the prototype CRDM to confirm the performance, reliability, and durability of the force sensor.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.3.1.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Vessel System

Description:

The Vessel System consists of the following pressure vessels:
- The Reactor Pressure Vessel (RPV)
- 2 Cross Vessels (CV) which connect the RPV to the Steam Generator Vessel (SGV)
- 2 Steam Generator Vessels (SGV)

This study assumes the entire vessel system is fabricated from the AREVA preferred material, Alloy SA508/533. This assumption is subject to confirmation during NGNP design. The vessel system provides the pressure boundary for the primary system coolant. Under normal operating conditions, the internal pressure of the primary coolant is 6.0 MPa and the non-insulated portions of the vessel system will be in contact with the cold leg coolant, which will be at 325℃. The primary interfaces of the vessel syste m are with the vessel internal components (which include the reactor core and the primary hot duct), the Vessel System supports, the Reactor Cavity Cooling System (via conductive and radiative heat transfer), and ancillary equipment (e.g., CRDM's).

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.T001	**Parent:** 1.1.5	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The Vessel System material is assumed to be Alloy SA508/533 steel for a core outlet temperature of 750℃ and a core inlet temperature of 325℃. The previous NGNP design had a higher outle t temperature of 900℃ and preferred the use of mod 9Cr1Mo steel for which much of the development work has been completed under the Raphael program in Europe. The roadmap for the development of ASME Code rules for HTGRs indicates that currently available technology and materials data exist today to develop ASME Code rules for the NGNP as currently envisioned. Short term code development is needed in some areas.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None (other than those identified at the subcomponent level)	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name:	H. L. Massie	**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:**	AREVA	

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: RPV Upper Closure Head

Description:

The RPV Upper Closure Head is the removable top of the RPV which is connected to the RPV Main Vessel via a flanged connection. The Upper Closure Head incorporates the required penetrations and interfaces for the Control Rods and Reserve Shutdown System. During normal operation, the internal surface of the RPV Upper Closure Head will operate at less than 325℃ and an internal pressure of 6.0 MPa. The primary purpose of the Upper Closure head is to form part of the primary coolant pressure boundary and provide large access to the reactor core, if necessary. The Upper Closure Head primary interfaces are the flange to the main RPV and the CRDM interfaces through which the control rods enter the Reactor Vessel and refueling operations are conducted. Removal of the Upper Closure Head is not expected to be necessary during the life of the NGNP. Therefore, it may be seal welded to the main vessel or the flange may be eliminated altogether but these are design decisions to be made as the NGNP design progresses.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.1.T001 | **Parent:** 1.1.5.1 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The preferred material for the RPV Upper Closure Head is Alloy SA508/533 based on a core outlet temperature of 750C and a core inlet temperature of 325C. The previous high temperature design with a core outlet temperature of 900C preferred the use of mod 9Cr1Mo steel.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Collect material test data	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: RPV Main Vessel

Description:

The Reactor Pressure Vessel (RPV) houses the reactor vessel internals and the reactor core. It is a large vessel which must be shipped to site in parts and site welded together. The vessel will operate at approximately 325°C unless a vessel cooling system is implemented. However, it is preferred to avoid using a vessel cooling system to reduce plant complexity and cost.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.2.T001 | **Parent:** 1.1.5.2 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The primary technology development issue with the Reactor Vessel Main Vessel is the use of the Alloy SA508/533 steel for a core outlet temperature of 750C and a core inlet temperature of 325C. The previous high temperature design with an outlet temperature of 900C preferred the use of mod 9Cr1Mo steel. The use of on-site welding should be evaluated for inaccessible sites.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Collect material test data from the European Program. Evaluate on-site welding. Verify that that high temperature reactor code case was. completed for transient conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Sealing Device

Description:

The RPV sealing device is comprised of a metallic tube that rests in a groove in the flange between the RPV Upper Closure Head and the RPV Main Vessel. The function of the device (which is a metallic o-ring), is to seal the primary coolant in the RPV.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.3.T001	**Parent:** 1.1.5.3	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

This technology is mature due to extensive use for other similar applications, including all light water reactors. It is rated as a TRL 7 for the 750°C reactor outlet NGNP with a conventional steam cycle because our current plan is to use a seal weld.

It was rated as a TRL 5 for the indirect steam cycle NGNP because we did not consider using a seal weld.

References:

1) AREVA 12-9076324-001, NGNP RPV and IHX Pressure Vessel Alternatives, April 2008

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name: H. L. Massie	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: RPV Fasteners

Description:

The reactor pressure vessel (RPV) Fasteners are the bolts, washers, and nuts used to secure the Reactor Vessel Upper Closure Head to the Reactor Vessel Main Vessel.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.4.T001 | **Parent:** 1.1.5.4 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

These fasteners will be installed on a flange that is on the outside of the pressure vessel and some distance from the main vessel or upper closure head. Therefore, the temperature requirements for these fasteners are well within the state of the art.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: CV Main Vessel

Description:

The Cross Vessel (CV) Main Vessel connects the RPV to the Steam Generators. It conducts cold leg He at 325C from the Steam Generators to the RPV. Coaxial with and internal to the CV is the primary hot duct. Although the hot duct contains hot leg He at 750C it is insulated to reduce regenerative heat losses to the cold leg He. Its main function is to provide a primary coolant pressure boundary. It interfaces with the primary hot duct, the RPV, and the Steam Generators. The preferred material for the CV is SA508/533. In the previous high temperature design, which has an outlet temperature of 900C, the preferred CV material was mod 9Cr1Mo steel.

Area: ☑ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 1.1.5.7.T001 | **Parent:** 1.1.5.7 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

The preferred material for the CV is Alloy SA508/533 for a core outlet temperature of 750C. The previous high temperature design preferred the use of mod 9Cr1Mo steel.

The anticipated temperatures are within the current range of experience using LWR steels. It may be necessary to examine potential issues related to operation in dry helium environments.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Collect material test data	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: SG Vessel

Description:
The Steam Generator (SG) Vessel connects the Cross Vessel. It contains the Stem Generator (tubes, tube sheet, header, duct work).

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC:	**Parent:**	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The preferred material for the Steam Generator Vessel is Alloy SA508/533 for a core outlet temperature of 750C. The previous high temperature design preferred the use of mod 9Cr1Mo steel.

The anticipated temperatures are within the current range of experience using LWR steels. It may be necessary to examine potential issues related to operation in dry helium environments.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Collect material test data	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.2.4.1, AREVA 2.2.4.2

SME Name:	R. D. Zimmerman	**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:**	AREVA	

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Helium Circulator

Description:

The reference NGNP design relies on two 4.0 MWe primary He gas circulators. The circulator impeller and diffuser extend into the SG and are supported on a rotor. The motor is submerged in helium, eliminating the need for a shaft seal.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.T001 | **Parent:** 2.1.1 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The reference NGNP design relies on two 4 MWe He gas circulators that operate at <400℃. 4 MWe circula tors are considered within the state of the art based on vendor willingness to accept an order with commercial terms and conditions. Similar gas circulator technology was demonstrated in the AGR reactors [5.25 MWe], AVR [220 KWe], and THTR [2.3 MWe]. The Fort St. Vrain circulator [4.1 MWth] used steam turbines instead of electric motors. The operating temperature and impeller diameter for the indirect steam cycle NGNP configuration was higher (8 MWe and 490°) and required more technolog y development (e.g., materials properties data above 400℃). Although analyses can be used to predict performance, verification of the acoustic and harmonic performance through tests is recommended by vendors. Acoustic treatment, such as lagging, silencers or acoustic enclosures may have to be added or modified based on this testing. Acceptance testing at the vendors is recommended. Integrated testing with the circulator shut off valve (flapper valve) and SG is required for equipment qualification (TRL 8).

References:

1) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*
2) AREVA 12-9075581-00, NGNP Risk Evaluation of Major Components, April 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration,

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Vendor tests - Magnetic bearings/catcher bearings with rotating equipment (impeller/rotor/motor) - Motor and bearings insulation in helium Integrated testing of the circulator assembly in air - Characterize fluid dynamics and acoustic harmonics - Characterize housing noise breakout power levels and frequencies - Test the inverter as part of the power controller for the motor/bearing assembly - Testing of housing penetrations and connectors Acceptance Testing at vendors facility - Integrated tests with shut off valve and SG mock-up	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Housing

Description:
The housing provides the mechanical structure for the other gas circulator components.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.1.T001 | **Parent:** 2.1.1.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	**7**	**8**	**9**

Basis for Rating *(Attach additional sheets as needed.)*

Circulator housing design methods are mature.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
3) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Impeller

Description:

The impeller is a bladed strut or "fan blade" that produces energy in the gas steam by centrifugal force and imparts a velocity to the coolant gas.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.2.T001 | **Parent:** 2.1.1.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

The reference NGNP design relies on two 4 MWe He gas circulators. 4 MW circulators are within the state of the art based on vendor willingness to accept orders with commercial terms and conditions. The circulator vendors perform component qualification tests and acceptance tests of the assembled machine. The impeller will operate at lower temperatures stess levels that were required for the 8 MWe primary He gas circulator envisioned for the indirect cycle NGNP. The operating temperatures will be <400℃, well below the temperature where alloy 718 begins to creep (around 540℃).

References:

1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Electric Motor

Description:
4 MW electrical motor and cooling system

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.3.T001 | **Parent:** 2.1.1.3 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

The electrical conductor sizes, power penetrations, and dynamic design loads from the rotor and bearings have not been finalized. Vendor qualification of the high voltage conductors, insulation and electrical penetrations in helium is required because of the high potential for electrical discharge in helium. The voltages for the 4 MWe circulator are within the state of the art.

References:
1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Vendor qualification of the motor windings, insulation and connectors - Arcing of conductors, connections, insulation and penetrations - Arcing of motor windings Integrated testing of the assembled He circulator (acceptance test with air at vendors) - Confirmation testing of the motor/bearing assembly with rotor - Confirm that motor temperature stays with design limits	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Bearings

Description:

The electromagnetic bearings allow the rotor to rotate within the housing. There are mechanical catcher bearings that support the rotating equipment if the electromechanical bearings fail.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.4.T001 | **Parent:** 2.1.1.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Preliminary design activities indicated that the design of the thrust bearings impacts the rotordynamics and that the bearings required for the 4 MW circulator are at the current state of electromagnetic bearing technology. Mechanical catcher bearings are recommended in case the electromagnetic bearings fail. The design of the bearing electronic controls cannot be finalized until after the rotordynamics is tested. Vendor qualification of the bearing power and instrument conductors and insulation is recommended.

References:

1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Rotor

Description:
The rotor transfers rotational energy from the motor to the impeller

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.5.T001 | **Parent:** 2.1.1.5 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

Mechanical and dynamic design methods for analyzing fan and blower rotors are mature and proprietary methods have been verified by testing. The rotor shaft design has to consider the inertial effects and stiffness of the bearings and impeller and provide margin when the design speed exceeds the critical speed (natural frequency of the rotor). The final design requires integration of the rotor, bearing, and motor designs. Demonstration testing of the rotor, motor and bearing system is recommended to verify the design.

References:
1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Air tests of the rotor/impeller in air at 0.2 to 0.4 scale Manufacturer to provide NGNP with a rotor dynamics feasibility study.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	
☐ Area	☐ System	☐ Subsystem/Structure	☐ Component	☑ Technology	

Title: Inverter

Description:

The inverter supplies power to the motor and controls the motor speed

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.6.T001 **Parent:** 2.1.1.6 **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Commercial inverters are available that can operate at frequencies of around 120Hz and 4 MWe. Specialized inverter design involves "detailed" input from motor and power transformer supplier. The circulator vendor will have to integrate the motor, inverter, and elecromechanical bearing design activities to verify the final system design. Testing of the inverter with the motor/rotor/bearings is required to verify the design.

References:
1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name:	R. D. Zimmerman	**Tech. Case File:**	(enter case file #)
Date: 03/26/09		**Originator:**	AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Diffuser

Description:

The diffuser assembly works aerodynamically with the impeller to convert shaft power into circulator power, which is proportional to the volumetric flow rate and the system pressure drop. The impeller is matched aerodynamically to a radial diffuser, radial to axial bend and a short annular diffusers. At this stage it is envisioned that the impeller configuration will be similar to the MHTGR conceptual design, where the gas circulator housing was vertically mounted on the top of the SG vessel with a machined flange that is bolted to a barrier plate and the annular diffuser assembly. The inlet section of the impeller diffuser assembly engages the circulator inlet pipe.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.1.7.T001 | **Parent:** 2.1.1.7 | **WBS:** #N/A #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Interaction between the wakes from the passing impeller generates discrete tones and harmonics at frequencies defined by the geometry of the impeller and diffuser and the impellers rotational speed. Diffuser dimensions are estimated by scaling dimensions from previous designs. Although analysis can be used to optimize the diffuser design, experience has shown that testing of the design is prudent.

References:
1) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
3) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, May 2008
4) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Circulator Shutoff Valve

Description:

Each gas circulator is equipped with a self-actuating shutoff valve set at the impeller inlet. This valve closes in the event of a malfunction or failure of the circulator or during a maintenance operation of the HTS or PCS system. The primary gas circulator shutoff valve minimizes reverse flow from the reactor and core by-pass from the shutdown cooling system or the other primary cooling loop. The valve must open without choking the circulator when it is turned on. The valve is currently envisioned as a butterfly type valve, which is opened by aerodynamic flow of gas over the eccentric disk (also referred to as a "butterfly" or "flapper") which rotates on a stem. The structural design details depend on the performance requirements (pressure, seal leak tightness). An actuator may be attached to the valve stem if the valve is used as part of the automated control system.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.2.T001 | **Parent:** 2.1.2 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The basic flap/counterweight type valve approach is technically feasible and has been used in previous multi-loop HTS, such as the FSV [4.1 MWth] and THTR [2.3 MWe], but the NGNP circulator shutoff valve has not been designed or demonstrated. Industry practice is that the circulator vendor supply both the circulator and the circulator shutoff valve because the shutoff valve and housing affects the aerodynamic performance and efficiency of the circulator. The bearings in this type of valve can become stiff after long exposure to high temperatures. AREVA plans on an ISI program to ensure that the torque required to open the valve is less than torque created by the aerodynamic forces on the flapper. Mechanical valve actuation is not desirable because of the added complexity and additional RAMI concerns.

References:
1) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*
2) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, April 2008
3) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
4) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Test valve operation in air at standard temperature and pressure: - test ability to open/close valve - test pressure drop across valve - demonstrate repeated operation without failure Test valve Integrated with the gas circulator in air: - test for stalling of circulator - test for flow obstruction	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Valve Mechanism

Description:

Each circulator includes a self-actuating shutoff valve set at the circulator impeller inlet. This valve has to operate automatically when the circulator shuts off and on. It is envisioned as a "butterfly" type valve, which will open by aerodynamic torque when the circulator starts pulling air through the valve. A counterweight mounted on the valve stem pulls the valve closed when the circulator stops pulling air through the inlet. The butterfly valve has a disk that rotates on the valve stem that minimizes reverse flow through the circulator from the higher pressure in the reactor inlet plenum. The valve does not have to be leak tight.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.2.1.T001 | **Parent:** 2.1.2.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The shape of the valve flapper effects the aerodynamic torque that opens the valve, the pressure drop over the valve, and disturbs the aerodynamics of flow to the circulator and effects both circulator efficiency and its stall speed. The valve is not required to be leak tight. Consequently the tolerance between the valve and valve seat can be set large enough to ensure reliable activation of the valve.

References:
1) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*
2) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, April 2008
3) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
4) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

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Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance testing at manufacturer's location Integrated testing with the gas circulator	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Housing

Description:

The housing maintains alignment between the valve mechanism and valve seat. The shut off valve is envisioned as a butterfly type valve, which has a butterfly disk (the valve mechanism), valve seat, the bearings and packing, and connects to the circulator and hot duct piping. The housing directs flow of gas over the eccentric disk that is the valve mechanism and into the circulator inlet. The valve disk turns on a valve stem, opening due to aerodynamic force and closing due to gravitational forces on a counterweight mounted on the valve stem. The valve disk impacts the HTS pressure drop and circulator efficiency. The housing interfaces with the valve seat, which is under compression when it is mounted in the valve seat, thus making a seal around the periphery of the butterfly disk and both upper and lower points where the valve steam passes through the seat.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.2.2.T001 | **Parent:** 2.1.2.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	**5**	**6**	**7**

Basis for Rating *(Attach additional sheets as needed.)*

The valve flapper and housing is expected to affect the aerodynamic performance and efficiency of the circulator.

References:
1) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*
2) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, April 2008
3) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
4) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance testing at manufacturer's location Integrated testing with the gas circulator	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Valve Seat

Description:

Each circulator shutoff valve has a valve seat which forms a seal with the valve mechanism when the valve is in the closed position. The valve closes in the event of a malfunction or failure of the circulator or when it is turned off during a HTS or PCS maintenance operation. The circulator shutoff valve minimizes reverse flow from the reactor gas plenum from the shutdown cooling system or the other primary cooling loop. The shutoff valve is envisioned as a butterfly type valve, which has a resilient seat which is under compression when it is mounted in the valve body, making a seal around the periphery of the disk and both upper and lower points where the stem passes through the seat.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.2.3.T001 | **Parent:** 2.1.2.3 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The alignment of the valve flapper and seat with minimal torque is critical to achieving a good seal. Full scale testing is required to demonstrate the design, fabrication and assembly methods are adequate. The valve seat is not required to be leak tight.

References:
1) AREVA 38-9097838-000, VHTR ANTARES Main Primary Circulator, Original issued November 2006 (AREVA proprietary)*
2) AREVA 12-9075581-000, NGNP Risk Evaluation of Major Components, April 2008
3) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
4) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance testing at manufacturer's location Integrated testing with the gas circulator	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.1.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Hot Duct

Description:

Hot ducts are used to transport the helium coolant between the reactor and the steam generators. The hot duct near the reactor outlet is considered bounding to all other hot duct sections in the reactor system. The hot duct is located internal and coaxial to the cross vessel between the reactor pressure vessel and the steam generators. The hot duct is a multi-layered insulated assembly that allows for the separation of hot and cold primary coolant within a single vessel. Hot helium coolant (750 ℃) from t he core travels internal to the hot duct while cold helium coolant (325 ℃) returns to the c ore in the annulus between the outside of the hot duct and the inside of the cross vessel.

Note: Both a ceramic composite and metallic liner are under consideration.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.T001 | **Parent:** 2.1.4 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Bench Scale Testing	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale
TRL	**4**	**5**	**6**

Basis for Rating *(Attach additional sheets as needed.)*

The Primary Hot Duct design will be based upon the design of the hot duct tested at the KVK test facility in Germany during the 1980s. However, careful evaluation of the design and materials will be required for long-term reliable performance at normal operating temperatures in the range of 850℃ (based on 750℃ outlet temperatu re plus hot streaks). The design will also have to consider off-normal conditions, and in particular temperatures on the order of 1000℃ duri ng the initial stage of conduction cooldown accidents. If these high temperatures exceed the allowable temperature for a metallic liner, a design based on use of a composite (C-C) liner will be chosen.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Component manufacturing development - qualify assembly of hot duct Analytical performance assessment - assess thermal-hydraulic performance - assess thermo-mechanical performance	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.6.1, AREVA 3.1.5.0, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Liner - Composite

Description:

The Hot Duct Liner is in direct contact with the hot helium coolant (750 ℃) and provides support for the insulation on the hot side of the assembly. Normal operating temperatures may be on the order of 900℃ when hot streaks are considered. Temperatures may exceed 1000℃ during off-normal conditions, such as conduction cooldown events. Composites will be selected if detailed design analyses determine that the stresses and temperatures exceed the ASME Section 8 design limits for 800H. The hot duct liner is subjected to a pressure loading equal to the core pressure drop (approximately 66kPa).

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.1.T001 | **Parent:** 2.1.4.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Bench Scale Testing	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale
TRL	4	5	6

Basis for Rating *(Attach additional sheets as needed.)*

A composite (C-C) hot duct liner was demonstrated for over 5000 hours at temperatures up to 950 ℃ at the KVK test loop in Germany during the 1980s. The hot duct tested was smaller than that intended for the NGNP so some development is needed, but the technology is considered relatively mature. The ANTERES design used Alloy 800H for the liner at 850℃. Detailed th ermal-hydraulic and structural analyses have not been performed for the NGNP conventional steam cycle to confirm whether Alloy 800H meets the design requirements. A composite material will be used if Alloy 800H cannot be used.

References:

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) Specialists' meeting on heat exchanging components of gas-cooled reactors Duesseldorf (Germany) 16-19 Apr 1984; International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, Vienna (Austria) IWGGCR--9
5) AREVA 38-9097833-000, Original issued September 2006 (AREVA proprietary)*
6) Subject Matter Expert opinion
* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Qualify manufacturing processes for the composite (C-C) liner and the assembly of the hot duct	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Liner - Metallic

Description:

The Hot Duct Liner is in direct contact with the hot helium coolant (750 ℃) and provides support for the insulation on the hot side of the assembly. Normal operating temperatures may be on the order of 900℃ when hot streaks are considered. Temperatures may exceed 1000℃ during off-normal conditions, such as conduction cooldown events. The hot duct liner is subjected to a pressure loading equal to the core pressure drop (approximately 55kPa).

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.2.T001 | **Parent:** 2.1.4.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The Hot Duct Liner is in direct contact with the hot helium coolant (750 ℃) and provides adequate mar gin for using 800H under ASME B&PV Code Section VIII design codes. The wall temperatures may be on the order of 900℃ when hot streaks a re considered. Alloy 800H was used in the ANTERES design (850℃).

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Complete detailed steady state and transient temperature analysis	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 2.3.6.1, AREVA 3.1.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** (enter the name of the vendor or subcontractor)

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Support Tube

Description:

The hot duct internals are housed in a gas tight Support Tube, which would be a closed metal cylinder. This cylinder could be a forging or made from a rolled plate. It would be made from a high temperature material, such as Alloy 800H, that can withstand a nominal design temperature of 325℃.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.3.T001 | **Parent:** 2.1.4.3 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

The hot duct Support Tube is based upon the design of the hot duct tested at the KVK test facility in Germany during the 1980s.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) Specialists' meeting on heat exchanging components of gas-cooled reactors Duesseldorf (Germany) 16-19 Apr 1984; International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, Vienna (Austria) IWGGCR--9
5) AREVA 38-9097833-000, High Temperature Helium Test Facility KVK, Original issued September 2006 (AREVA proprietary)*

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Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.2.3.1, AREVA 3.1.5.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Insulation

Description:
Ceramic wrapped mat is used to provide the insulation capabilities of the hot duct and limit the temperature experienced by the support tube.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.4.T001 | **Parent:** 2.1.4.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

The ceramic wrapped mat insulation is considered a fairly mature technology and has been demonstrated in the hot duct demonstration at the KVK test facility in Germany during the 1980s. Ceramic fiber insulation was used successfully at FSV and other HTR applications.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) Specialists' meeting on heat exchanging components of gas-cooled reactors Duesseldorf (Germany) 16-19 Apr 1984; International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, Vienna (Austria) IWGGCR--9
5) AREVA 38-9097833-000, Original issued September 2006 (AREVA proprietary)*

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Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Obtain vendor thermo-mechanical data	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.3.6.1, AREVA 3.1.5.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Intermediate Foil

Description:

Intermediate Foil is a non-porous thin foil located between layers of ceramic wrapped mat insulation. It provides a high flow resistance to the circulation of helium, reducing free helium convection. It is not clear if this is required for the 750℃ design.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.5.T001 | **Parent:** 2.1.4.5 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

The intermediate foil material needs to be identified but is not considered to require development.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) Specialists' meeting on heat exchanging components of gas-cooled reactors Duesseldorf (Germany) 16-19 Apr 1984; International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, Vienna (Austria) IWGGCR--9
5) AREVA 38-9097833-000, High Temperature Helium Test Facility KVK, Original issued September 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 3.1.5.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Ceramic Spacer

Description:

The Ceramic Spacers serve two functions. The first is to position the liner relative to the metal support pipe. The second is to retain the proper location of the fibrous ceramic insulation along the axial dimension of the hot duct segment. The spacers will be fabricated using a relatively low-density ceramic fiber insulation material that is formed into about 1.5 meter diameter rings.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.6.T001 | **Parent:** 2.1.4.6 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The material to be used for the ceramic spacers will be a commercially available product. A relatively low-density fiber insulation material will be selected to have the proper combination of low thermal conductivity and moderate strength. The strength requirement will driven by the need to maintain the position of the ceramic liner. The spacers will be formed by casting the insulation materials into large diameter rings, followed by machining. The primary candidate materials are based on high-purity alumina, zirconia and alumina-silica mixtures.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) Specialists' meeting on heat exchanging components of gas-cooled reactors Duesseldorf (Germany) 16-19 Apr 1984; International Atomic Energy Agency, International Working Group on Gas-Cooled Reactors, Vienna (Austria) IWGGCR--9
5) AREVA 38-9097833-000, Original issued September 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Evaluate commercially available ceramic fiber insulation materials and select primary candidate Engineering scale demonstration - confirm thermo-mechanical behavior - confirm design adequacy of attachment method (between support pipe and liner) - confirm long-term stability in He environment	See Test Plan	See Test Plan	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 2.1.1.0, AREVA 2.3.6.1, AREVA 3.1.5.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Metallic Spacer

Description:

Metallic Spacers are an option that would be selected if the hot duct liner operating condition is below the Section 8 design limits for 800H. The spacers serve two functions. The first is to position the liner relative to the metal support pipe. The second is to retain the proper location of the fibrous ceramic insulation along the axial dimension of the hot duct segment. The spacers will be fabricated into about 1.5 meter diameter rings made of 800H.

Area: ☐ NHSS ☑ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: 2.1.4.7.T001 | **Parent:** 2.1.4.7 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The spaces will be a commercially available material designed to meet appropriate design codes. The Section 8 design limit for 800H is 800℃. The normal operating condition of the hot h elium coolant is 750℃ with local temperatures at t he duct liner as high as 930℃ when hot streaks are considered. The maximum temperature of the spaces has not been determined for the Conventional Steam Cycle.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Complete the detailed steady state and transient temperature analysis of the hot duct flow field, insulation and internal structure.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.5.0, AREVA 4.1.2.1, AREVA 4.1.2.2, AREVA 4.2.2.2

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** (enter the name of the vendor or subcontractor)

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Steam Generator

Description:

Helical tube steam generator with 315MWt capacity operating at T_{in} = 750ºC and T_{out} = 320ºC (helium gas) on the shell side and T_{in} =281 ºC and T_{out} = TBDºC (water/steam) on the tube side of evaporator and super heater, and T_{in} = TBDºC and T_{out} = 566ºC (steam) on the tube side of re-heater. Total heat transfer area is approximately TBD [it was 1025 m² for the steam generator used in the indirect steam cycle configuration]. The Steam Generator System interfaces with the Steam Generator Vessel (SGV), which is part of the Vessel System.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.T001	**Parent:** 4.1.1	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The helical tube steam generator design is based on the design technology of MHI experience in HTGR heat exchanger and FBR steam generator. The helical tube steam generator with re-heater was operated at THTR-300 in Germany and FSV (FORT ST. VRAIN) in USA. The conventional steam cycle NGNP is designed to operate at 750℃ and produces 566℃ 16.7 MPa steam. The i ndirect steam cycle NGNP was designed to operate ~825℃ and produce 566℃ 17.2 M Pa steam. Materials testing was recommended in the indirect cycle TDRM to: 1) extend the creep fatigue data for Alloy 800H above 700℃ to support codification of 60 year design lif e, 2) bi-metallic welds of Alloy 800H and 2.25Cr-1Mo. Alloy 800H is already approved for use up to 760℃ under ASME III-NH and efforts are under way to extend its use to higher temperatures. The SG Vessel is SA508 and is part of the Vessel System. The SG design will be 50% larger than previous designs which were developed by others. Engineering scale testing of the heat transfer tube bundles would be beneficial to reduce performance uncertainties.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
3) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Vendor qualification of tube welds and header forging Assess performance risk (risk of low SG performance to NGNP success demonstrating reactor concept) If high risk, recommend engineering scale demonstration (>1/10 scale with >3 helical tube layers at the NGNP tube size and pitch) - Confirm thermal hydraulic performance - Estimate flow induced vibration - Confirm flow stability and controllability of water and steam system - Validate ISI equipment of tubes (If ISI of tubes required)	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.6.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)

Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Steam Generator Hot Header

Description:

The ring-shaped SG hot header resides at the hot end of the SG and provides a mounting point for the tubes.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.1.T001 | **Parent:** 4.1.1.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

Hot header of SG has been operated in the conventional thermal power plant.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Verify manufacturing techniques for Alloy 800H	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.6.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Evaporator and Super Heater Tube Bundle

Description:

The evaporator and super heater tube bundle is a complex set of approximately 200 helical tubes that carry the secondary fluid (water/steam) through the primary helium. The secondary fluid is evaporated and super heated in the tube bundle. The evaporator tubes are 2.25Cr-1Mo. The super heater tubes are 800H.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.2.T001	**Parent:** 4.1.1.2	**WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*

Helical tube bundle was used and operated at THTR-300 and FSV. Further experience is available in other commercial environments.

Materials testing was recommended in the indirect cycle TDRM to: 1) extend the creep fatigue data for Alloy 800H at bounding temperatures and extension of allowables to cover a 60 year design life, and 2) qualification of bi-metallic welds of Alloy 800H and 2.25Cr-1Mo for the NGNP. Efforts are already underway to extend ASME III-NH codification of Alloy 800H. The current code case has a 760℃ design limit, which is adequate for the conventional steam cycle NGNP. Extensive experience exists with bi-metallic weld joints between Alloy 800H and 2.25Cr-1Mo but vendor qualification is required for fabricating the NGNP SG.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Vendor qualification of dissimilar material welding joint - Measure flow induced vibration (Reg Guide 1.20) - Validate ISI equipment of tubes	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.6.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA		**Document Number:** TDR-3001463		**Revision:** 000	
☐ Area	☐ System	☐ Subsystem/Structure	☐ Component	☑ Technology	

Title: Re-Heater Tube Bundle

Description:

The re-heater tube bundle is a complex set of approximately 360 helical tubes that carry the secondary fluid (steam) through the primary helium. The secondary fluid is re-heated in the tube bundle. The reheater tubes and vessel are made of 800H.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.3.T001 **Parent:** 4.1.1.3 **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

Helical tube bundle was used and operated at THTR-300 and FSV. Further experience is available in other commercial environments.

The conventional steam cycle NGNP is designed to operate at 750℃ and produces 566℃ 16.7 MPa steam. The indirect steam cycle NGNP was designed to operate ~825℃ and produces 566℃ 1 7.2 MPa steam. Materials testing was recommended in the indirect cycle TDRM to extend the creep fatigue data for Alloy 800H at bounding temperatures and extension of allowables to cover a 60 year design life. Alloy 800H has ASME III-NH codification to 760℃ and efforts a re underway to extend the limit to higher temperatures. Consequently, there are no technology development issues for the conventional steam cycle.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
3) AREVA 51-9103803-001, NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
- Measure flow induced vibration (Reg Guide 1.20) - Validate ISI equipment of tubes	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.1.6.0

SME Name:	R. D. Zimmerman	**Tech. Case File:**	(enter case file #)
Date: 03/26/09	**Originator:**	AREVA	

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Steam Generator Hot Duct

Description:
The SG hot duct carries the secondary helium from the helium inlet to the hot header of the re-heater.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.4.T001 | **Parent:** 4.1.1.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	6	7	8

Basis for Rating *(Attach additional sheets as needed.)*
The hot duct has been operated in heat exchanger of FSV, HTTR, HENDEL and others. No technology development issues or design data needs have been identified for the SG hot duct.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
N/A	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: N/A

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☑ Technology

Title: Steam Generator Support Plate

Description:

The SG support plate is used to mount the evaporator, super heater and re-heater within the vessel system.

Area: ☐ NHSS ☐ HTS ☐ HPS ☑ PCS ☐ BOP

PASSC: 4.1.1.5.T001 | **Parent:** 4.1.1.5 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration	System Tested and Qualified
TRL	**6**	**7**	**8**

Basis for Rating *(Attach additional sheets as needed.)*

Support plate has been operated in heat exchanger of FSV, HTTR, HENDEL and others. No technology development needs or design data needs have been identified for the SG support plate.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
None	N/A	N/A	(enter the estimated cost of the actions)

DDN(s) Supported: None

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Steam Reboiler System

Description:

The reboiler transfers heat from the steam leaving the turbine to the process heat loop, heating the water in the process heat transfer loop to boiling (saturated steam) and possibly super-heating the steam, depending on the process heat steam pressure and the temperature of the steam leaving the gas turbines.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: | **Parent:** | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Reboilers are a well established technology. The engineering principles are well understood and demonstrated. Current technology development needs are driven by the need for very high efficiency equipment and operation in highly corrosive environments (geothermal, carbon sequestration, and waste heat recovery). There are numerous vendors who design and install catalogue reboilers and custom cogeneration systems, including Alstom, Babcock Power, MHI, and Siemens.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance and qualification testing.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.2.4.1

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: HP Reboiler

Description:

The reboiler transfers heat from the steam leaving the turbine to the process heat loop, heating the water in the process heat transfer loop to boiling (saturated steam) and possibly super-heating the steam, depending on the process heat steam pressure and the temperature of the steam leaving the gas turbines.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC:	**Parent:**	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Reboilers are a well established technology. The engineering principles are well understood and demonstrated. Current technology development needs are driven by the need for very high efficiency equipment and operation in highly corrosive environments (geothermal, carbon sequestration, and waste heat recovery). There are numerous vendors who design and install catalogue reboilers and custom cogeneration systems, including Alstom, Babcock Power, MHI, and Siemens.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance and qualification testing.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.2.4.1

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: LP Reboiler

Description:

The reboiler transfers heat from the steam leaving the turbine to the process heat loop, heating the water in the process heat transfer loop to boiling (saturated steam) and possibly super-heating the steam, depending on the process heat steam pressure and the temperature of the steam leaving the gas turbines.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: | **Parent:** | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	System Engineering Scale Demonstration	System Tested and Qualified	Plant Operational
TRL	7	8	9

Basis for Rating *(Attach additional sheets as needed.)*

Reboilers are a well established technology. The engineering principles are well understood and demonstrated. Current technology development needs are driven by the need for very high efficiency equipment and operation in highly corrosive environments (geothermal, carbon sequestration, and waste heat recovery). There are numerous vendors who design and install catalogue reboilers and custom cogeneration systems, including Alstom, Babcock Power, MHI, and Siemens.

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Acceptance and qualification testing.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.2.4.1

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Primary Loop Instrumentation

Description:

The Primary Loop Instrumentation provides inputs to the NGNP Plant Protection System, which includes safety (reactor trip) and non-safety (normal operations) function.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC:	**Parent:**	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

A limited amount of design work has been devoted to the Primary Loop Instrumentation systems and no feasibility issues have been identified for these systems (temperature, pressure, flow, and moisture). The thermocouples used today in Nuclear Plants are capable of operating up to 1200°C. This does not preclude the identification of new sensor research and development needs to meet NGNP safety and reliability goals. Demonstration and qualification testing of commercially available sensors is required in He at expected normal and off-normal pressures and temperatures.

Reference:
1) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconcilliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Demonstration tests in He at normal and off-normal operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Flow Rate Sensor

Description:

The flow rate through the reactor is monitored during normal operations and is used to initiate a reactor trip. There are two sensor types. An inline ultrasonic flow sensor and a magnetic pickup on the circulator rotor shaft. The circulator flow rate is calculated using the circulator performance curve.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: | **Parent:** | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

A limited amount of design work has been devoted to the Primary Loop Instrumentation systems and no feasibility issues have been identified for these systems. The flow rate through the reactor can be calculated using the circulator motor speed and the circulator performance curve. Direct flow measurements are not required, although direct measurements could be made using a venturi meter or possibly the reactor core pressure drop. The NGNP Conceptual Design will identify safety and instrument performance requirements. Demonstration and qualification testing of commercially available sensors is required in He at expected normal and off-normal pressures and temperatures.

References:

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Demonstration tests in He at normal and off-normal operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Reactor Cold Leg Temperature Sensor

Description:

The cold leg temperatures are important core performance parameters are used with the Nuclear Instrumentation (neutron flux) to monitor core power and adjust the position of the control rods. The reactor inlet (cold leg) temperature and control rod position have the biggest effect on core reactivity.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: | **Parent:** | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

A limited amount of design work has been devoted to the Primary Loop Instrumentation systems and no feasibility issues have been identified for these systems. Pt-Rh thermocouples can operate at temperatures up to 1300 ℃. The details of the p enetrations and mechanical assemble has not been designed. Demonstration and qualification testing of commercially available sensors is required in He at expected normal and off-normal pressures and temperatures.

References:
1) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconcilliation, March 2009
2) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Demonstration tests in He at normal and off-normal operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA	**Document Number:** TDR-3001463	**Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Pressure Sensor

Description:

The pressure is used to monitor performance and is an input to the He purification and supply system, which supplies purified He at pressure to the Primary Loop. There is no need to measure in two locations, although one could. Pressure transducers meet this function.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC:	**Parent:**	**WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	**5**	**6**	**7**

Basis for Rating *(Attach additional sheets as needed.)*

A limited amount of design work has been devoted to the Primary Loop Instrumentation systems and no feasibility issues have been identified for these systems. Commercially available pressure transducers have been used successfully in previous He cooled reactors. The details of the penetration assembly has not been designed. Demonstration and qualification testing of commercially available sensors is required in He at expected normal and off-normal pressures and temperatures.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Demonstration tests in He at normal and off-normal operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman	**Tech. Case File:** (enter case file #)
Date: 03/26/09	**Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☐ Component ☐ Technology

Title: Moisture Sensor

Description:

There are two moisture sensors under consideration. One approach uses an electrical capacitance sensor located in a measuring chamber. A gas sample is extracted from the Primary Loop from a sampling line that runs between the gas circulator outlet back to the IHX. A moisture sensor is also included in He purification and supply system. That system uses a hygrometer.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☐ BOP

PASSC: | **Parent:** | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

A limited amount of design work has been devoted to the Primary Loop Instrumentation systems and no feasibility issues have been identified for these systems. An optical measurement of dew point is under consideration for the NGNP. AREVA has tested other sensors (e.g., electrical capacitance and hygrometers) but they are not accurate at low enough ppm levels when used at high temperatures. Low moisture measurements are required to control the humidity levels below the level where materials corrosion becomes a concern. The details of the penetration assembly has not been designed. Demonstration and qualification testing of commercially available sensors is required in He at expected normal and off-normal pressures and temperatures.

Reference:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Demonstration tests in He at normal and off-normal operating conditions.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.5.0

SME Name: R. D. Zimmerman | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

NON-PROPRIETARY

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☑ Subsystem/Structure ☐ Component ☐ Technology

Title: Fuel Handling System

Description:

The Fuel Handling System consists of a series of machines and devices that are capable of carrying out the functions of the system. The system is based on the design of Fort St. Vrain and GT-MHR with the exception of the Fuel Storage Server (FSS) instead of Fuel Transfer Casks. The FSS reduces the estimated refueling time.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☑ BOP

PASSC: 5.3.T001 | **Parent:** 5.3 | **WBS:**

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The designs of the Fuel Handling System and its components are based on similar systems that were used in the Ft. St. Vrain reactor and proposed for several GA modular reactor designs. The system should be demonstrated at an engineering scale in a high purity helium environment after the seal and bearing materials and lubricants are selected.

References:

1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Identify materials and lubricants for required seals and bearings. Perform functional testing on completed sub-components.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.3.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Fueling Adaptor

Description:

The Fueling Adaptor (FA) is a mechanical device that extends the CRDM nozzles. The FA is a welded steel structure that fits over the CRDM nozzles and creates a soft seal around each nozzle, to permit the removal of CRDMs and insertion of the FE and FHM without opening the reactor coolant boundary to the RAB maintenance hall. The weight of the FA is carried on the FHS support skirt, which is in turn supported by the reactor vessel. The FA is designed with soft or inflatable seals which operate on the outside surface of the CRDM nozzle. On the inner CRDM nozzles and the central column nozzle, the FA will also have horizontal valves. Conceptual valves have been located at three separate levels, so the gate enclosures and operators do not interfere with each other.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☑ BOP

PASSC: 5.3.1.T001 | **Parent:** 5.3.1 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The designs of the Fuel Handling System and its components are based on similar systems that were used in the Ft. St. Vrain reactor and proposed for several GA modular reactor designs. The system requires demonstration at an engineering scale in a high purity helium environment after the seal and bearing materials and lubricants are selected.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) AREVA 12-9029953-001, ANTARES Fuel Charge and Discharge System Description, December 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Identify materials and lubricants for required seals and bearings. Perform functional testing on completed sub-components.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.3.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Fuel Elevator

Description:

The Fuel Elevator (FE) is a machine that can be inserted through the Fueling Adaptor into the reactor vessel. The central penetration on the reactor head, which normally contains in-core instruments, is used for the FE. The FE supports blocks from the bottom, and has a vertical range of motion. It can also rotate, so that the elevator car can face the FHM at any sector, and the car can face the Fuel Server in the raised position. Because fuel in the fuel elevator is always inside the reactor vessel or the Fuel Storage Server, the FE does not need to provide any shielding or specific ventilation capability. A soft seal between the fuel elevator and the Reactor Vessel is sufficient to maintain the reactor coolant boundary during refueling.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☑ BOP

PASSC: 5.3.2.T001 | **Parent:** 5.3.2 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The designs of the Fuel Handling System and its components are based on similar systems that were used in the Ft. St. Vrain reactor and proposed for several GA modular reactor designs. The system needs to be demonstrated at an engineering scale in a high purity helium environment after the seal and bearing materials and lubricants are selected.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) AREVA 12-9029953-001, ANTARES Fuel Charge and Discharge System Design Description, December 2006 (AREVA proprietary)*

* reference to this document does not transfer right of use nor access to the document

Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Identify materials and lubricants for required seals and bearings. Perform functional testing on completed sub-components.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.3.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Fuel Handling Machine

Description:

The Fuel Handling Machine (FHM) is a robotic manipulator that can be inserted into an inner control rod drive penetration. It is equipped with a grapple probe that can be inserted into the handling hole in the top of any hexagonal block. The probe can be expanded to engage the block so the machine can lift it. The FHM is equipped with a pantograph-like mechanism giving it the capability to extend the grapple out to a radius sufficient to reach all the blocks within a sector, including all hexagonal reflector blocks. The FHM can rotate, extend, and raise/lower, so that it can access all the hexagonal blocks in a sector from an inner CRDM nozzle.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☑ BOP

PASSC: 5.3.3.T001 | **Parent:** 5.3.3 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The designs of the Fuel Handling System and its components are based on similar systems that were used in the Ft. St. Vrain reactor and proposed for several GA modular reactor designs. The system requires demonstration at an engineering scale in a high purity environment after the seal and bearing materials and lubricants are selected.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) AREVA 12-9029953-001, ANTARES Fuel Charge and Discharege System Design Description, December 2006 (AREVA proprietary)*

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Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Identify materials and lubricants for required seals and bearings. Perform functional testing on completed sub-components.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.3.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA

TRL Rating Sheet

Vendor: AREVA | **Document Number:** TDR-3001463 | **Revision:** 000

☐ Area ☐ System ☐ Subsystem/Structure ☑ Component ☐ Technology

Title: Fuel Storage Server

Description:

The Fuel Storage Server (FSS) is a proprietary AREVA fuel element handling device designed to replace the cask-based handling systems envisioned for most past prismatic HTR systems. Fuel elements are transferred between the FE and the module Spent Fuel Storage area utilizing the FSS. The FSS was developed to decrease refueling times and to reduce worker exposure during refueling operations.

Area: ☐ NHSS ☐ HTS ☐ HPS ☐ PCS ☑ BOP

PASSC: 5.3.4.T001 | **Parent:** 5.3.4 | **WBS:** #N/A

Technology Readiness Level

	Next Lower Rating Level	Calculated Rating	Next Higher Rating Level
Generic Definitions *(abbreviated)*	Component Verified at Experimental Scale	Subsystem Verified at Pilot Scale	System Engineering Scale Demonstration
TRL	5	6	7

Basis for Rating *(Attach additional sheets as needed.)*

The designs of the Fuel Handling System and its components are based on similar systems that were used in the Ft. St. Vrain reactor and proposed for several GA modular reactor designs. The system should be demonstrated at an engineering scale in a high purity helium environment after the seal and bearing materials and lubricants are selected.

References:
1) AREVA TDR-3001031-001, NGNP Technology Development Road Mapping Report, January 2009
2) AREVA TDR-3000807-001, NGNP Composites R&D Technical Issues Study, October 2008
3) AREVA 12-9102279-001, NGNP Conceptual Design DDN/PIRT Reconciliation, March 2009
4) AREVA 12-9029953-001, ANTARES Fuel Charge and Discharge System Design Description, December 2006 (AREVA proprietary)*

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Outline of plan to get from current level to next level *(Attach additional sheets as needed.)*

Actions *(list all)*	**Actionee**	**Schedule**	**Cost ($K)**
Identify materials and lubricants for required seals and bearings. Perform functional testing on completed sub-components.	TBD	TBD	(enter the estimated cost of the actions)

DDN(s) Supported: AREVA 3.3.3.0

SME Name: H. L. Massie | **Tech. Case File:** (enter case file #)

Date: 03/26/09 | **Originator:** AREVA