AREVA NP Inc.,

an AREVA and Siemens company

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NGNP – DESIGN DATA NEEDS FOR AREVA 750°C PRISMATIC REACTOR CONCEPT

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List of Acronyms

ASME	American Society of Mechanical Engineers
AGR	Advanced Gas Reactor
BEA	Battelle Energy Alliance
B&W	Babcock & Wilcox Company
CEA	Commissariat a L'Energie Atomique
CFD	Computational Fluid Dynamics
CTE	Coefficient of Thermal Expansion
DDN	Design Data Need
DOE	U.S. Department of Energy
EDF	Electricité de France
EVO	Energieversorgung Oberhausen AG
FHS	Fuel Handling System
FIV	Flow-Induced Vibration
FOAK	First-of-a-Kind
FSV	Fort Saint Vrain
FZJ	Forschungszentrum Jülich
HPS	Helium Purification System
HTGR	High Temperature Gas-Cooled Reactor
HTTR	High Temperature Engineering Test Reactor
INL	Idaho National Laboratory
ISFSI	Independent Spent Fuel Storage Installation
ISI	In-Service Inspection
JAEA	Japan Atomic Energy Agency
KTA	Kerntechnischer Ausschuss
LBB	Leak Before Break
MHI	Mitsubishi Heavy Industries
MHTGR	Modular High Temperature Gas-Cooled Reactor
MIR	Matched Index-of-Refraction
NDE	Non-Destructive Examination
NGNP	Next Generation Nuclear Plant
NHS	Nuclear Heat Source
NRC	Nuclear Regulatory Commission

PBMM	Pebble Bed Micro Model
PBMR	Pebble Bed Modular Reactor
PCDSR	Preconceptual Design Studies Report
PDRD	Plant Design Requirements Document
PIRT	Phenomena Identification and Ranking Table
PWHT	Post-Weld Heat Treatment
R&D	Research and Development
RCCS	Reactor Cavity Cooling System
RPV	Reactor Pressure Vessel
SCC	Stress Corrosion Cracking
SCS	Shutdown Cooling System
SG	Steam Generator
SNL	Sandia National Laboratories
SRM	System Requirements Manual
SSC	Systems, Structures and Components
TDRM	Technology Development Road Map
THTR	Thorium High Temperature Reactor
VHTR	Very High Temperature Reactor

1.0 INTRODUCTION

The Next Generation Nuclear Plant (NGNP) project is intended to demonstrate the technical and economic viability of high temperature gas-cooled reactor (HTGR) technology for high-efficiency electricity production and nuclear process heat applications. The Idaho National Laboratory (INL) is facilitating the NGNP project for the U.S. Department of Energy (DOE).

Modern HTGRs use advanced nuclear reactor technology. Significant research and development (R&D) will be necessary to support the design, licensing and deployment of HTGRs. Such R&D needs are identified by reactor designers through design data needs (DDNs). Needs range from development of advanced fuels to testing of SSCs, benchmarking of codes, qualification of materials and more.

1.1 Purpose and Scope

Lists of DDNs were created by AREVA in the previous NGNP phases. They were based on different reference design concepts and usually provided limited details. AREVA Design data needs were previously identified, first, for the AREVA ANTARES design. After that, the NGNP Preconceptual Design Studies Report (PCDSR) [1] included a list of DDNs, which were based on the initial reference design (900°C reactor outlet temperature, intermediate heat exchanger, etc).The most recent DDN identification task performed was a reconciliation effort of the DDNs to the Nuclear Regulatory Commission (NRC) Phenomena Identification and Ranking Table (PIRT) review results [2] . That set of DDNs was based on a design very similar to the current AREVA NGNP reference design. There were, however, slight differences such as core power level, reactor inlet temperature and steam supply temperature.

The purpose of this document is to reassess and provide a uniform format for the DDNs originating from the DDN/PIRT reconciliation report [2]. As part of the current task, the DDNs were reviewed for strict consistency with the current concept. They were also updated based on potentially new requirements, AREVA's current reference NGNP design and recent tasks such as the Technology Development Road Map report [3]. New DDNs were identified, again, based on the current requirements, recent technology development tasks and expert review.

Attention was paid to providing a uniform level of detail so that the current set of DDNs would have consistent content. This was accomplished by creating a standard DDN template to be used for each data need.

The importance of a new and up-to-date DDN list stems from the need to support identification of the most necessary and critical R&D tasks. Such an effort will help refine the R&D program plans and be incorporated in the R&D schedule.

1.2 Organization of Report

The remaining sections of this report are organized in the following manner:

- Section 2.0 of this report describes the methodology used to obtain the current list of DDNs.
- Section 3.0 describes the current AREVA NGNP reference design.
- Section 4.0 provides a detailed description of how the previous DDNs (from the DDN/PIRT reconciliation report [2]) were broken down, updated, and new DDNs developed. The format and contents

of the detailed DDN template are explained. Then, the revised DDNs are highlighted and new DDNs are presented.

- Section 5.0 contains a summary table of the current DDNs with their associated origin.
- Section 6.0 summarizes key conclusions from this report.
- Finally, all of the detailed DDNs can be found in Appendix A and the previous table of DDNs from Reference [2] has been inserted in Appendix B.

2.0 METHODOLOGY TO DEVELOPING THE DDN LIST

In order to develop the new DDN list, discrete steps were taken as illustrated in Figure 2-1. The steps taken are also described below:

- **Establish a Uniform DDN Format:** To ensure all DDNs are consistent in their format and level of detail, a generic DDN template was created and used to populate information concerning each data need.
- **Breakdown, Review and Update Previous DDNs:** Many DDNs from the DDN/PIRT reconciliation report [2] identified large amounts of required information and several needs or tests were lumped together. Therefore, each DDN was analyzed to determine if it could be broken down into separate and unique needs or tests. The DDNs were also reviewed and updated as needed based on the current requirements and design concept, as well as to ensure uniformity of content. A small number of DDNs were removed due to duplication or because they were determined to be part of normal design activities.
- **Identify New DDNs:** Based on the current requirements and recent technical development activities (such as the latest TDRM report [3]), new DDNs were identified.
- **Fill Out Detailed DDNs:** The reviewed/updated DDNs and new DDNs were then each incorporated into a DDN template.
- **Review by Expert Panel:** All detailed DDNs were then submitted to the expert panel for review.
- **Document Results:** Comments received from the expert panel were incorporated and the final list of detailed DDNs was issued as part of this document (Appendix A).

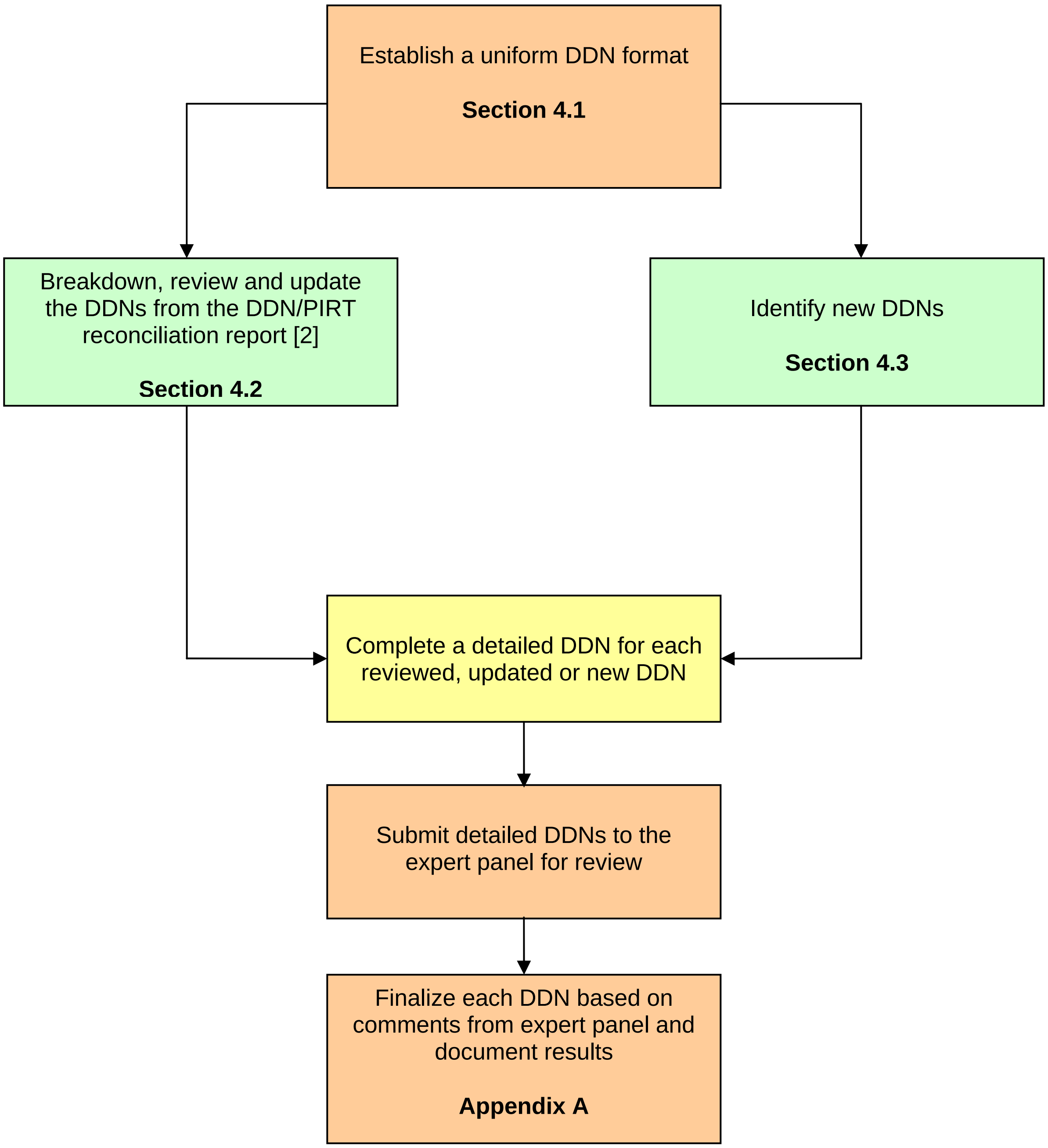

Figure 2-1: DDN Update Process

3.0 SELECTED REFERENCE DESIGN

The DDNs are strongly linked to the NGNP reference design. Other lists of DDNs, based on different reference designs, were generated in the past; however, many of the DDNs were found to be irrelevant due to differences in equipment, operating temperatures and more.

The selected reference design for the AREVA NGNP was discussed at the September 22 and October 28, 2008 Senior Advisory Group meetings and is consistent with the resulting revised NGNP design requirements presented in the updated Next Generation Nuclear Plant System Requirements Manual [4] . It is a 750°C conventional steam cycle commercial First-of-a-Kind (FOAK) concept as described in Reference [5].

Key parameters of the reference design are summarized below in Table 3-1 and a schematic representation is provided in Figure 3-1.

Table 3-1: Parameters for Selected Reference Design

Reactor Core Configuration	Prismatic Annular, 102 columns, 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 (SG) in primary gas loop Steam Turbine uses steam from SG Extraction steam available for process heat applications
Number of Main Loops	2
Number of Side Loops	0
Process Steam Supply	Steam/Steam Reboiler

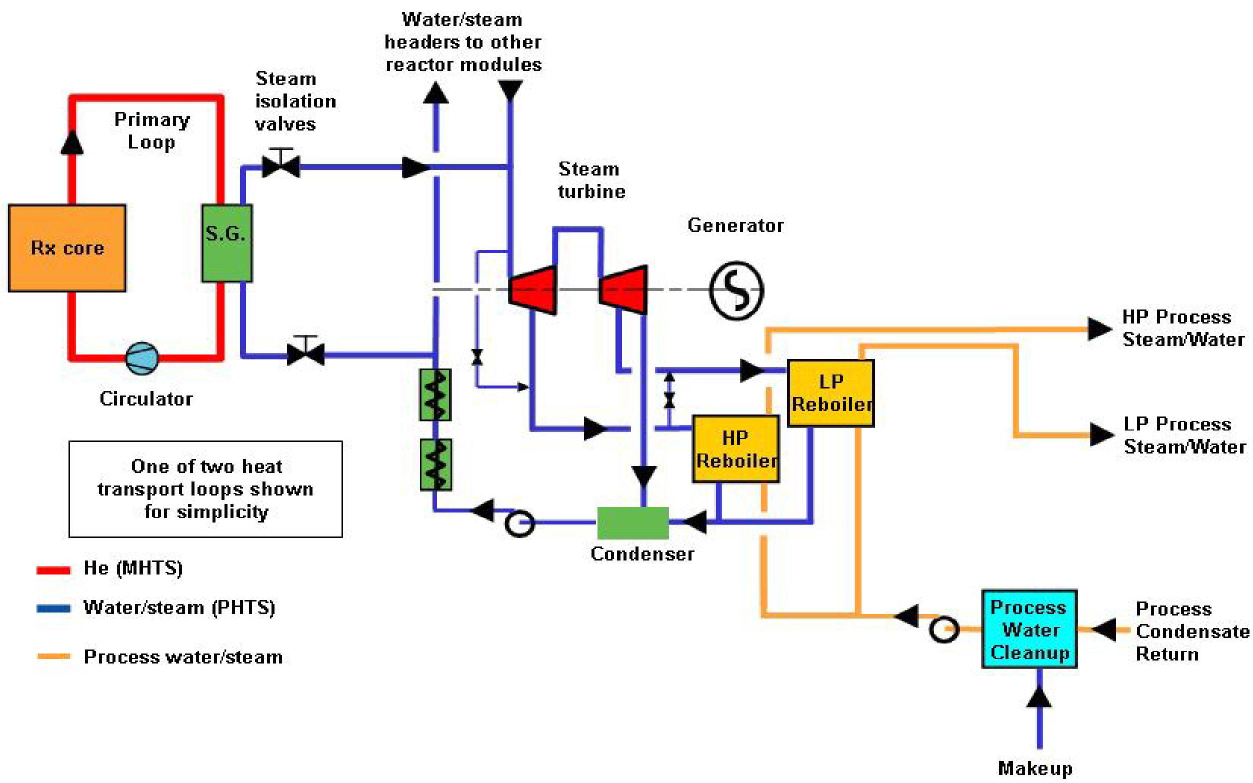

Figure 3-1: Reference NGNP System Configuration

4.0 DDN UPDATE AND DEVELOPMENT

The previous list of DDNs (from the DDN/PIRT reconciliation report [2]) serves as the starting point for this DDN update effort. The update effort was necessary to make all DDNs consistent in their format and contents, and to add new DDNs based on recent tasks (TDRM report) and the current design and requirements.

4.1 Format and Contents of Detailed DDN Template

Each DDN template is broken down into four sections: DDN Summary, DDN Requirement, DDN Importance, and DDN Issue.

The first section, DDN Summary, contains the following information:

- **DDN Number:** Assigned number loosely based on the numbering system from the DDN/PIRT reconciliation report [2].
- **DDN Revision:** Since this is the first version of this DDN list, all the current DDNs are identified as revision 01. As the DDNs get revised, the revision number will be updated.
- **DDN Title:** Concise identification of the DDN topic.
- **DDN Category:** Choose between Fuels, SSCs, Materials, Phenomena or Codes/Methods.
- **DDN Description:** Description of required new data, data confirmation or validation testing necessary to support design. This includes how data relates to or supports design and any relevant background information.
- **Current State of Knowledge:** Summary of existing information including the extent, uncertainty and adequacy of that information.

The second section, DDN Requirement, contains the following information:

- **Data Needed:** Description or list of the specific data necessary to satisfy the DDN.
- **Data Range/Service Conditions:** Range over which data is required or testing is to be performed. This includes (but is not limited to) operating mode, environmental conditions, temperature and pressure.
- **Accuracy Requirements:** Explicit accuracy testing requirements if known in advance. Normally, DDN author will provide latitude for R&D organization.
- **Special Testing Considerations:** Any non-standard or atypical testing constraints, requirements or issues. This is normally N/A.
- **Need Date:** Date when the requested DDN information is needed to support the project schedule. Without formal project schedule, may be a project phase or milestone instead of a specific date.

The third section of the detailed DDN template is DDN Importance. It is made up of the following information:

- **Alternatives to DDN Completion:** Alternate design solutions which would reduce or eliminate the need for the DDN. A simpler alternate test could also be considered if it has a smaller design impact than having no DDN.

- **Selected Design Approach and Fallback:** The selected design approach is the preferred design solution and basis which is usually the current design. Also provided are the consequences and/or fallback position (preferred alternative to DDN completion) in the event that the DDN is not executed or the outcome is not successful.

- **Project Risks:** This includes both the risk to the project of not running the test, and the risk of getting unfavorable data from the test. Both aspects should be evaluated based on consequences, likelihood and timing.

- **Importance of New Data:** Significance or effect of new data on the design. Considerations include (but are not limited to) impact on design, project risk and cost-benefit tradeoff.

- **Schedule Priority:** Schedule priority of DDN execution considering data need date and anticipated duration of DDN preparation and execution. If information is available, rate priority as follow:
    - High (H) = start in the next two years
    - Medium (M) = start in next four years
    - Large (L) = start beyond four years

- **Critical Issues:** Any special concerns or issues highlighted by the DDN author beyond normal definition of the DDN. Normally, this item is left as N/A.

The fourth and last section is DDN Issue. It covers the following:

- **Preparer:** Name of the DDN author (preparer).

- **DDN Issue Date:** Date on which the DDN was issued.

Information not yet available is designated as TBD and information which is not applicable is marked N/A.

Based on the requirements in the scope of work [6] associated with the current DDN update task, only the DDN Number, DDN Revision, DDN Title, DDN Category, DDN Description, Data Needed, Need Date, and Selected Design Approach and Fallback entries were completed for all detailed DDNs. Additional entries were completed in those cases where the information was readily available or deemed necessary to support the required entries.

4.2 Revision of Previous DDNs

Before this document was generated, the most recent DDN effort was undertaken as part of the DDN/PIRT reconciliation task [2]. DDNs were created based on the PCDSR [1], expert evaluation, and reconciliation with the NRC PIRTs.

Because many of the previous DDNs each contained several tests or tasks, they were all analyzed to determine if they could be broken down into individual tasks or tests. This can be observed by comparing Table B-1 (originally Table 4-9 of the reconciliation report [2]) and the final list of DDNs (Table 5-1). Additionally, although based on the then current AREVA NGNP design, a DDN was found to not be applicable based on the TDRM report [3]. A significant amount of effort went into updating the TDRM report which was thoroughly evaluated. Since this effort was accomplished so recently, it provides a sound basis for any changes to DDNs originating from said report.. Other DDNs were updated in order to provide consistent contents for all DDNs or remove duplication between DDNs.

All removed and significantly modified DDNs can be found in Table 4-1. The table includes the section number and title to which each DDN belongs, the AREVA DDN number, the DDN title, the origin of the DDN (including the DDN number based on Table B-1), as well as the reason for modification of the DDN.

Table 4-1: Removed and Significantly Modified DDNs Originating from the Reconciliation Report [2]

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]	Reason for Modification of DDN [1]
1	**Fuel**			
	REMOVED	Compact Manufacture – Irradiation Tests to Demonstrate Performance for Nominal and Off-Nominal Operating Conditions	**Table 4-9 – DDN 1.1.3.1** **Table 4-9 – DDN 1.1.3.2**	**Duplicate of DDN 1.1.3.1b**
	REMOVED	Compact Manufacture – Expansion of B&W Fuel Line	**Table 4-9 – DDN 1.1.3.2**	**Once the compacting process is developed and demonstrated, it is fairly insensitive to the scale of the manufacturing line. Expansion of the line is a purely process engineering activity. Any data needs identified during fabrication line expansion would be covered by DDN 1.1.4.1a.**
	1.2.1.0	Quality Control Methods – Fuel QC Inspection Techniques	**Table 4-9 – DDN 1.2.1.0** **Table 4-9 – DDN 1.2.2.0**	**Two DDNs from Table 4-9 combined into one (duplicate)**
2	**Materials Development and Qualification**			
	REMOVED	Control Rod Sheaths – Codification	**Table 4-9 – DDN 2.3.1.1**	**Codification is an administrative process**
	REMOVED	Solid Control Rods – Thermal-Physical Properties	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1a)**
	REMOVED	Solid Control Rods – Mechanical Properties	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1b)**
	REMOVED	Solid Control Rods – Fracture Properties	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1c)**
	REMOVED	Solid Control Rods – Fatigue Strength	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1d)**
	REMOVED	Solid Control Rods – Oxidation Characteristics and Effects on Material Properties	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1e)**
	REMOVED	Solid Control Rods – Irradiation and Testing of Mock-Ups	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1f)**
	REMOVED	Solid Control Rods – Development of Fabrication and Qualification Methods	**Table 4-9 – DDN 2.3.1.2**	**Duplicate (see 2.3.1.1g)**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]	Reason for Modification of DDN [1]
	REMOVED	Solid Control Rods – Codification	**Table 4-9 – DDN 2.3.1.2**	**Codification is an administrative process**
	REMOVED	Upper Core Restraints – Codification	**Table 4-9 – DDN 2.3.2.1**	**Codification is an administrative process**
	REMOVED	Ceramic Insulation – Effects of Irradiation at High Temperature on Properties of Ceramic Insulation	**Table 4-9 – DDN 2.3.6.1**	**Irradiation impacts are considered under previous ceramic insulation DDNs**
	REMOVED	Graphite – Development of ASME and ASTM Codes and Standards	**Table 4-9 – DDN 2.4.1.0**	**Administrative process based on data obtained in other DDNs**
	REMOVED	Graphite – Tribology	**Table 4-9 – DDN 2.4.1.0**	**Tribology for all core internals materials, including graphite, is covered by DDN 2.1.1.0**
	REMOVED	Graphite – Codification	**Table 4-9 – DDN 2.4.1.0**	**Codification is an administrative process**
3	**Components Testing**			
	REMOVED	Primary Gas Circulator – Tests of Age-Related Impeller Failure Modes	**Table 4-9 – DDN 3.1.1.0**	**At the current operating temperatures, we are below the creep regime.** **Detailed stress, thermal and cycle analysis to assess fatigue, stress, etc of impeller will be performed. Existing data will be reviewed, and if necessary, additional fatigue testing will be preformed.**
	REMOVED	Study of Hot Streaks with V-Shaped Metallic Concept for the Hot Gas Ducts	**Table 4-9 – DDN 3.1.5.0**	**This is a design activity**
	3.1.6.0c	Steam Generator – Engineering-Scale Demonstration	**Table 4-9 – DDN 3.1.6.0** **New (TDRM)**	**Includes thermal-hydraulic performance testing and flow stability/controllability testing**
	REMOVED	Helium Purification System Component Sizing for Desired Flow Rates	**Table 4-9 – DDN 3.3.1.0**	**Sizing components for the desired flow rates is a normal design activity**
	REMOVED	Helium Purification System – Charcoal Selection	**Table 4-9 – DDN 3.3.1.0**	**Selection of charcoal is a normal design activity**
	REMOVED	Fuel Server System Control Software Development	**Table 4-9 – DDN 3.3.3.0**	**Activity determined to be normal design activity or confirmatory testing**
	REMOVED	Mechanical Design of the Fuel Server System Shield Enclosure	**Table 4-9 – DDN 3.3.3.0**	**Activity determined to be normal design activity or confirmatory testing**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]	Reason for Modification of DDN [1]
	REMOVED	Design of the Robotic Fuel Server System Fuel Cart	**Table 4-9 – DDN 3.3.3.0**	**Activity determined to be normal design activity or confirmatory testing**
	3.3.5.0c	Instrumentation – In-Core Neutronics Measurement Sensor R&D for Qualification of CABERNET	**Table 4-9 – DDN 4.2.1.1**	**The code qualification section was not the right place for this DDN. So it was moved to this spot.**
	REMOVED	Neutron Flux Detectors R&D and Qualification Efforts	**Table 4-9 – DDN 3.3.5.0**	**Neutron flux detectors R&D and qualification efforts – was added to Table 4-9 based on rev 1 of the TDRM. Then when the TDRM report was updated, need was completely removed. This is consistent with the current TDRM.**
4	**Computer Codes, Methods Development and Qualification**			
	4.1.3.1b	Fuel – Development of Fuel Hydrolysis Modeling in ATLAS	**Table 4-9 – DDN 4.1.4.1**	**The FP transport section was not the right place for this need so it was moved to this spot with the fuel DDNs**
	REMOVED	FP Transport – Mechanical Analysis Code for the NHS	**Table 4-9 – DDN 4.1.4.1**	**Redundant with 4.1.4.2a-d**
	MOVED	FP Transport – Fuel Hydrolysis	**Table 4-9 – DDN 4.1.4.1**	**Moved to 4.1.3.1b**
	REMOVED	Modeling of the Effects of Water Ingress from Small and Large SG Breaks on the System	**Table 4-9 – DDN 4.1.4.3**	**The needs of this DDN are covered under several other DDNs**
	MOVED	Instrumentation – In-Core Neutronics Measurement Sensor R&D for Qualification of CABERNET	**Table 4-9 – DDN 4.2.1.1**	**Moved to 3.3.5.0c**
	REMOVED	Neutronics – Qualification of CABERNET for Initial Operation Power Margin Calculations	**Table 4-9 – DDN 4.2.1.1**	**Deleted – determined to be an operational issue, not a DDN**
	4.2.2.3	Thermal-Hydraulics – Validation of RELAP5-3D Consistent with that Planned for MANTA	**Table 4-9 – DDN 4.2.2.1**	**Changed numbering for consistency**

[1] All references to Table 4-9 in the "DDN Origin" column refer to Table 4-9 of the DDN/PIRT reconciliation report [2] which can also be found in Table B-1 of this report

4.3 New DDNs

As part of this DDN updating effort, the AREVA NGNP reference design, requirements, and new tasks (TDRM [3]) were reviewed. Expert review sessions were also conducted.

These efforts led to the creation of a number of new DDNs which can be found in Table 4-2. The table lists the section number and title to which the DDN belongs, the AREVA DDN number, the DDN title, and the origin of the DDN.

Table 4-2: List of New DDNs

Section	AREVA DDN Number	DDN Title	DDN Origin
1	**Fuel**		
	1.4.1.0a	Spent Fuel – Long-Term Release of Fission Products from TRISO Fuel	**New (Expert Review)**
	1.4.1.0b	Spent Fuel – ^{14}C Production	**New (Expert Review)**
2	**Materials Development and Qualification**		
	2.2.3.1h	Mechanical Properties of 9Cr1Mo in a HTGR Environment up to [650°C]	**New (Expert Review)**
	2.2.4.2b	Vessel Inspection	**New (Expert Review)**
	2.2.4.3	Validation of a RPV Sealing Device	**New (Expert Review)**
	2.3.6.1b	Ceramic Insulation – Mechanical Properties	**New (Expert Review)**
	2.4.1.0h	Graphite – Impure Helium Oxidation Characteristics and Effect on Material Properties	**New (Expert Review)**
	2.4.3.0	Graphite Machineability	**New (Expert Review)**
3	**Components Testing**		
	3.1.6.0b	Steam Generator – Circular Hot Header Manufacturability Development	**New (Identified in Current TDRM)**
	3.3.3.0	Fuel Handling System – Material/Subcomponent Testing	**New (Identified in Current TDRM)**
	3.3.4.0c	RCCS – Characteristic Effects of Particulate and Plateout on Radiation Heat Transfer	**New (Identified in Current TDRM)**
	3.4.1.0	Reactor Core – Test Block Interface Flow Characteristics	**New (Identified in Current TDRM)**
4	**Computer Codes, Methods Development and Qualification**		
	4.1.1.2	Neutronics – Development of Cross-Section Data for Modeling in NEPHTIS	**New (Expert Review)**
	4.2.4.1	Experimental Work for Fission Product Transport Model Qualification	**New (Expert Review)**
	4.2.1.5	Neutronics – Results of Fuel Irradiation Experiments for NEPHTIS Qualification	**New (Expert Review)**

5.0 CURRENT DDN SUMMARY TABLE

The final list of DDNs generated in this report was based on the DDN/PIRT reconciliation report [2]. As noted in the previous sections, the DDNs were broken down, DDNs were removed, others were added, and yet others were modified to provide adequate uniformity. Table 5-1 is the summary table of the final list of DDNs. DDN details and full contents can be found in Appendix A.

Table 5-1 contains the section number and name to which the DDNs belong. It also provides the AREVA DDN number for each DDN, the DDN title, and the origin of the DDN.

Table 5-1: Summary Table of the Current List of DDNs

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
1	**Fuel**		
1.1	**Fuel Development**		
1.1.1	**Kernel**		
	1.1.1.1	Kernel Materials – Advanced Carbon Source Development	**Table 4-9 – DDN 1.1.1.1**
	1.1.1.2a	Kernel Manufacturing – Advanced Kernel Wash and Dry System Development	**Table 4-9 – DDN 1.1.1.2**
	1.1.1.2b	Kernel Manufacturing – Enhanced Sintering with a Focus on Increased Throughput and Reduced Cost	**Table 4-9 – DDN 1.1.1.2**
1.1.2	**Coating**		
	1.1.2.2	Coating Manufacturing – Coating Batch Size	**Table 4-9 – DDN 1.1.2.2**
1.1.3	**Compact**		
	1.1.3.1a	Compact Materials Selection	**Table 4-9 – DDN 1.1.3.1**
	1.1.3.1b	Compact Materials – Performance of Compacts	**Table 4-9 – DDN 1.1.3.1**
	1.1.3.2a	Compact Manufacture – Compact Pressures and Temperatures	**Table 4-9 – DDN 1.1.3.2**
	1.1.3.2b	Compact Manufacture – Heat Treat Process Development	**Table 4-9 – DDN 1.1.3.2**
1.1.4	**Fuel Mass Production**		
	1.1.4.1a	Fuel Mass Production – Process Scale-Up	**Table 4-9 – DDN 1.1.4.1**
	1.1.4.1b	Fuel Mass Production – Irradiation Testing	**Table 4-9 – DDN 1.1.4.1**
1.2	**Fuel Qualification**		
	1.2.1.0	Quality Control Methods – Fuel QC Inspection Techniques	**Table 4-9 – DDN 1.2.1.0** **Table 4-9 – DDN 1.2.2.0**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
1.3	**Fuel Materials**		
	1.3.1.0a	Fuel Air Oxidation	**Table 4-9 – DDN 1.3.1.0**
	1.3.1.0b	Fuel Water/Steam Oxidation	**Table 4-9 – DDN 1.3.1.0**
	1.3.2.0a	Fuel Compact – Fission Product Interactions	**Table 4-9 – DDN 1.3.2.0**
	1.3.2.0b	Fuel Compact Properties and Fission Product Interactions – Empirical Fission Product Release Rate Constant	**Table 4-9 – DDN 1.3.2.0**
	1.3.3.0	FP Speciation During Mass Transfer – Chemical Speciation Within the Primary System and Confinement	**Table 4-9 – DDN 1.3.3.0**
1.4	**Spent Fuel**		
	1.4.1.0a	Spent Fuel – Long-Term Release of Fission Products from TRISO Fuel	**New (Expert Review)**
	1.4.1.0b	Spent Fuel – ^{14}C Production	**New (Expert Review)**
2	**Materials Development and Qualification**		
2.1	**All Materials**		
	2.1.1.0	Tribology – Tests on Expected Couples of Materials in Representative HTGR Conditions	**Table 4-9 – DDN2.1.1.0**
2.2	**Metallic Materials**		
2.2.3	**Reactor Internal Materials**		
	2.2.3.1a	Thermal Properties of Alloy 800H	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1b	Thermal Properties of 9Cr1Mo	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1c	Corrosion Effects on Alloy 800H in a HTGR Environment	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1d	Corrosion Effects on 9Cr1Mo in a HTGR Environment	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1e	Irradiation Effects on Alloy 800H in a HTGR Environment	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1f	Irradiation Effects on 9Cr1Mo in a HTGR Environment	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1g	Mechanical Properties of Alloy 800H in a HTGR Environment up to [1000°C]	**Table 4-9 – DDN 2.2.3.1**
	2.2.3.1h	Mechanical Properties of 9Cr1Mo in a HTGR Environment up to [650°C]	**New (Expert Review)**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
2.2.4	**RPV Low Temperature Materials**		
	2.2.4.1a	Irradiation Effects on SA-508 and SA-533 in a HTGR Environment	**Table 4-9 – DDN 2.2.4.1** **New (Expert Review)**
	2.2.4.1b	Time Dependent Material Properties of SA-533 and SA-508 in a HTGR Environment	**Table 4-9 – DDN 2.2.4.1**
	2.2.4.1c	Corrosion Effects on SA-508 and SA-533 in a HTGR Environment	**Table 4-9 – DDN 2.2.4.1** **New (Expert Review)**
	2.2.4.1d	Emissivity of SA-508 and SA-533	**Table 4-9 – DDN 2.2.4.1**
	2.2.4.2a	Vessel Field Fabrication Process Control and Property Control	**Table 4-9 – DDN 2.2.4.2**
	2.2.4.2b	Vessel Inspection	**New (Expert Review)**
	2.2.4.3	Validation of a RPV Sealing Device	**New (Expert Review)**
2.3	**Ceramic Materials**		
2.3.1	**Control Rods**		
	2.3.1.1a	Control Rod – Thermal-Physical Properties	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1b	Control Rod – Mechanical Properties	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1c	Control Rod – Fracture Properties	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1d	Control Rod – Fatigue Strength	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1e	Control Rod – Oxidation Characteristics and Effects on Material Properties	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1f	Control Rod – Irradiation and Testing of Mock-Ups	**Table 4-9 – DDN 2.3.1.1**
	2.3.1.1g	Control Rod – Development of Fabrication and Qualification Methods	**Table 4-9 – DDN 2.3.1.1**
2.3.2	**Upper Core Restraints**		
	2.3.2.1a	Upper Core Restraints – Thermal-Physical Properties	**Table 4-9 – DDN 2.3.2.1**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
	2.3.2.1b	Upper Core Restraints – Mechanical Properties	**Table 4-9 – DDN 2.3.2.1**
	2.3.2.1c	Upper Core Restraints – Fracture Properties	**Table 4-9 – DDN 2.3.2.1**
	2.3.2.1d	Upper Core Restraints – Fatigue Strength	**Table 4-9 – DDN 2.3.2.1**
	2.3.2.1e	Upper Core Restraints – Oxidation Characteristics and Effects on Material Properties	**Table 4-9 – DDN 2.3.2.1**
	2.3.2.1f	Upper Core Restraints – Irradiation and Testing of Mock-Ups	**Table 4-9 – DDN 2.3.2.1**
	2.3.2.1g	Upper Core Restraints – Development of Fabrication and Qualification Methods	**Table 4-9 – DDN 2.3.2.1**
2.3.6	**Ceramic Insulation**		
	2.3.6.1a	Ceramic Insulation – Thermal-Physical Properties	**Table 4-9 – DDN 2.3.6.1**
	2.3.6.1b	Ceramic Insulation – Mechanical Properties	**New (Expert Review)**
	2.3.6.1c	Ceramic Insulation – Oxidation Characteristics and Effects on Material Properties	**Table 4-9 – DDN 2.3.6.1**
2.4	**Graphite Materials**		
	2.4.1.0a	Graphite – Thermal-Physical Properties	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0b	Graphite – Mechanical Properties	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0c	Graphite – Physical Characteristics	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0d	Graphite – Fracture Properties	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0e	Graphite – Fatigue Strength	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0f	Graphite – Air Oxidation Characteristics and Effect on Material Properties	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0g	Graphite – Water/Steam Oxidation Characteristics and Effects on Material Properties	**Table 4-9 – DDN 2.4.1.0**
	2.4.1.0h	Graphite – Impure Helium Oxidation Characteristics and Effect on Material Properties	**New (Expert Review)**
	2.4.2.0a	Interactions Between Graphite Components and Key Radionuclides	**Table 4-9 – DDN 2.4.2.0**
	2.4.2.0b	Fission Product Uptake and Release in Dust and Transport by Dust	**Table 4-9 – DDN 2.4.2.0**
	2.4.2.0c	Graphite/FP Interactions – Empirical Release Rate Coefficients	**Table 4-9 – DDN 2.4.2.0**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
	2.4.3.0	Graphite Machineability	**New (Expert Review)**
3	**Components Testing**		
3.1	**Helium Loop**		
	3.1.1.0a	Primary Gas Circulator Impeller Tests in Air	**Table 4-9 – DDN 3.1.1.0**
	3.1.1.0b	Primary Gas Circulator Magnetic and Catcher Bearing Tests in Helium	**Table 4-9 – DDN 3.1.1.0**
	3.1.1.0c	Primary Gas Circulator Shutoff Valve Testing	**Table 4-9 – DDN 3.1.1.0**
	3.1.1.0d	Primary Gas Circulator – Integrated Full Size Test	**Table 4-9 – DDN 3.1.1.0**
	3.1.5.0a	Hot Gas Ducts – Elementary Tests of Subcomponents	**Table 4-9 – DDN 3.1.5.0**
	3.1.5.0b	Hot Gas Ducts – Helium Tests on Small Mock-Up in Test Facility	**Table 4-9 – DDN 3.1.5.0**
	3.1.5.0c	Hot Gas Ducts – Tests on Full Scale Mock-Up in Helium	**Table 4-9 – DDN 3.1.5.0**
	3.1.6.0a	Steam Generator – Integrity Testing of Dissimilar Material Welding Joint in Tubes	**Table 4-9 – DDN 3.1.6.0** **New (TDRM)**
	3.1.6.0b	Steam Generator – Circular Hot Header Manufacturability Development	**New (Identified in Current TDRM)**
	3.1.6.0c	Steam Generator – Engineering-Scale Demonstration	**Table 4-9 – DDN 3.1.6.0** **New (TDRM)**
3.3	**Other Systems and Subsystems**		
	3.3.1.0	Helium Purification System – Charcoal Qualification	**Table 4-9 – DDN 3.3.1.0**
	3.3.3.0	Fuel Handling System – Material/Subcomponent Testing	**New (Identified in Current TDRM)**
	3.3.4.0a	RCCS – Characterization of the Teat Transfer Characteristics of Surface Treatments for the Reactor Vessel and the Panel Heat Exchanger	**Table 4-9 – DDN 3.3.4.0**
	3.3.4.0b	RCCS – Optional Large Scale Test	**Table 4-9 – DDN 3.3.4.0**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
	3.3.4.0c	RCCS – Characteristic Effects of Particulate and Plateout on Radiation Heat Transfer	**New (Identified in Current TDRM)**
	3.3.5.0a	Instrumentation – R&D and Qualification of Pt-Rh Thermocouples	**Table 4-9 – DDN 3.3.5.0**
	3.3.5.0b	Instrumentation – Qualification Testing in Helium	**Table 4-9 – DDN 3.3.5.0**
	3.3.5.0c	Instrumentation – In-Core Neutronics Measurement Sensor R&D for Qualification of CABERNET	**Table 4-9 – DDN 4.2.1.1**
3.4	**Reactor Core**		
	3.4.1.0	Reactor Core – Test Block Interface Flow Characteristics	**New (Identified in Current TDRM)**
4	**Computer Codes, Methods Development and Qualification**		
4.1	**Code Development**		
4.1.1	**Neutronics**		
	4.1.1.1	Neutronics – Enhancement of Capabilities of CABERNET (Reactor Physics-Thermofluid Dynamic Coupling) for the Calculation of Transient Analyses	**Table 4-9 – DDN 4.1.1.1**
	4.1.1.2	Neutronics – Development of Cross-Section Data for Modeling in NEPHTIS	**New (Expert Review)**
4.1.2	**Thermal-Hydraulic**		
	4.1.2.1a	Thermal-Hydraulics – Modeling of RELAP5-3D	**Table 4-9 – DDN 4.1.2.1**
	4.1.2.1b	Thermal-Hydraulics – Coupling of CFD Models to RELAP5-3D	**Table 4-9 – DDN 4.1.2.1**
	4.1.2.2	Thermal-Hydraulics – STAR-CD Graphite Oxidation Model Development for Water and Air Ingress	**Table 4-9 – DDN 4.1.2.2**
4.1.3	**Fuel**		
	4.1.3.1a	Fuel – Improvement of the Diffusion and the Coatings Corrosion Modeling in ATLAS	**Table 4-9 – DDN 4.1.3.1**
	4.1.3.1b	Fuel – Development of Fuel Hydrolysis Modeling in ATLAS	**Table 4-9 – DDN 4.1.4.1**
	4.1.3.1c	Fuel – Improvement of the Coated Particle and Compact Irradiation Modeling in ATLAS at Relevant Operating Conditions	**Table 4-9 – DDN 4.1.3.1**
	4.1.3.1d	Fuel – Heat-Up Experiment Modeling of Irradiated Fuel Particles in ATLAS	**Table 4-9 – DDN 4.1.3.1**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
	4.1.3.1e	Fuel – Development of UCO Models in ATLAS	**Table 4-9 – DDN 4.1.3.1**
4.1.4	**Other Codes**		
	4.1.4.1a	FP Transport – Development of Model for Activation Product Assessment in the Primary Circuit	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1b	FP Transport – Modeling of Tritium Migration and Control in SG and Secondary Water Loops	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1c	FP Transport – Modeling of Radio-Contaminant Distribution in the Primary Circuit during Both Normal Operation and Accidental Situations	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1d	FP Transport – Modeling of Radio-Contaminant Release Outside the Primary Pressure Boundary	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1e	FP Transport – Modeling of Radio-Contaminant Releases in the Environment for Accidental Situations	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1f	FP Transport – Development of Fission Product Wash-Off Modeling	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.1g	FP Transport – Data Collection for Fission Product Aerosols	**Table 4-9 – DDN 4.1.4.1**
	4.1.4.2a	Structural Analysis – Completion of Experimental Databases for Structural Mechanics Codes	**Table 4-9 – DDN 4.1.4.2**
	4.1.4.2b	Structural Analysis – Development of Block-Type Core Dynamic Modeling	**Table 4-9 – DDN 4.1.4.2**
	4.1.4.2c	Structural Analysis – Modeling of Fluid Structure Interaction and Flow-Induced Vibration	**Table 4-9 – DDN 4.1.4.2**
	4.1.4.2d	Structural Analysis – Development of LBB Methodology for Gas-Cooled Reactors	**Table 4-9 – DDN 4.1.4.2**
4.2	**Code Qualification**		
4.2.1	**Neutronics**		
	4.2.1.1a	Neutronics – Experimental Data on Representative Fuel Assembly Geometry for Qualification of CABERNET	**Table 4-9 – DDN 4.2.1.1**
	4.2.1.1b	Neutronics – Partial Data for Qualification of CABERNET	**Table 4-9 – DDN 4.2.1.1**
	4.2.1.1c	Neutronics – In-Core Measurements for Qualification of Coupled Calculations in CABERNET	**Table 4-9 – DDN 4.2.1.1**
	4.2.1.2	Neutronics – New Dedicated Critical Experiments for Qualification of MCNP	**Table 4-9 – DDN 4.2.1.2**
	4.2.1.3a	Neutronics –Results of Fuel Irradiation Experiments for MONTEBURNS Qualification	**Table 4-9 – DDN 4.2.1.3**
	4.2.1.3b	Neutronics – Experimental Results of Decay Heat for MONTEBURNS Qualification	**Table 4-9 – DDN 4.2.1.3**

Section	AREVA DDN Number	DDN Title	DDN Origin (and # of origin as applicable) [1]
	4.2.1.4	Neutronics – New Dedicated Critical Experiments for Qualification of NEPHTIS	**Table 4-9 – DDN 4.2.1.4**
	4.2.1.5	Neutronics – Results of Fuel Irradiation Experiments for NEPHTIS Qualification	**New (Expert Review)**
4.2.2	**Thermal-Hydraulic**		
	4.2.2.1	Thermal-Hydraulics – Benchmarks Against Experimental Data for Qualification of MANTA	**Table 4-9 – DDN 4.2.2.1**
	4.2.2.2a	Thermal-Hydraulics – Qualification of STAR-CD for Modeling Conduction Cooldown	**Table 4-9 – DDN 4.2.2.2**
	4.2.2.2b	Thermal-Hydraulics – Qualification of STAR-CD for Modeling Diffusion, Turbulence and Stratification/Mixing	**Table 4-9 – DDN 4.2.2.2**
	4.2.2.2c	Thermal-Hydraulics – Qualification of STAR-CD for Modeling Oxidation	**Table 4-9 – DDN 4.2.2.2**
	4.2.2.3	Thermal-Hydraulics – Validation of RELAP5-3D Consistent with that Planned for MANTA	**Table 4-9 – DDN 4.2.2.1**
4.2.3	**Fuel**		
	4.2.3.1a	Fuel – Qualification of ATLAS for Modeling Irradiation of Coated Particles	**Table 4-9 – DDN 4.2.3.1**
	4.2.3.1b	Fuel – Qualification of ATLAS for Modeling Heat-Up Experiment	**Table 4-9 – DDN 4.2.3.1**
4.2.4	**Other Codes**		
	4.2.4.1	Experimental Work for Fission Product Transport Model Qualification	**New (Expert Review)**

[1] All references to Table 4-9 in the “DDN Origin” column refer to Table 4-9 of the DDN/PIRT reconciliation report [2] which can also be found in Table B-1 of this report

6.0 CONCLUSIONS

AREVA has reviewed and updated its list of NGNP DDNs based on the NGNP DDN/PIRT reconciliation report [2], expert panel discussions, NGNP requirements, the AREVA NGNP selected design and other recent tasks. The TDRM report [3] is one of those tasks with which the DDNs are now coordinated. The results of this effort, the AREVA detailed DDNs, can be found in Appendix A.

As a result, some existing DDNs were modified for consistency of contents. Other DDNs were removed and some were added.

Certain DDNs were removed because of duplication with other DDNs or with other programs. A number of DDNs were removed because the activities were determined to be administrative. This includes codification and the development of ASME and ASTM codes and standards which are administrative processes. They require inputs such as material properties which can be found in existing DDNs.

Other DDNs were removed on the basis that they are part of the normal design activities. Topics include the study of hot streaks with the V-shaped metallic concept for the hot gas ducts, HPS component sizing and charcoal selection, Fuel Server System software development and various other design activities.

Finally, the neutron flux detectors R&D and qualification efforts DDN was removed after the need was removed from the second revision of the TDRM report which was issued after the reconciliation report.

As some DDNs were removed, others were added as a result of the update activity. Topics of the added DDNs include:

- Spent Fuel – No spent fuel DDNs were previously identified. DDNs concerning the long-term release of fission products from TRISO fuel and ^{14}C production were added based on an expert evaluation of likely data needs in this area.

- Materials Development and Qualification – Through expert review, DDNs concerning the properties of 9Cr1Mo, vessel inspection, validation of a RPV sealing device, mechanical properties of ceramic insulation, as well as graphite machineability and properties were added.

- SSCs – Based on issues raised in the TDRM report [3], DDNs concerning the circular hot header manufacturability, material testing for the FHS, characteristic effects of particulate and plateout on radiation heat transfer, and block interface flow characteristic tests were added.

- Codes and Methods – The need for cross-section data for modeling in NEPHTIS, results of fuel irradiation experiments for NEPHTIS qualification, and qualification of fission product transport model were identified by the expert panel.

The list of DDNs provided in this report is a dynamic list based on the current state of the NGNP design. DDNs will be added, removed or modified as necessary as the design matures, as technology advances, and as the project evolves.

7.0 REFERENCES

1. AREVA Document, 12-9051191-001, "NGNP with Hydrogen Production Preconceptual Design Studies Report", June 2007

2. AREVA Document, 12-9102279-001, "NGNP Conceptual Design DDN/PIRT Reconciliation", February 2009

3. AREVA Document, TDR-3001031-003, "NGNP Technology Development Road Mapping Report", September 2009

4. INL Document, INL/EXT-07-12999, Rev. 2, "Next Generation Nuclear Plant System Requirements Manual", March 2009

5. AREVA Document, 51-9103803-002, "NGNP Conceptual Design Baseline Document for Conventional Steam Cycle for Process Heat and Cogeneration", April 2009

6. INL Document, SOW-7512, Rev. 0, "NGNP Reactor Design Supplier Update of Design Data Needs", July 2009

APPENDIX A: DETAILED DDNS

This appendix contains detailed DDNs for each DDN listed in the summary table found in Table 5-1. The format and contents of each template are detailed in Section 4.1.

DDN SUMMARY

DDN Number: 1.1.1.1

DDN Revision: 01

DDN Title: Kernel Materials – Advanced Carbon Source Development

DDN Category: Fuels

DDN Description:

This DDN is established to identify, evaluate and qualify new sources of carbon black for UCO kernel production.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Carbon black supplied from any new material source must meet the requirements specified in the fuel supplier product specification for this material. In addition, it is anticipated that UCO kernels fabricated using a new supply of carbon black will be examined and qualified to meet applicable fuel kernel product specifications.

From our experience, a close relationship has to be established with the provider in order to guarantee the product quality on the long-term.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

Regarding quality tests, specific area and surface quality of carbon black are key features to control, as process reproducibility depends strongly on them. Chemical treatment can modify the hydrophobic or hydrophilic behavior of the carbon black powder. This parameter influences the dispersion of the carbon black powder in the broth thus the final fuel kernel homogeneity.

Need Date:

In order to meet the production needs for NGNP fuel, a reliable source of carbon black must be maintained. To minimize production schedule risk, back-up sources of this material need to be maintained. Such back-up sources should be in place prior to the start of production-scale fuel fabrication activities.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

In order to help assure uninterrupted production of NGNP fuel, alternate suppliers of key feed materials need to be identified and qualified. Developing of advanced carbon black sources will help to meet this objective.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.1.2a

DDN Revision: 01

DDN Title: Kernel Manufacturing – Advanced Kernel Wash and Dry System Development

DDN Category: Fuels

DDN Description:

This DDN is established to effectively increase throughput of fuel kernel production line, with no degradation in kernel quality, by developing a new kernel wash and dry system.

Current State of Knowledge:

Pieces of information from the former German manufacturing processes transferred to South Africa, emphasize the importance of these process steps. A continuous and controlled motion is required, and criticality aspects have to be taken into account.

DDN REQUIREMENT

Data Needed:

The new kernel wash and dry system will be qualified to meet the applicable fuel vendor process and product specifications with respect to fuel kernel attributes required prior to the sintering step in the production process.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Increased kernel throughput for the wash and dry step is required prior to the start of full scale fuel production activities for the initial NGNP core.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The new fuel kernel wash and dry system will be designed to meet the applicable fuel vendor specifications. Qualification of the processes and equipment will be conducted prior to use for production fuel.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.1.2b

DDN Revision: 01

DDN Title: Kernel Manufacturing – Enhanced Sintering with a Focus on Increased Throughput and Reduced Cost

DDN Category: Fuels

DDN Description:

This DDN is established to effectively increase throughput and reduce the operational costs of the fuel kernel production line, with no degradation in kernel quality, by developing a new kernel sintering system. This system is anticipated to employ large fluidized bed sintering for UCO or static bed sintering for UO_2.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The new kernel sintering system will be qualified to meet the applicable fuel vendor process and product specifications with respect to required fuel kernel attributes at that point in the production process.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Increased kernel throughput for the sintering process step is required prior to the start of full scale fuel production activities for the initial NGNP core.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The new fuel kernel sintering system will be designed to meet the applicable fuel vendor specifications. Qualification of the processes and equipment will be conducted prior to use for production fuel

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.2.2

DDN Revision: 01

DDN Title: Coating Manufacturing – Coating Batch Size

DDN Category: Fuels

DDN Description:

This DDN is written to investigate the largest coating batch size that is practical in the existing 6" coater or in a larger coater. It includes economic feasibility assessment of using a 6" (or larger) coater for production. Additionally, should a larger coater be required, a plan for implementing the R&D of that coater as part of the facility expansion for production is reviewed.

Current State of Knowledge:

Furnace size is limited by criticality aspects (U loading) and the regulatory rules in force.
Any change in the coater size shall require further optimization of the deposition process.
Preliminary modeling work has been performed in France (2006-2008) in support of coater size optimization.

DDN REQUIREMENT

Data Needed:

Physical characteristics of coatings, including the statistical distributions of key variables, after manufacture are assessed against applicable product specifications to measure compliance to allow a better understanding of the influence of these parameters and optimizing of the process.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

The size of the production coater and batch size must be established, and associated qualification activities completed, prior to the start of production of the first batch of fuel for the NGNP.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The coater will be run with varying batch sizes to determine the largest batch size that results in acceptable coating properties. Qualification runs will be run for that batch size to support justification for production use.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.3.1a

DDN Revision: 01

DDN Title: Compact Materials Selection

DDN Category: Fuels

DDN Description:

Potential sources of materials for compact production, including graphitic matrix and resin materials, will be reviewed and selections made to support production of thermosetting compacts.

Current State of Knowledge:

The main part of the matrix material is natural graphite (higher stability under irradiation conditions), the quality of which being a key process parameter. The natural graphite sourcing cannot be the same over the long term because mines work out. A close relationship has thus to be established with the graphite provider in order to maintain the same natural graphite powder quality whatever the natural graphite flake sourcing. Chemical refining is also an important step.

Phenolic resin is a chemical product thus not so variable.

DDN REQUIREMENT

Data Needed:

It is anticipated that the selection will be based on existing experimental data coupled with design requirements developed during the qualification of the compact design.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

Regarding product quality test (CERCA experience), main features to control are:

- Physical properties: particle size (mean value and distribution in the powder), density (real and apparent), open porosity, specific surface area and crystallinity (Lc parameter).
- Chemical properties : individual impurity, ash and moisture contents
- Nuclear properties : Equivalent Boron content

Need Date:

The compact material sources must be established in time to support the start of production of the first batch of NGNP fuel.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Materials will be reviewed and assessed based on demonstrated ability to meet compact design requirements, economics, and stability of supply.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.3.1b

DDN Revision: 01

DDN Title: Compact Materials – Performance of Compacts

DDN Category: Fuels

DDN Description:

This DDN is established to determine the irradiation performance of the fuel compacts anticipated to be used in the NGNP. The performance data will be used to qualify the compacts for use under NGNP operational and accident conditions by focused evaluation of expected performance in the NGNP.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The fuel compacts will be evaluated to determine their ability to perform as designed and not adversely impact the performance of the contained fuel particles. This will be primarily achieved through qualitative assessment of overall fuel particle failure rates and identification of any which may be attributed to compact performance.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the compacts is required to support initial core loading and operation of the NGNP. Ideally, the qualification would be completed prior to the start of fuel fabrication activities. However, due to the long required fabrication schedule, and the necessary compact sample irradiation and inspection times, some overlap will likely be necessary.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of NGNP fuel, including fuel compacts, are described in ORLN/TM-2002/262, "Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Program". This plan includes details of the planned irradiation program and associated post-irradiation inspections and accident heat-up testing.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.3.2a

DDN Revision: 01

DDN Title: Compact Manufacture – Compact Pressures and Temperatures

DDN Category: Fuels

DDN Description:

This DDN is to confirm the pressures and temperatures used during the compact manufacturing process. These temperatures and pressures are a balance between the ability to make a high-integrity compact (generally higher values) and the need to reduce the potential for damaging fuel (generally lower values).

Current State of Knowledge:

The CERCA fuel compacting process has been developed at lab-scale over the period 2003-2009.

DDN REQUIREMENT

Data Needed:

Various combinations of compacting temperature and pressure are used to form fuel compacts. These samples will be assessed to ascertain the number of potentially damaged fuel particles. An assessment of compact integrity will also be made. From these results, temperature and pressure values for manufacturing use will be optimized for industrialization.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Optimized ranges of compacting temperature and pressure will be required prior to the start of full scale fuel production activities for the initial NGNP core.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The compacting temperature and pressure will be chosen to meet the applicable fuel vendor specifications. Qualification of the processes and equipment will be conducted prior to use for production fuel

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.3.2b

DDN Revision: 01

DDN Title: Compact Manufacture – Heat Treat Process Development

DDN Category: Fuels

DDN Description:

This DDN is established to optimize the heat treatment process used during compact manufacture. This process must ensure sufficient removal of volatile materials, including H_2, from the compact matrix material to produce a high integrity compact while eliminating the potential for heat-related damage to the contained fuel particles...

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Various combinations of sintering temperature, below values expected to cause fuel particle damage, and duration are used to form fuel compacts. These samples will be assessed to ascertain the integrity of the fuel compact. From these results, optimized ranges of temperature and duration will be established for industrial manufacturing use. It is anticipated that these tests will be conducted utilizing surrogate fuel particles (ZrO_2 or other).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Determination of optimized temperature and duration for compact industrial manufacture will be required prior to the start of full scale fuel production activities for the initial NGNP core.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The compacting temperatures and durations will be chosen to meet the applicable fuel vendor specifications. Qualification of the processes and equipment will be conducted prior to use for production fuel.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.4.1a

DDN Revision: 01

DDN Title: Fuel Mass Production – Process Scale-Up

DDN Category: Fuels

DDN Description:

This DDN does not address the basic process development needs, only scale-up.

Potential scale up processes include: kernel wash and dry, sintering, coating (assuming larger than 6” coater required), compact matrix formulation, and compact fabrication. During manufacturing strategy development processes will be reviewed to decide where scale-up is needed and where it is not needed to support the required product throughput.

Current State of Knowledge:

Storage, transport and quality assurance requirements are of prime importance in the design of an industrial scaled fuel production line. In particular for a given design capability, storage areas, product handling policy, availabilities and storage capacities are to be proportionally designed.

DDN REQUIREMENT

Data Needed:

Specific data requirements will be developed as necessary once the processes necessitating scale-up (and the issues associated with it) are identified. R&D should focus on areas where product uniformity and quality are most at jeopardy:

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Required process scale-up for NGNP fuel manufacture will be required prior to the start of full scale fuel production activities for the initial NGNP core.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

The processes chosen for scale-up will be reviewed to assure the ability of the revised process to meet the applicable fuel vendor specifications. Qualification of the processes and equipment will be conducted prior to use for production fuel.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.1.4.1b

DDN Revision: 01

DDN Title: Fuel Mass Production – Irradiation Testing

DDN Category: Fuels

DDN Description:

This DDN is established to confirm that the irradiation performance of the fuel produced by the production scale processes and facilities matches the performance from the laboratory/pilot facilities. The performance data will be used to verify that the production fuel will demonstrate the same expected performance in the NGNP as the earlier tested fuel produced using the laboratory/pilot scale equipment.

Current State of Knowledge:

The preparation work for the AGR2 irradiation, performed in collaboration with CEA (2007-2009), could be useful.

DDN REQUIREMENT

Data Needed:

The fuel will be evaluated to determine its ability to perform as designed, primarily through qualitative assessment of overall fuel particle failure rates.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the fuel is required to support initial core loading and operation of the NGNP. Ideally, the qualification would be completed prior to the start of fuel fabrication activities. However, due to the long required fabrication schedule, and the necessary sample irradiation and inspection times, some overlap will likely be necessary.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of NGNP fuel are described in ORLN/TM-2002/262, "Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Program". This plan includes details of the planned irradiation program and associated post-irradiation inspections and accident heat-up testing.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.2.1.0

DDN Revision: 01

DDN Title: Quality Control Methods – Fuel QC Inspection Techniques

DDN Category: Fuels

DDN Description:

This DDN is established to support development of new techniques, instrumentation, and associated data acquisition software related to the quality control inspection of completed and in-process fuel particles and compacts or industrialization of existing ones. Techniques to be addressed could be: micro focus x-ray of particles (dimensional inspection of particle layers), mercury porosymetry (buffer density), sink-float (IPyC, SiC, and OPyC density), anisotropy measurements of the IPyC and OPyC layers, leach-burn-leach test or weak irradiation techniques (particle leak tightness), etc.

In order to support economic fuel production, instrumentation and data acquisition software should be highly reliable and developed with mass production in mind. Techniques for large-scale production capabilities that minimize the quantity of materials requiring destructive evaluation to ensure statistically acceptable fuel production should be emphasized.

Current State of Knowledge:

The NDE methods assessment work performed in France with Intercontrole (ex-SFE) led to at least 3 patents (X-ray Phase Contrast Imaging, Eddy current and laser US methods), and to the development of a control strategy able to replace "classical" HTGR fuel control method based on sampling.

DDN REQUIREMENT

Data Needed:

In order to ensure acceptable fuel particle and compact quality and to capture data necessary to support fuel certification, the modern methods already developed should be industrialized and additional modern methods should likely be developed to replace or complement standard ones. Nevertheless, an effort is also to be made for industrialization of some standard techniques. As development of these techniques continues, specific data needs will be identified and applicable DDNs generated. Inspection techniques will be related to the irradiation performance of fuel to help ensure the correct attributes are being measured and characterized.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

All quality control processes, including all required instrumentation and software, must be developed, installed and qualified prior to the start of fabrication of the initial batch of fuel for the NGNP.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

As critical manufacturing-related parameters that support acceptable performance of the NGNP fuel particles and compacts are uncovered by the ongoing fuel testing and qualification program, quality control tests and inspections will be developed to assure that these parameters and kept within acceptable bounds.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.3.1.0a

DDN Revision: 01

DDN Title: Fuel Air Oxidation

DDN Category: Fuels

DDN Description:

This DDN is established to develop performance data describing the oxidation behavior and associated property changes of fuel materials under air ingress conditions. The performance data will be used to qualify the fuel for use under NGNP operational and accident conditions by focused evaluation of expected performance in the NGNP.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The fuel will be evaluated to determine its ability to perform as designed under air oxidation conditions. The oxidation behavior of the kernel, buffer, IPyC, SiC, OPyC, and compact will be determined as a function of time, temperature, and specific environmental conditions (atmospheric oxygen content, etc.). These data will be used to support development of predictive oxidation models and should include parameters such as weight gain, base material consumption, and oxide layer penetration distance into base material.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the fuel is required to support initial core loading and operation of the NGNP. Ideally, the qualification would be completed prior to the start of fuel fabrication activities. However, due to the long required fabrication schedule, and the necessary sample irradiation and inspection times, some overlap will likely be necessary.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of NGNP fuel are described in ORLN/TM-2002/262, “Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Program”. This plan includes details of the planned irradiation program and associated post-irradiation inspections and accident heat-up testing.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.3.1.0b

DDN Revision: 01

DDN Title: Fuel Water/Steam Oxidation

DDN Category: Fuels

DDN Description:

This DDN is established to develop performance data describing the oxidation behavior and associated property changes of fuel materials under water ingress conditions. The performance data will be used to qualify the fuel for use under NGNP operational and accident conditions by focused evaluation of expected performance in the NGNP.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The fuel will be evaluated to determine its ability to perform as designed under water/steam oxidation conditions. The oxidation behavior of the kernel, buffer, IPyC, SiC, OPyC, and compact will be determined as a function of time, temperature, and specific environmental conditions (atmospheric steam and oxygen content, etc.). These data will be used to support development of predictive oxidation models and should include parameters such as weight gain, base material consumption, and oxide layer penetration distance into base material.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the fuel is required to support initial core loading and operation of the NGNP. Ideally, the qualification would be completed prior to the start of fuel fabrication activities. However, due to the long required fabrication schedule, and the necessary sample irradiation and inspection times, some overlap will likely be necessary.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of NGNP fuel are described in ORLN/TM-2002/262, "Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Program". This plan includes details of the planned irradiation program and associated post-irradiation inspections and accident heat-up testing. **As currently configured, this test and qualification effort considers only air oxidation, not water/steam oxidation. Sufficient testing should be added to identify differences in oxidation kinetics and morphology between air and water/steam environments. Differences in material properties impacts must also be assessed.**

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.3.2.0a

DDN Revision: 01

DDN Title: Fuel Compact – Fission Product Interactions

DDN Category: Phenomena

DDN Description:

This DDN is established to determine the interactions between the fuel matrix material and key radionuclides which impact fission product transport through the matrix material. This data will be used to support modeling of fission product and activation product release from, and transport within, the fuel compact.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Data needed for transport model development includes:

- Radionuclide transport rates through the matrix material
- Sorbtivity of matrix material
- Fluence effect on transport in the matrix material
- Radionuclide speciation in carbonaceous material and during mass transport
- Radionuclide absorption and deabsorption on fuel compact surfaces.

Impacts of chemical forms of radionuclides on transport, holdup and chemical reactivity should be considered and examined. The examination should also include impacts of matrix material oxidation during air and water ingress events.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

Should sufficient historical data be available, use such data to reasonably bound expected fluence effects in the fuel matrix material.

Selected Design Approach and Fallback:

Much of the needed phenomenological data can be generated based on fairly simple laboratory bench testing of individual chemical species determined to be of interest. Evaluation of fluence effects will require development of more elaborate test programs. An alternate to such testing may be possible should sufficient historical data be available to reasonably bound expected fluence effects in the fuel matrix material.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.3.2.0b

DDN Revision: 01

DDN Title: Fuel Compact Properties and Fission Product Interactions – Empirical Fission Product Release Rate Constant

DDN Category: Phenomena

DDN Description:

This DDN is established to explore development of effective fission product release rate coefficients (empirical constants) as an alternative to development of detailed phenomenological models. These coefficients would include impacts of fuel matrix oxidation during air and water ingress events. This data would be used to support modeling of fission product and activation product release from, and transport within, the fuel compact.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Data needed to support this DDN include integrated radionuclide release rates for various fuel matrix types and environments.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

Develop detailed phenomenological models.

Selected Design Approach and Fallback:

The key to development of effective release rate coefficients is to determine representative fuel matrix types, radionuclide species and operational environments. Once these have been determined, a series of experiments can be conducted to assess integrated radionuclide release as a function of appropriate independent variables. Should development of such coefficients be deemed to be too costly or difficult to produce useable results, development of detailed phenomenological models would be pursued.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.3.3.0

DDN Revision: 01

DDN Title: FP Speciation during Mass Transfer – Chemical Speciation within the Primary System and Confinement

DDN Category: Phenomena

DDN Description:

This DDN is established to determine the likely chemical forms of key radionuclides present in the primary system and confinement during certain accident sequences, including both air ingress and water ingress events.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

For each radionuclide of significance, from a dose standpoint during postulated accident sequences, the thermodynamically likely chemical forms will be identified for each radionuclide. These forms will be identified for accident sequences including both air and water ingress events.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Many of the likely chemical species may be identified based on published thermodynamic data. Experimental data may be needed to confirm some data and can be obtained from fairly simple laboratory experiments.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.4.1.0a

DDN Revision: 01

DDN Title: Spent Fuel – Long-Term Release of Fission Products from TRISO Fuel

DDN Category: Phenomena

DDN Description:

This DDN is established to evaluate the long-term fission product release characteristics of the TRISO fuel particles under representative fuel storage conditions. It is anticipated that varied storage conditions would be considered, including short term storage in or near the reactor (characterized by relatively high fuel temperatures in a dry helium environment), storage in an Independent Spent Fuel Storage Installation (ISFSI) (characterized by moderate temperatures in a dry helium or air environment), and eventual repository storage (characterized by low fuel temperatures in a helium, air, or water environment).

Current State of Knowledge:

These topics have been considered in Europe through the nearly completed FP6 Raphael Project, and possibly the forthcoming FP7 HTR project.

DDN REQUIREMENT

Data Needed:

Data needed includes diffusion coefficients for each dose-significant radionuclide through each particle layer and, potentially, the fuel matrix as a function of temperature and particle exposure (to the extent that this impacts the starting inventory and internal particle environment). In addition, the impact of external environment on exposed particle surfaces should be assessed for impacts near-surface diffusion rates and release characteristics.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This information will be needed to refine and optimize the storage of spent NGNP fuel. It is anticipated that this will be an ongoing program of monitoring fuel in storage, both fuel from initial qualification testing and, later, fuel from the operational NGNP.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Initial design of NGNP spent fuel storage systems will necessarily be based on available historical data, first-principles materials behavior information, and conservative design assumptions. As more specific fuel behavior is obtained, storage system designs may be refined and optimized to more efficiently provide storage solutions.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 1.4.1.0b

DDN Revision: 01

DDN Title: Spent Fuel – ^{14}C Production

DDN Category: Phenomena

DDN Description:

This DDN is established to evaluate the production of ^{14}C in fuel and reflector blocks during NGNP operation. The production of ^{14}C in gas-cooled graphite moderated reactors is primarily from two sources: activation of ^{13}C and ^{14}N. The production profile from ^{13}C can be ascertained from first-principles calculations. The production profile from ^{14}N is based on the presence of residual nitrogen contamination within the graphite fuel and reflector blocks.

Current State of Knowledge:

In Europe, ^{14}C issues are being examined in the frame of the current FP7 Carbowaste Project.

DDN REQUIREMENT

Data Needed:

In order to calculate the production of ^{14}C within the fuel and reflector blocks from neutron activation of ^{14}N, the uptake and release characteristics of nitrogen for the graphite from which these blocks are made is required. This data should be evaluated for both normal atmospheric conditions, where nitrogen uptake in the fuel will occur, and for dry helium conditions representative of operation in the reactor.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to help formulate fuel cycle and reflector replacement strategies, in that the final ^{14}C content of these components will impact the available storage and disposal options. That is, at a certain content, these components will no longer be able to be disposed of as Class C low level radioactive waste. As such, this data is necessary prior to final determination of the NGNP fuel cycle and reflector replacement strategies.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Much of the needed data can be developed based on fairly simple laboratory experiments. The impact of irradiation on nitrogen release may be assessed based on either historical data or first principles calculations. The results of these assessments can be used to determine the need for measurements of irradiated material.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.1.1.0

DDN Revision: 01

DDN Title: Tribology – Test on Expected Couples of Materials in Representative HTGR Conditions

DDN Category: Materials

DDN Description:

This DDN is established to identify, evaluate and quantify the interactions between materials at their interfaces under representative NGNP conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

The following will be needed for each material couple tested, under each environmental condition:

- Friction factors (including static, sliding, impact, etc)
- Wear rates of each material as a function of interface force
- Material loss/dust generation characteristics

Materials couples to be considered are:

- Metal/Metal
- Metal/Graphite
- Graphite/Graphite

Environmental conditions considered during the tests should include all expected normal operation helium coolant chemistries, and temperatures. Accident conditions should also be considered in cases where material interactions are important to safety or investment protection.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Tribological effects may have significant impact on the choice of materials for certain components or may require investigation of use of material coatings to alleviate negative impacts. As such, at least preliminary data is needed by the latter stages of the conceptual design process to validate material choices.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite (described in INL/EXT-07-13165, "Graphite Technology Development Plan") include determination of the required tribological information for the preferred graphite types of the three NGNP vendors (AREVA, GA and Westinghouse/PBMR). Similar information for metals and other material types, including ceramics and composites, should be developed in a similar manner.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1a

DDN Revision: 01

DDN Title: Thermal Properties of Alloy 800H

DDN Category: Materials

DDN Description:

Alloy 800H is one of the materials being considered for use in the HTGR design. Some foreseen applications for 800H exceed the temperatures at which specific heat, thermal conductivity, and coefficient of thermal expansion data is readily available. Data for the emissivity of this material are needed at various temperatures and surface conditions as well.

The data needed in this section of this DDN is emissivity, thermal conductivity, specific heat, and coefficient of thermal expansion. Coefficient of thermal expansion information is required for the mechanical design of various components within the reactor coolant containment vessels. Emissivity, specific heat, and thermal conductivity data is needed to accurately predict component temperatures and heat removal from the reactor core during a shutdown conduction cooldown event.

Current State of Knowledge:

Specific heat, thermal conductivity, and thermal expansion data up to 1000°C is available in other standards, such as Germany's KTA 3221.1 Draft 1992 version Appendix 5. Any data obtained must meet the quality assurance requirements of 10CFR 50, Appendix B.

DDN REQUIREMENT

Data needed:

Property data for specific heat, thermal conductivity, and coefficient of thermal expansion for temperatures up to and including 1000°C is needed. The data for the coefficient of thermal expansion needs to be gathered and presented in a manner suitable for ASME Code approval and as described in ASME Section II, Part D, Appendix 5, 2007 Edition, 2008 Addenda. Property data for specific heat, thermal conductivity must be documented to meet the NRC's 10CFR 50, Appendix B quality assurance requirements.

Emissivity data needs to be collected for this material with a machined surface and an "as rolled" surface. Emissivity values are required for both fresh and aged material of both surface finishes described. Aging should be performed in an HTGR environment as follows:

- No aging (new material)
- At 325°C for minimum of 1000 hours
- At 750°C for a minimum of 1000 hours
- Previously aged material 325°C heated to 625°C for 200 hours

In each case the material will be allowed to cool naturally while maintaining an HTGR environment. Data should be provided at 200°C increments between 200°C and 1000°C for each of the aged material conditions and surface finishes described above. if the material produces an emissivity value less than .6, or comparison of the aged vs. fresh material indicates that aging reduces emissivity, research will be required to develop a surface that produces emissivity of .6 or greater that can withstand the HTGR environment.

ASTM testing standards should be employed whenever possible.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

06/01/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) One alternative to not completing this DDN is to use a different material that will withstand the conditions and that useful data exists. However, there are a limited number of choices and the information in question is limited for any of those choices.
2) Another alternative is to allow large enough design margin to accommodate the uncertainty in the limited available data. Where applicable, data could be extrapolated from similar materials in order to reduce uncertainties.

Selected Design Approach and Fallback:

The design approach is to use the specific heat, thermal expansion, and thermal conductivity data from the KTA standard until it (or other) data can be QA'd and prepared. For design, an emissivity value of .6 will be assumed. The fallback position would be to research different materials for one that has the required data and that meets all physical requirements of the design. The consequence is that it would likely require more work and time to have the material approved for use by ASME than the testing in question and there is no guarantee that a suitable material can be found that has reliable property data for all factors required to support it.

Project Risks:

1) Risk to project of not running test:

Not running the test is not really an option and poses a high risk to the project as there is likely no material available with the required property database that will perform as needed. There is a low risk to the project by postponing testing for specific heat, thermal expansion, and thermal conductivity. The preliminary information provided in the KTA specification could be used until proven "QA'd" data can be assembled. Emissivity and the effects on emissivity due to aging in an HTGR environment need to be known early in the conceptual design.

2) Risk of getting unfavorable data from test:

There is little risk of getting unfavorable data from the testing for specific heat, thermal expansion, and thermal conductivity. The risk to the project is much greater of getting unfavorable emissivity results. If new or aged material does not produce emissivity greater than .6, R&D must be performed to find a suitable means of producing a surface emissivity of .6 or greater that will retain its emissivity over time. Dependant upon what method is found to gain the surface emissivity required, there could be untimely design changes and schedule setbacks. The later into the project these changes occur, the greater the risk to the project.

Importance of New Data:

As described above, the emissivity data need is very important. The remaining data described above is less important; however, it will be needed before the design can be approved.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

<u>DDN ISSUE</u>

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1b

DDN Revision: 01

DDN Title: Thermal Properties of 9Cr1Mo

DDN Category: Materials

DDN Description:

9Cr1Mo is one of the materials being considered for use in the HTGR design. Data for the emissivity of this material are needed at various temperatures and surface conditions.

Emissivity data is needed to accurately predict component temperatures and heat removal from the reactor core during a shutdown conduction cooldown event.

Current State of Knowledge:

Emissivity data as described has not yet been found to exist. Any data obtained must meet the quality assurance requirements of 10CFR 50, Appendix B.

DDN REQUIREMENT

Data needed:

Emissivity data needs to be collected for this material with a machined surface and an "as rolled" surface. Emissivity values are required for both fresh and aged material of both surface finishes described. Aging should be performed in an HTGR environment as follows:

- No aging (new material)
- At 325°C for minimum of 1000 hours
- At 650°C for a minimum of 1000 hours
- Previously aged material 325°C heated to 625°C for 200 hours

In each case the material will be allowed to cool naturally while maintaining an HTGR environment. Data should be provided at 200°C increments between 150°C and 650°C for each of the aged material conditions and surface finishes described above. if the material produces an emissivity value less than .6, or comparison of the aged vs. fresh material indicates that aging reduces emissivity, research will be required to develop a surface that produces emissivity of .6 or greater that can withstand the HTGR environment.

ASTM testing standards should be employed whenever possible.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

06/01/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) One alternative to not completing this DDN is to use a different material that will withstand the conditions and that useful data exists. However, there are a limited number of choices and the information in question is limited for any of those choices.
2) Another alternative is to allow large enough design margin to accommodate the uncertainty in the limited available data. Where applicable, data could be extrapolated from similar materials in order to reduce uncertainties.

Selected Design Approach and Fallback:

For design, an emissivity value of .6 will be assumed. The fallback position would be to research different materials for one that has the required data and that meets all physical requirements of the design. The consequence is that it would likely require more work and time to have the material approved for use than the testing in question and there is no guarantee that a suitable material can be found that has reliable property data for all factors required to support it.

Project Risks:

1) Risk to project of not running test:

Not collecting the data is not really an option and poses a high risk to the project as there is likely no material available with the required property database that will perform as needed. Emissivity and the effects on emissivity due to aging in an HTGR environment need to be known early in the conceptual design.

2) Risk of getting unfavorable data from test:

The risk to the project is considerable for getting unfavorable emissivity results. If new or aged material does not produce emissivity greater than .6, R&D must be performed to find a suitable means of producing a surface emissivity of .6 or greater that will retain its emissivity over time. Dependant upon what method is found to gain the surface emissivity required, there could be untimely design changes and schedule setbacks. The later into the project these changes occur, the greater the risk to the project.

Importance of New Data:

As described above, the emissivity data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

<u>DDN ISSUE</u>

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1c

DDN Revision: 01

DDN Title: Corrosion Effects on Alloy 800H in a HTGR Environment

DDN Category: Materials

DDN Description:

Information is needed to understand the effect of long-term exposure to a HTGR environment (temperature and the chemical makeup of the coolant) on representative base metal and weldment. Information is needed for the cause and effect of surface degradation and thermal aging on material properties.

Current State of Knowledge:

There is a large amount of information from the former German HTGR program available for this material used at elevated temperatures in a helium coolant environment.

DDN REQUIREMENT

Data needed:

An evaluation is needed of the type and severity of corrosion encountered in a HTGR environment at various temperatures ranging from 325°C to 1000°C. Some high temperature data may be for short term (accident condition) durations. Temperature and duration (hours) to be determined (TBD) later.

- Corrosion rate
- Pitting
- Stress corrosion cracking

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Use conservative allowances to ensure adequate life of the product

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of extended periods of time in a HTGR environment for various components which operate at different temperatures. The fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a low risk to the project by postponing testing for the effects of corrosion. There is a high risk to the project if these tests are not performed due to the complications of seeking NRC approval without data to quantify appropriate margins.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from testing for corrosion effects. Assumptions can be made for corrosion effects. The later into the project that confirmed corrosion data becomes available, the greater the risk to the project.

Importance of New Data:

As described above, the corrosion data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1d

DDN Revision: 01

DDN Title: Corrosion Effects on 9Cr1Mo in a HTGR Environment

DDN Category: Materials

DDN Description:

Information is needed to understand the effect of long-term exposure to a HTGR environment (temperature and the chemical makeup of the coolant) on representative base metal and weldment. Information is needed for the cause and effect of surface degradation.

Current State of Knowledge:

While there may be information available for this material used at elevated temperatures in a helium coolant environment, the primary coolant chemical makeup is yet undecided as is the allowable or average level of various impurities. Once the level of impurities allowed in this design are decided, a better assessment can be made.

DDN REQUIREMENT

Data needed:

An evaluation is needed of the type and severity of corrosion encountered in a HTGR environment at various temperatures ranging from 425°C to 650°C. Sufficient mechanical property data are required to determine the effects of corrosion and thermal aging in this temperature range for up to 60 years. Some high temperature data may be for short term (accident condition) durations. Temperature and hours to be determined (TBD) later. The mechanical properties in question are: (all time dependent and fatigue testing to be performed in a primary coolant atmosphere)

- Corrosion rate
- Pitting
- Stress corrosion cracking

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Use conservative allowances to ensure adequate life of the product

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of extended periods of time in a HTGR environment for various components which operate at different temperatures. The fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a low risk to the project by postponing testing for the effects of corrosion. There is a high risk to the project if these tests are not performed due to the complications of seeking NRC approval without data to quantify appropriate margins.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from testing for corrosion effects. Assumptions can be made for corrosion effects. The later into the project that confirmed corrosion data becomes available, the greater the risk to the project.

Importance of New Data:

As described above, the corrosion data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1e

DDN Revision: 01

DDN Title: Irradiation Effects on Alloy 800H in a HTGR Environment

DDN Category: Materials

DDN Description:

Alloy 800H is one of the materials being considered for use in the HTGR design for various components. Information is needed to understand the effect of irradiation on material properties at various temperatures on representative base metal and weldment.

Current State of Knowledge:

- Data does exist from the former German program

DDN REQUIREMENT

Data needed:

Irradiated material property data in a HTGR environment at various temperatures ranging from 325°C to 1000°C is needed to ensure sufficient design. The design life of the components that this material is to be used for is 60 years. Fluence levels and HTGR atmosphere are to be determined (TBD) at a later date. The mechanical properties in question are: (all time dependent and fatigue testing to be performed in a primary coolant atmosphere)

- Minimum ultimate elongation
- Fracture toughness
  - Critical stress intensity factor
  - Fatigue crack growth rate (dn/dt)
  - Creep crack growth rate (da/dt)
- Creep properties
  - Minimum creep rupture stress
  - Minimum stress to a strain of 1%
- High cycle fatigue strength to TBD cycles
- Low cycle fatigue parameters TBD
- Material swelling
- Crack growth testing (SCC)
- Thermal conductivity

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

<u>DDN IMPORTANCE</u>

Alternatives to DDN Completion:

1) Choose an alternate material
2) Allow extra margin in the design to account for limited data (only applicable for postponing completion)

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of irradiation on 800H in a HTGR environment for various components which operate at different temperatures. The fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a high risk to the project by not testing for material properties after irradiation. It may be very difficult to obtain NRC licensing approval without knowing all environmental effects on the material properties used for design of safety related components.

2) Risk of getting unfavorable data from test:

There is a medium risk of getting unfavorable data from the testing for irradiation effects on material properties. The effects of irradiation on material properties could necessitate finding a material replacement. If this happens, the later into the project this change occurs, the greater the risk to the project.

Importance of New Data:

As described above, the irradiated material data need is important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1f

DDN Revision: 01

DDN Title: Irradiation Effects on 9Cr1Mo in a HTGR Environment

DDN Category: Materials

DDN Description:

9Cr1Mo is one of the materials being considered for use in the HTGR design for various components. Information is needed to understand the effect of irradiation on material properties at various temperatures on representative base metal and weldment.

Current State of Knowledge:

A 9Cr1Mo welded joint has been irradiated at ~ 400°C up to an integrated fast fluence corresponding to a lifetime of 60 years for the reactor vessel, and tested for mechanical properties at operating temperature and at 550°C.

DDN REQUIREMENT

Data needed:

Irradiated material property data in a HTGR environment at various temperatures ranging from 325°C to 650°C is needed to ensure sufficient design. The design life of the components that this material is to be used for is 60 years. Fluence levels and HTGR atmosphere are to be determined (TBD) at a later date. The mechanical properties in question are: (all time dependent and fatigue testing to be performed in a primary coolant atmosphere)

- Minimum ultimate elongation
- Fracture toughness
  - Critical stress intensity factor
  - Fatigue crack growth rate (dn/dt)
  - Creep crack growth rate (da/dt)
- Creep properties
  - Minimum creep rupture stress
  - Minimum stress to a strain of 1%
- High cycle fatigue strength to TBD cycles
- Low cycle fatigue parameters TBD
- Material swelling
- Crack growth testing (SCC)
- Thermal conductivity

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Allow extra margin in the design to account for limited data (only applicable for postponing completion)

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of irradiation on 9Cr1Mo in a HTGR environment for various components which operate at different temperatures. The fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a high risk to the project by not testing for material properties after irradiation. It may be very difficult to obtain NRC licensing approval without knowing all environmental effects on the material properties used for design of safety related components.

2) Risk of getting unfavorable data from test:

There is a medium risk of getting unfavorable data from the testing for irradiation effects on material properties. The effects of irradiation on material properties could necessitate finding a material replacement. If this happens, the later into the project this change occurs, the greater the risk to the project.

Importance of New Data:

As described above, the irradiated material data need is important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1g

DDN Revision: 01

DDN Title: Material Properties of Alloy 800H in a HTGR Environment up to [1000°C]

DDN Category: Materials

DDN Description:

Material properties are needed for Alloy 800H up [1000°C] for a design life of 60 years including the effects of the HTGR environment where applicable.

Current State of Knowledge:

There is a lot of data already available. This data needs to be reviewed against the requirements of 10CFR Appendix B and ASME to ensure it can be accepted by both. Testing is required to fill any voids in existing data.

DDN REQUIREMENT

Data needed:

Mechanical properties are needed for Alloy 800H in a HTGR environment at various temperatures up to [1000°C] for a design life of 60 years. Some high temperature data may be for short term (accident condition) durations. Chemical makeup of the HTGR environment, short term excursion hours, and excursion temperatures are to be determined (TBD) later. The mechanical properties in question are: (all time dependent and fatigue data to be gathered both in air and in a primary coolant atmosphere)
Properties as described in ASME Section III, Subsection NH

- Sm – time independent allowable stress
- Smt – time dependent allowable stress
- So – Maximum allowable primary membrane stress
- St – Minimum creep stress to rupture
- Sy – Yield strength
- R – Ratio of weld metal and base metal creep rupture strength (See NH for weld material)
- Sr – Minimum stress-to-rupture strength
- Isochronous stress strain curves extended to [1000°C] and 60 years
- Strain range vs. number of allowable cycles (Appendix T NH)

Other properties needed

- Modulus of elasticity
- Shear Modulus
- Fracture toughness
    - Critical stress intensity factor
    - Fatigue crack growth rate (dn/dt)
    - Creep crack growth rate (da/dt)

- Creep properties
  - Minimum creep stress to cause tertiary creep
  - Minimum stress to a strain of 1%
  - Creep rate
- High cycle fatigue strength to TBD cycles
- Low cycle fatigue parameters TBD

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

<u>DDN IMPORTANCE</u>

Alternatives to DDN Completion:

1) Choose an alternate material
2) Use existing available data with conservative estimation of HTGR atmospheric effects

Selected Design Approach and Fallback:

The design approach is to use the data generated for the design of various components which operate at different temperatures and with proper consideration of the effects of the HTGR atmosphere. The fallback position is to use existing available data with conservative estimation of HTGR atmospheric effects and of any material data not yet available.

Project Risks:

1) Risk to project of not running test:

There is a high risk to the project by not testing for the properties described. The information is needed for design and there is a high probability that a suitable replacement material with the required material database would not be found.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from the testing. Considerable information is already available but in a draft or non-QA'd form. The later into the project that this information is gathered and/or confirmed, the greater the risk to the project.

Importance of New Data:

As described above, the data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

<u>DDN ISSUE</u>

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.3.1h

DDN Revision: 01

DDN Title: Material Properties of 9Cr1Mo in a HTGR Environment up to [650°C]

DDN Category: Materials

DDN Description:

Material properties are needed for 9Cr1Mo up [650°C] for a design life of 60 years including the effects of the HTGR environment where applicable.

Current State of Knowledge:

ASME Section III, Subsection NH contains material data up to [650°C] in air.

DDN REQUIREMENT

Data needed:

Mechanical properties are needed for 9Cr1Mo in a HTGR environment at various temperatures up to [650°C] for a design life of 60 years. Some high temperature data may be for short term (accident condition) durations. Chemical makeup of the HTGR environment, short term excursion hours, and excursion temperatures are to be determined (TBD) later. The mechanical properties in question are: (all time dependent and fatigue data to be gathered both in air and in a primary coolant atmosphere)
Properties as described in ASME Section III, Subsection NH

- Isochronous stress strain curves extended to [650°C] and 60 years
- Strain range vs. number of allowable cycles (Appendix T NH)
- Fracture toughness
  - Critical stress intensity factor
  - Fatigue crack growth rate (dn/dt)
  - Creep crack growth rate (da/dt)
- Creep properties
  - Minimum creep stress to cause tertiary creep
  - Minimum stress to a strain of 1%
- High cycle fatigue strength to TBD cycles
- Low cycle fatigue parameters TBD

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

<u>DDN IMPORTANCE</u>

Alternatives to DDN Completion:

1) Choose an alternate material
2) Provide margin to account for the possible effects of the NGNP atmosphere

Selected Design Approach and Fallback:

The design approach is to use the data generated for the design of various components which operate at different temperatures and with proper consideration of the effects of the HTGR atmosphere. The fallback position is to provide margin to account for the possible effects of the NGNP atmosphere.

Project Risks:

1) Risk to project of not running test:

There is a high risk to the project by not testing for the properties described. The information is needed for design and there is a possibility that a suitable replacement material with the required material database would not be found. The affect of the NGNP atmosphere will likely be needed for NRC approval.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from the testing. The NGNP atmosphere is not expected to have a very large impact on material properties. The later into the project that this information is gathered and/or confirmed, the greater the risk to the project.

Importance of New Data:

As described above, the data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.1a

DDN Revision: 01

DDN Title: Irradiation Effects on SA-508 and SA-533 in a HTGR Environment

DDN Category: Materials

DDN Description:

SA-508 and SA-533 is one of the materials being considered for use in the HTGR design for various components. Both specifications are basically the same material, SA-508 is for forgings and SA-533 is for plate. Information is needed to understand the effect of irradiation on material properties at various temperatures.

Current State of Knowledge:

There is vast knowledge of the effects of irradiation on this material due to its use in light water reactors. It is unknown what data exists for the effect of irradiation at elevated temperatures such as those seen by NGNP.

DDN REQUIREMENT

Data needed:

Irradiated material property data in a HTGR environment at various temperatures ranging from 100°C to 538°C is needed to ensure sufficient design. The design life of the components that this material is to be used for is 60 years. Fluence levels, HTGR atmosphere, material thickness, and hold time and temperature are to be determined (TBD) at a later date. The mechanical properties in question are: (all time dependent and fatigue data to be gathered in a primary coolant atmosphere on both product forms listed)

- Minimum ultimate elongation
- Fracture toughness
  - Critical stress intensity factor
  - Fatigue crack growth rate (dn/dt)
  - Creep crack growth rate (da/dt)
- Creep properties
  - Minimum creep stress to cause tertiary creep
  - Minimum stress to a strain of 1%
- High cycle fatigue strength to TBD cycles
- Low cycle fatigue parameters TBD
- Material swelling
- Crack growth testing (SCC)
- Thermal conductivity

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Allow extra margin in the design to account for limited data (only applicable for postponing completion)
3) Install irradiation test capsules within the reactor vessel to determine the effect real time

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of irradiation on the material in a HTGR environment for various components which operate at different temperatures. One fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a medium risk to the project by not testing for material properties after irradiation. The fluence levels on light water reactor are much greater than those of NGNP and the effect is well established; however, the effect of irradiation at elevated temperatures is less clear. It may be very difficult to obtain NRC licensing approval without knowing all environmental effects on the material properties used for design of safety related components.

2) Risk of getting unfavorable data from test:

There is a medium risk of getting unfavorable data from the testing for irradiation effects on material properties. The effects of irradiation on material properties could necessitate finding a material replacement. If this happens, the later into the project this change occurs, the greater the risk to the project.

Importance of New Data:

As described above, the irradiated material data need is important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.1b

DDN Revision: 01

DDN Title: Time Dependent Material Properties of SA-533 and SA-508 in a HTGR Environment

DDN Category: Materials

DDN Description:

Material properties are needed for SA-533 and SA-508 with consideration of the effects of the HTGR environment.

Current State of Knowledge:

ASME Code Case N-499-1 contains material properties in the creep regime for SA-533 and SA-508. What are needed are the effects of the HTGR environment on these properties.

DDN REQUIREMENT

Data needed:

Mechanical properties are needed for SA-533 and SA-508 in an HTGR environment. ASME Code Case N-499-1 lists temperature and hour limits that may be used for design. The materials will need to be tested in a HTGR environment for the accumulative temperature and time limits provided by the Code Case. The chemical makeup of the HTGR environment will be determined (TBD) later.

The following data is needed in air and HTGR environment

- Fracture toughness
  - Critical stress intensity factor
  - Fatigue crack growth rate (dn/dt)
  - Creep crack growth rate (da/dt)

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2012

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Provide margin to account for the possible effects of the HTGR atmosphere

Selected Design Approach and Fallback:

The design approach is to use ASME Code Case N-499-1 for design with proper consideration of the effects of the HTGR atmosphere. The fallback position is to provide margin to account for the possible effects of the HTGR atmosphere.

Project Risks:

1) Risk to project of not running test:

There is a high risk to the project by not testing for the data described. The affect of the HTGR atmosphere will likely be needed for NRC approval.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from the testing. The HTGR atmosphere is not expected to have a very large impact on material properties. The later into the project that this information is gathered and/or confirmed, the greater the risk to the project.

Importance of New Data:

As described above, the data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.1c

DDN Revision: 01

DDN Title: Corrosion Effects on SA-508 and SA-533 in a HTGR Environment

DDN Category: Materials

DDN Description:

Information is needed to understand the effect of long-term exposure to a HTGR environment (temperature and the chemical makeup of the coolant). Information is needed for the cause and effect of surface degradation.

Current State of Knowledge:

There is little experience with using this material in a HTGR environment and the exact NGNP environment has yet to be defined. Once the level of impurities allowed in this design are decided, a better assessment can be made.

DDN REQUIREMENT

Data needed:

An evaluation is needed of the type and severity of corrosion encountered in a HTGR environment at various temperatures ranging from 325°C to 538°C. Sufficient mechanical property data are required to determine the effects of corrosion and thermal aging in this temperature range for up to 60 years. The material is to be tested for 3000 hours at 427°C and also at 1000 hours at 538°C. Other temperature temperature/time excursions may be determined later. The mechanical properties in question are:

- Corrosion rate
- Pitting
- Stress corrosion cracking

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

04/30/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Choose an alternate material
2) Use conservative allowances to ensure adequate life of the product

Selected Design Approach and Fallback:

The design approach is to use the data generated to quantify the effects of extended periods of time in a HTGR environment for various components which operate at different temperatures. The fallback position is to use conservative allowances to ensure adequate life of the product.

Project Risks:

1) Risk to project of not running test:

There is a low risk to the project by postponing testing for the effects of corrosion. There is a high risk to the project if these tests are not performed due to the complications of seeking NRC approval without data to quantify appropriate margins.

2) Risk of getting unfavorable data from test:

There is a low risk of getting unfavorable data from testing for corrosion effects. Assumptions can be made for corrosion effects. The later into the project that confirmed corrosion data becomes available, the greater the risk to the project.

Importance of New Data:

As described above, the corrosion data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.1d

DDN Revision: 01

DDN Title: Emissivity of SA-508 and SA-533

DDN Category: Materials

DDN Description:

SA-508 and SA-533 is one of the materials being considered for use in the HTGR design. Data for the emissivity of this material are needed at various temperatures and surface conditions. Both specifications are for the same material but in different product form, forging and plate.

Emissivity data is needed to accurately predict component temperatures and heat removal from the reactor core during a shutdown conduction cooldown event.

Current State of Knowledge:

Emissivity data as described below has not yet been found to exist. Any data obtained must meet the quality assurance requirements of 10CFR 50, Appendix B.

DDN REQUIREMENT

Data needed:

Emissivity data needs to be collected for this material with a machined surface and an “as rolled” surface. Emissivity values are required for both fresh and aged material of both surface finishes described. Aging should be performed in an HTGR environment as follows:

- No aging (new material)
- At 325°C for minimum of 1000 hours
- At 427°C for a minimum of 1000 hours
- 538°C for a minimum of 1000 hours

In each case the material will be allowed to cool naturally while maintaining an HTGR environment. Data should be provided at 200°C increments between 150°C and 538°C for each of the aged material conditions and surface finishes described above. if the material produces an emissivity value less than .6, or comparison of the aged vs. fresh material indicates that aging reduces emissivity, research will be required to develop a surface that produces emissivity of .6 or greater that can withstand the HTGR environment.

ASTM testing standards should be employed whenever possible.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

06/01/2010

DDN IMPORTANCE

Alternatives to DDN Completion:

1) One alternative to not completing this DDN is to use a different material that will withstand the conditions and that useful data exists. However, there are limited choices within the ASME Code and the information in question is limited for any of those choices.
2) Another alternative is to allow large enough design margin to accommodate the uncertainty in the limited available data. Where applicable, data could be extrapolated from similar materials in order to reduce uncertainties.

Selected Design Approach and Fallback:

For design, an emissivity value of .6 will be assumed. The fallback position would be to research different materials for one that has the required data and that meets all physical requirements of the design. The consequence is that it would likely require more work and time to have the material approved for use by ASME than the testing in question and there is no guarantee that a suitable material can be found that has reliable property data for all factors required to support it.

Project Risks:

1) Risk to project of not running test:

Not running the test is not really an option and poses a high risk to the project as there is likely no material available with the required property database that will perform as needed. Emissivity and the effects on emissivity due to aging in an HTGR environment need to be known early in the conceptual design.

2) Risk of getting unfavorable data from test:

The risk to the project is considerable for getting unfavorable emissivity results. If new or aged material does not produce emissivity greater than .6, R&D must be performed to find a suitable means of producing a surface emissivity of .6 or greater that will retain its emissivity over time. Dependant upon what method is found to gain the surface emissivity required, there could be untimely design changes and schedule setbacks. The later into the project these changes occur; the greater the risk to the project.

Importance of New Data:

As described above, the emissivity data need is very important.

Schedule Priority:

Schedule priority of this DDN execution is high (start in next two years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.2a

DDN Revision: 01

DDN Title: Vessel Field Fabrication Process Control and Property Control

DDN Category: Materials

DDN Description:

The NGNP pressure vessels are too large to fabricate in a shop and deliver to the job site whole. Methods and processes will need to be developed for on-site welding and post weld heat treatment (PWHT) of these vessels.

Current State of Knowledge:

Welding and PWHT of the proposed vessel material (SA-533 and SA-508) are very well understood.

DDN REQUIREMENT

Data needed:

What is needed are conceptual processes and tooling to perform this large scale fabrication work on site. The processes and tooling will need to mocked up and a qualification program undertaken to ensure the success of the tooling and processes. Metallurgical testing will be needed as part of this qualification program. The metallurgical requirements and specific vessel weld configurations will be set at a later date.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

06/01/2012

DDN IMPORTANCE

Alternatives to DDN Completion:

The alternative is to design modular reactor units small enough to accommodate shop fabrication or to limit NGNP site locations to those that have barge access.

Selected Design Approach and Fallback:

The design approach is to fabricate the vessels on site by welding together segments manufactured in a fabrication shop. The fallback position is to limit NGNP to sites with barge access.

Project Risks:

1) Risk to project of not running test:

Not performing this qualification could cause a substantial redesign of the NGNP if smaller modules are chosen as the fallback position. The current design offers the best economy for the operation of the plant.

2) Risk of getting unfavorable data from test:

The risk to the project is considerable for getting unfavorable qualification results of the tooling and processes. This successful qualification is vital to the success of the project. However, given the existing knowledge of vessel manufacture with these materials, there is a low risk of getting unfavorable results. It is more a matter of ensuring that processes and equipment are ready when needed.

Importance of New Data:

As described above, this development and qualification is very important.

Schedule Priority:

Schedule priority of this DDN execution is medium (start in next four years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.2b

DDN Revision: 01

DDN Title: Vessel Inspection

DDN Category: Materials

DDN Description:

The NGNP pressure vessels will require periodic inspection to ensure reliable operation. Inspection techniques that can be delivered remotely as well as real-time monitoring will need to be developed. Other components contained within the vessel may need integrity monitoring as well.

Current State of Knowledge:

Numerous inspection methods are used to determine the integrity of pressure vessels and piping throughout the world. Development of these methods for use in the unique environment imposed by the NGNP is needed.

DDN REQUIREMENT

Data needed:

What is needed are conceptual processes and tooling to perform vessel weld inspections in the NGNP environment. In some cases real-time monitoring may be needed. These processes will need to be approved by the NRC. Specific weld configurations and component inspection needs have yet to be developed, nor has proposed NDE methods been decided. This data need is unique as the design entities and those developing inspection and integrity monitoring methods need to work together to ensure that the design can accommodate post construction inspection and integrity monitoring.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

Full scale test should be required

Need Date:

06/01/2012

DDN IMPORTANCE

Alternatives to DDN Completion:

The alternative is to design the vessels around existing inspection methods.

Selected Design Approach and Fallback:

The design approach is to design the vessels and/or components in a manner that will ensure successful post construction inspection. The fallback position is to design the vessels around existing inspection methods.

Project Risks:

1) Risk to project of not running test:

Not performing this development could result in some welds or features that cannot be properly inspected after construction.

2) Risk of getting unfavorable data from test:

N/A

Importance of New Data:

As described above, this development program is important.

Schedule Priority:

Schedule priority of this DDN execution is medium (start in next four years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.2.4.3

DDN Revision: 01

DDN Title: Validation of a RPV Sealing Device

DDN Category: Materials

DDN Description:

The current concept is to provide a removable reactor vessel head with flexible metallic seal to prevent loss of coolant. A development program needs to be conducted to design a sealing solution that can withstand the NGNP environment.

Current State of Knowledge:

Flexible metallic seals are currently used in light water reactors and have been used in test scale high temperature gas-cooled reactors as well.

DDN REQUIREMENT

Data needed:

What is needed is development of a sealing solution for the NGNP reactor vessel closure head. The exact dimensions, temperatures, transients, pressures, and chemical makeup of the primary coolant have yet to be determined.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

06/01/2012

DDN IMPORTANCE

Alternatives to DDN Completion:

The alternative is to design the reactor vessel with a seal welded head.

Selected Design Approach and Fallback:

The design approach is to design the reactor vessel with a removable flexible metallic seal. The fallback approach is to design the vessel with head welded in place or an omega type welded seal around the circumference.

Project Risks:

1) Risk to project of not running test:

Not performing this development could result in untimely design changes.

2) Risk of getting unfavorable data from test:

If a flexible metallic seal cannot be developed that can withstand the NGNP environment, design changes will need to be made. The later in the project that this can be answered the higher the risk to the project.

Importance of New Data:

As described above, this development program is very important.

Schedule Priority:

Schedule priority of this DDN execution is medium (start in next four years).

Critical Issues:

N/A

DDN ISSUE

Preparer: Duane Spencer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1a

DDN Revision: 01

DDN Title: Control Rods – Thermal-Physical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Thermal-physical properties (including k, CTE, Cp and emissivity) will need to be determined for each proposed type of composite (or when a selection has been made). CTE is very dependent on the structure of the carbon-based composite and can be significantly altered by neutron irradiation. Therefore, CTE is critical in determining dimensional changes due to temperature change in the material. Thermal conductivity should be fully characterized for the composite material chosen. A correlation of thermal conductivity as a function of irradiation and temperature needs to be developed. Specific heat values need to be defined as well.

These properties are needed to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Thermal-physical properties including k, CTE, Cp, emissivity

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If the thermal-physical properties of the proposed types of composites are not obtained or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1b

DDN Revision: 01

DDN Title: Control Rod – Mechanical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Mechanical properties will need to be determined for each proposed type of composite (or when a selection has been made). This includes elastic constants necessary to determine the stresses to the selected composite and material strength (multiaxial, tensile, etc).

These properties are needed to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Mechanical properties including elastic constants and material strength

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If the mechanical properties of the proposed types of composites are not obtained or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1c

DDN Revision: 01

DDN Title: Control Rod – Fracture Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

The fracture properties will need to be determined for each proposed type of composite (or when a selection has been made). The enhanced fracture properties of continuous fiber composites are some of the primary reasons why they are envisioned for use in the NGNP.

These properties are needed to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fracture properties

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If the fracture properties of the proposed types of composites are not obtained or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1d

DDN Revision: 01

DDN Title: Control Rod – Fatigue Strength

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Fatigue strength will need to be determined for each proposed type of composite (or when a selection has been made).

This property is necessary to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fatigue strength

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If the fatigue strength of the proposed types of composites is not obtained or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1e

DDN Revision: 01

DDN Title: Control Rod – Oxidation Characteristics and Effects on Material Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Carbon-based composite materials are susceptible to increasingly rapid oxidation at temperatures greater than 500°C. Oxidation characteristics and oxidation effects on control rod material properties will therefore need to be determined for each proposed type of composite (or when a selection has been made).

These properties are necessary to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Oxidation characteristics of the control rod material and oxidation effects on the control rod material properties

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If the oxidation characteristics of the proposed types of composites are not obtained or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1f

DDN Revision: 01

DDN Title: Control Rod – Irradiation and Testing of Mockups

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Irradiation and testing of mockups will need to be performed for each proposed type of composite (or when a selection has been made) to assess irradiation characteristics and their effects on material properties as well as on the mockup as a whole.

These tests are necessary to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Irradiation and testing of mockups

Data Range/Service Conditions:

Under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If irradiation and testing of mockups of the proposed types of composites are not performed or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.1.1g

DDN Revision: 01

DDN Title: Control Rod – Development of Fabrication and Qualification Methods

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different control rod material alternatives are being considered. Later during conceptual design, a decision will be made. Materials currently envisioned are C/C, SiC/SiC or C/SiC composites although other options such as hybrid or metal rods are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Fabrication and qualification methods will need to be developed for each proposed type of composite (or when a selection has been made).

These methods are necessary to ensure that the control rods will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fabrication and qualification methods

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use metallic rods with proper restrictions
2) Use hybrid rods (metallic and ceramic components)

Selected Design Approach and Fallback:

Selected approach: A design selection for control rod material and detailed design configuration has not been made yet. Ceramic rods are the current reference. C/C, SiC/SiC and C/SiC ceramics have been used before in other industries. The use of composites for control rods is suggested by the high temperatures to which the control rods are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as control rod or other nuclear applications is not proven.
Hybrid (metal and ceramic) rods are being considered as part of anticipated conceptual design studies. Additionally, metallic rods are an acceptable interim solution if appropriate operational constraints (higher investment risk) are taken into account. All options are being actively considered in order to meet anticipated design requirements.

Fallback position: The hybrid (metal and ceramic) rod design is the current fallback position.

If the necessary properties for the selected approach are not obtained, it will be eliminated as an option and the hybrid option will be pursued. Or an additional fallback option will have to be identified.

Project Risks:

If fabrication development and qualification methods for the proposed types of composites fail or results are unfavorable, the hybrid design (or an additional fallback option) will be pursued.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1a

DDN Revision: 01

DDN Title: Upper Core Restraints – Thermal-Physical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Thermal-physical properties (including k, CTE, Cp and emissivity) will need to be determined for each proposed type of composite (or when a selection has been made). CTE is very dependent on the structure of the carbon-based composite and can be significantly altered by neutron irradiation. Therefore, CTE is critical in determining dimensional changes due to temperature change in the material. Thermal conductivity should be fully characterized for the composite material chosen. A correlation of thermal conductivity as a function of irradiation and temperature needs to be developed. Specific heat values also need to be defined as well.

These properties are needed to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Thermal-physical properties including k, CTE, Cp, emissivity

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If the thermal-physical properties of the proposed types of composites are not obtained or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1b

DDN Revision: 01

DDN Title: Upper Core Restraints – Mechanical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Mechanical properties will need to be determined for each proposed type of composite (or when a selection has been made). This includes elastic constants necessary to determine the stresses to the selected composite and material strength (multiaxial, tensile, etc).

These properties are needed to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Mechanical properties including elastic constants and material strength

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If the mechanical properties of the proposed types of composites are not obtained or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1c

DDN Revision: 01

DDN Title: Upper Core Restraints – Fracture Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

The fracture properties will need to be determined for each proposed type of composite (or when a selection has been made). The enhanced fracture properties of continuous fiber composites are some of the primary reasons why they are envisioned for use in the NGNP.

These properties are needed to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fracture properties

Data Range/Service Conditions: TBD

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If the fracture properties of the proposed types of composites are not obtained or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1d

DDN Revision: 01

DDN Title: Upper Core Restraints – Fatigue Strength

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Fatigue strength will need to be determined for each proposed type of composite (or when a selection has been made).

This property is necessary to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fatigue strength

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If the fatigue strength of the proposed types of composites is not obtained or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1e

DDN Revision: 01

DDN Title: Upper Core Restraints – Oxidation Characteristics and Effects on Material Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Carbon-based composite materials are susceptible to increasingly rapid oxidation at temperatures greater than 500°C. Oxidation characteristics and oxidation effects on upper core restraint material properties will therefore need to be determined for each proposed type of composite (or when a selection has been made).

These properties are necessary to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Oxidation characteristics of the upper core restraint material and oxidation effects on the upper core restraint material properties

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If the oxidation characteristics of the proposed types of composites are not obtained or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1f

DDN Revision: 01

DDN Title: Upper Core Restraints – Irradiation and Testing of Mockups

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Irradiation and testing of mockups will need to be performed for each proposed type of composite (or when a selection has been made) to assess irradiation characteristics and their effects on material properties as well as on the mockup as a whole.

These tests are necessary to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Irradiation and testing of mockups

Data Range/Service Conditions:

Under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If irradiation and testing of mockups of the proposed types of composites are not performed or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.2.1g

DDN Revision: 01

DDN Title: Upper Core Restraints – Development of Fabrication and Qualification Methods

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different upper core restraint material alternatives are being considered. Later during conceptual design, a decision will be made. Previously, Alloy 800H was the primary candidate. Material backup options currently envisioned are C/C, SiC/SiC or C/SiC composites. All options are being actively considered to meet anticipated design requirements. This DDN focuses on the need for data on the C/C, SiC/SiC and C/SiC composites.

Fabrication and qualification methods will need to be developed for each proposed type of composite (or when a selection has been made).

These methods are necessary to ensure that the upper core restraints will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.

DDN REQUIREMENT

Data Needed:

Fabrication and qualification methods

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use other metal or composite materials.

Selected Design Approach and Fallback:

Selected approach: A design selection for upper core restraint material and detailed design configuration has not been made yet. Alloy 800H was the first choice in the past, but all options are being actively considered in order to meet anticipated design requirements.

Fallback position: C/C, SiC/SiC and C/SiC ceramics have been used before in other industries.
The use of composites for upper core restraints is suggested by the high temperatures to which the restraints are exposed during off-normal conditions. Although many composites are relatively mature materials, their use as upper core restraints or other nuclear applications is not proven.

If the necessary properties for the fallback option are not obtained, it will be eliminated as an option and the metallic option will have to be pursued, even if detailed analysis shows that significant reduction in reactor operating envelope is required as a consequence. Or an additional fallback option will have to be identified.

Project Risks:

If fabrication development and qualification methods for the proposed types of composites fail or results are unfavorable, the metallic design (or an additional fallback option) will have to be pursued although it may reduce margins or operating conditions in the reactor.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.6.1a

DDN Revision: 01

DDN Title: Ceramic Insulation – Thermal-Physical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different ceramic insulation alternatives are being considered. Later during conceptual design, a decision will be made.

Thermal-physical properties (including k, CTE and Cp – CTE and Cp for solid rigid material selection) will need to be determined for each proposed material (or when a selection has been made) under normal and accident temperatures. CTE is critical in determining dimensional changes due to temperature change in the material. Thermal conductivity should be fully characterized for the ceramic material chosen. A correlation of thermal conductivity as a function of irradiation and temperature needs to be developed. Specific heat values need to be defined as well. Values will be collected as-received and under irradiation.

These properties are needed to ensure that the insulation will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

Data exists for some candidate materials from previous HTGR programs.

DDN REQUIREMENT

Data Needed:

Thermal-physical properties (k, CTE, Cp, etc as applicable)

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

A selected approach has not been determined yet. Options are being considered (such as kaowool, solid ceramics, etc). A decision will be made during conceptual design and fallback options will be determined at that time.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.6.1b

DDN Revision: 01

DDN Title: Ceramic Insulation – Mechanical Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different ceramic insulation alternatives are being considered. Later during conceptual design, a decision will be made.

Mechanical properties will need to be determined for each proposed material (or when a selection has been made) over the expected temperature range. This includes rigidity, frangibility, friability, resistance to vibration and acoustic loading, etc. Values will be collected as-received and under irradiation.

These properties are needed to ensure that the insulation will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Mechanical properties (including rigidity, frangibility, friability, resistance to vibration and acoustic loading, etc)

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

A selected approach has not been determined yet. Options are being considered (such as kaowool, solid ceramics, etc). A decision will be made during conceptual design and fallback options will be determined at that time.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.3.6.1c

DDN Revision: 01

DDN Title: Ceramic Insulation – Oxidation Characteristics and Effects on Material Properties

DDN Category: Materials

DDN Description:

Material selection has not been performed yet although different ceramic insulation alternatives are being considered. Later during conceptual design, a decision will be made.

Oxidation characteristics and oxidation effects on ceramic insulation properties will need to be determined for each proposed material (or when a selection has been made). Values will be collected as-received and under irradiation.

These properties are needed to ensure that the insulation will perform as intended during normal and off-normal conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Oxidation characteristics of ceramic insulation and oxidation effects on ceramic insulation properties

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

A selected approach has not been determined yet. Options are being considered (such as kaowool, solid ceramics, etc). A decision will be made during conceptual design and fallback options will be determined at that time.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0a

DDN Revision: 01

DDN Title: Graphite – Thermal-Physical Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the thermal-physical properties of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

Physical and mechanical characterization of as fabricated PCEA and NGB-17 has been performed. Some irradiation data have already been acquired.

DDN REQUIREMENT

Data Needed:

The following thermal-physical properties must be established for the identified grades of nuclear graphite:

- Thermal Expansion
- Thermal Conductivity
- Specific Heat
- Emissivity

These properties should be established for as-fabricated graphite material, including examination of variations introduced by the fabrication process. In addition, the impact of anticipated environmental conditions of temperature and neutron fluence, as well as the impact of oxidation of the graphite, should also be considered. **The current reference design core inlet temperature of 325°C is below the minimum temperature of the current AGC test program.**

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, "Graphite Technology Development Plan". This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0b

DDN Revision: 01

DDN Title: Graphite – Mechanical Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the mechanical properties of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

Physical and mechanical characterization of as fabricated PCEA and NGB-17 has been performed. Some irradiation data have already been acquired.

DDN REQUIREMENT

Data Needed:

The following mechanical properties must be established for the identified grades of nuclear graphite:

- Static and Dynamic Elastic Modulus
- Shear Modulus
- Poisson's Ratio
- Creep Poisson's Ratio
- Strength
- Strain to Failure
- Fracture Toughness
- Multi-Axial Failure Criteria

These properties should be established for as-fabricated graphite material, including examination of variations introduced by the fabrication process. In addition, the impact of anticipated environmental conditions of temperature and neutron fluence should also be considered. **The current reference design core inlet temperature of 325°C is below the minimum temperature of the current AGC test program.**

In addition to these basic mechanical properties, the irradiation creep behavior and the tribological properties of the graphite grades must also be determined.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, "Graphite Technology Development Plan". This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0c

DDN Revision: 01

DDN Title: Graphite – Physical Characteristics

DDN Category: Materials

DDN Description:

This DDN is established to determine the physical properties of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

Physical and mechanical characterization of as fabricated PCEA and NGB-17 has been performed. Some irradiation data have already been acquired.

DDN REQUIREMENT

Data Needed:

In order to support development of thermal, mechanical and physical models for nuclear graphite grades, determination of the following microstructural characteristics are required:

- Grain size and distribution
- Morphology/anisotropy
- Pore size and distribution
- Material density

These characteristics should be determined for as-fabricated graphite material, including examination of variations introduced by the fabrication process. In addition, the impact of anticipated environmental conditions of temperature and neutron fluence should also be considered. **The current reference design core inlet temperature of 325°C is below the minimum temperature of the current AGC test program.**
In addition to microstructural characteristics, the macroscopic changes in graphite volume and density are required as a function of neutron dose.

In order to support development of radionuclide transport and release models, the permeability, tortuosity, connected pore structure should be determined both for as-fabricated and irradiated graphite. **These properties are not currently included in the work scope for the Graphite Technology Development Plan and should be added.**

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, “Graphite Technology Development Plan”. This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0d

DDN Revision: 01

DDN Title: Graphite – Fracture Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the local fracture properties of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Significant uncertainty exists as to the stress state of any graphite component in the core. Moreover, the strength of the components changes with dose, temperature, and creep strain. The combination of these factors makes the probability of local failure, graphite spalling, and possible blockage of a coolant channel in a reactivity control block difficult to determine. An assessment of localized surface effects, particularly identification of potential local failure modes and frequencies, as a function of graphite neutron dose and temperature must be made. **The current reference design core inlet temperature of 325°C is below the minimum temperature of the current AGC test program.**

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:
Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, “Graphite Technology Development Plan”. This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized. **Specific observation and assessment of graphite surface effects must be included in the data gathering activities associated with this program.**

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0e

DDN Revision: 01

DDN Title: Graphite – Fatigue Strength

DDN Category: Materials

DDN Description:

This DDN is established to determine the reduction in strength due to fatigue for nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The extent to which the selected graphite grades suffer from fatigue reduction in strength must be determined for both unirradiated and irradiated graphite. Prior data show this to be a small effect; however, confirmation may be necessary. It is anticipated that these tests or evaluations may include assessment of the impacts of multi-axial stress effects.
The current reference design core inlet temperature of 325°C is below the minimum temperature of the current AGC test program.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available.

DDN IMPORTANCE

Alternatives to DDN Completion:

Review of existing fatigue test data, coupled with comparative analysis of other mechanical test data from both older and current graphite grades may be sufficient to justify use of existing fatigue strength models.

Selected Design Approach and Fallback:

Materials fatigue testing of both as-fabricated and irradiated graphite samples should be conducted to confirm limited reduction in strength due to cyclic fatigue loadings. Should such testing reveal unexpected reductions in material strength, a more significant test program will be required to evaluate the impacts on expected graphite performance. Should testing not be performed, review of existing fatigue test data coupled with comparative analysis of other mechanical test data from both older and current graphite grades may be sufficient to justify use of existing fatigue strength models.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0f

DDN Revision: 01

DDN Title: Graphite – Air Oxidation Characteristics and Effect on Material Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the air oxidation characteristics of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The oxidation rate of graphite during off-normal, air-ingress events is required to determine the effect of oxidation on the specific graphite properties as well as the entire core performance. Kinetic models resulting from experimental data will be required to predict weight loss. Additionally, thermal and mechanical testing of previously oxidized material will need to be performed to determine the chronic effects oxidation may have on graphite material properties. Mechanical and thermal properties will be investigated from both acute and chronic oxidized material. The affects due to chemical and physical (pores) differences for each graphite type will be required.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, "Graphite Technology Development Plan". This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0g

DDN Revision: 01

DDN Title: Graphite – Water/Steam Oxidation Characteristics and Effect on Material Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the water/steam oxidation characteristics of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures. The properties data will be used to qualify such graphite grades for use under NGNP operational and accident conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The oxidation rate of graphite during off-normal, water/steam-ingress events is required to determine the effect of oxidation on the specific graphite properties as well as the entire core performance. Kinetic models resulting from experimental data will be required to predict weight loss. Additionally, thermal and mechanical testing of previously oxidized material will need to be performed to determine the chronic effects oxidation may have on graphite material properties. Mechanical and thermal properties will be investigated from both acute and chronic oxidized material. The affects due to chemical and physical (pores) differences for each graphite type will be required.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:
TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, "Graphite Technology Development Plan". This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized. **As currently configured, this test and qualification effort considers only air oxidation, not water/steam oxidation. Sufficient testing should be added to identify differences in oxidation kinetics and morphology between air and water/steam environments. Differences in material properties impacts must also be assessed.**

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.1.0h

DDN Revision: 01

DDN Title: Graphite – Impure Helium Oxidation Characteristics and Effect on Material Properties

DDN Category: Materials

DDN Description:

This DDN is established to determine the oxidation characteristics of nuclear grade graphite anticipated to be used for NGNP fuel elements and core structures under long term operation in an impure helium environment. The properties data will be used to qualify such graphite grades for use under NGNP operational conditions, either through formulation of ASME/ASTM codes and standards or by focused evaluation of expected performance in the NGNP. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be qualified under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

The oxidation rate of graphite during normal operation in an impure helium environment is required to determine the effect of oxidation on the specific graphite properties as well as the entire core performance. Kinetic models resulting from experimental data will be required to predict weight loss. Additionally, thermal and mechanical testing of previously oxidized material will need to be performed to determine the chronic effects oxidation may have on graphite material properties. Mechanical and thermal properties will be investigated from both acute and chronic oxidized material. The affects due to chemical and physical (pores) differences for each graphite type will be required.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Completed qualification of the identified graphite grades, at least for irradiation conditions expected during the first few cycles of operation, is required to support final submittal of the NGNP licensing documentation to the NRC as well as production of the NGNP graphite components. Longer term impacts of higher neutron fluences may need to be evaluated and submitted after initial licensing activities have been completed. Initial conceptual design activities can proceed based on available data, with refinement of the design as additional data becomes available. Current schedules anticipate approval of the ASME code case for nuclear graphite components as well as implementation of ASTM specifications, should be possible in the 2016 time frame.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Current plans, related to test and qualification of nuclear grade graphite, are described in INL/EXT-07-13165, "Graphite Technology Development Plan". This plan includes the preferred graphite types of the three NGNP vendors, AREVA, GA, and Westinghouse/PBMR. Amongst these preferred graphite types are several alternates that are primarily considered for security of supply. However, in the event that the primary preferred grade does not achieve successful qualification within the time required, these may also be utilized.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.2.0a

DDN Revision: 01

DDN Title: Interactions between Graphite Components and Key Radionuclides

DDN Category: Phenomena

DDN Description:

This DDN is established to determine the interactions between selected types of nuclear grade graphite, anticipated to be used for NGNP fuel elements and core structures, and key radionuclides. This data will be used to support modeling of fission product and activation product release from, and transport within, the core graphite structures. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be considered under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Data needed for transport model development includes:

- Radionuclide transport rates through the graphite
- Sorbtivity of graphite
- Fluence effect on transport in graphite
- Radionuclide speciation in carbonaceous material and during mass transport
- Radionuclide absorption and deabsorption on graphite surfaces

Impacts of chemical forms of radionuclides on transport, holdup and chemical reactivity should be considered and examined. The examination should also include impacts of graphite oxidation during air and water ingress events.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

Should sufficient historical data be available, such data could be used to reasonably bound expected fluence effects in the more modern graphite grades.

Selected Design Approach and Fallback:

Much of the needed phenomenological data can be generated based on fairly simple laboratory bench testing of individual chemical species determined to be of interest. Evaluation of fluence effects will require development of more elaborate test programs. An alternate to such testing may be possible should sufficient historical data be available to reasonably bound expected fluence effects in the more modern graphite grades.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.2.0b

DDN Revision: 01

DDN Title: Fission Product Uptake and Release in Dust and Transport by Dust

DDN Category: Phenomena

DDN Description:

This DDN is established to determine the uptake and release characteristics of various key radionuclides in graphite dust. In addition, the impacts of contained radionuclides on dust transport and mobility are also to be assessed. This data will be used to support modeling of fission product and activation product transport within, and release from, the NGNP reactor.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Data needed for model development includes radionuclide absorption and deabsorption on graphite dust surfaces as well as retention within the dust particles. The impact of the contained radionuclides on dust transport, including the impacts of chemical activity and electrostatic effects, should also be investigated.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Much of the needed phenomenological data can be generated based on fairly simple laboratory bench testing of individual chemical species determined to be of interest, or developed based on review of historical data. Since the differences between the various grades of graphite are not expected to be retained in the dust for, testing of the individual graphite grades is not considered necessary at this time.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.2.0c

DDN Revision: 01

DDN Title: Graphite/FP Interactions – Empirical Release Rate Coefficients

DDN Category: Phenomena

DDN Description:

This DDN is established to explore development of effective fission product release rate coefficients (empirical constants) as an alternative to development of detailed phenomenological models. These coefficients would include impacts of graphite oxidation during air and water ingress events. This data would be used to support modeling of fission product and activation product release from, and transport within, the core graphite structures. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be considered under this DDN.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Data needed to support this DDN include integrated radionuclide release rates for various graphite configurations and environments.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to support development of radionuclide transport models that will form one part of the set of codes used to evaluate the dose consequences of various accident and operational scenarios. Since these models are necessary to proceed into preliminary design, the data is needed prior to that time.

DDN IMPORTANCE

Alternatives to DDN Completion:

Develop detailed phenomenological models.

Selected Design Approach and Fallback:

The key to development of effective release rate coefficients is to determine representative graphite configurations, radionuclide species and operational environments. Once these have been determined, a series of experiments can be conducted to assess integrated radionuclide release as a function of appropriate independent variables. Should development of such coefficients be deemed to be too costly or difficult to produce useable results, development of detailed phenomenological models would be pursued.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 2.4.3.0

DDN Revision: 01

DDN Title: Graphite Machineability

DDN Category: Materials

DDN Description:

This DDN is established to review the various fabrication techniques necessary to produce a finished graphite fuel or reflector block from a graphite billet. Of particular concern are the positional tolerances achievable when drilling fuel and coolant holes through the block. Based on evaluation of available nuclear graphite grades, AREVA recommends that GrafTech PCEA and SGL NBG-17 be considered under this DDN.

Current State of Knowledge:

Some of the needed data identified below may exist at graphite manufacturers' for some of the identified grades.

DDN REQUIREMENT

Data Needed:

Key data needed to support this DDN are fabrication parameters determined to achieve the optimum positional tolerances for fuel and reflector block holes. Such data may include, amongst other things:

- Drill type and geometry
- Drill material
- Drill rotational speed
- Drill insertion force

Data describing the best repeatable hole configuration are also required, including

- Hole diameter distribution
- Hole drift distribution over the block length

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

This data is needed to develop a final design for the fuel and reflector blocks, which must be reflected in final core design calculations. In addition, it must also be completed prior to the required start of fuel fabrication activities. As such, completion of this DDN prior to the start of preliminary design is recommended.

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

This data will be developed by reviewing historical fabrication practices as well as conducting various fabrication test runs to establish the required optimal parameters. This data will be integrated into the final fuel block design to assure an appropriate balance between core performance and fabricability.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: John Mayer

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.1.0a

DDN Revision: 01

DDN Title: Primary Gas Circulator Impeller Tests in Air

DDN Category: SSCs

DDN Description:

Haynes Alloy 718 is a candidate for the impeller material because of its high creep strength at design temperatures. Final material selection, however, will be made during conceptual design.

Air tests at ambient temperature and pressure need to be performed to characterize the aerodynamic efficiency of the impeller design at least at scale 0.2 to 0.4. Large air test loops are available in manufacturer facilities.

These are standard small scale tests which will be performed prior to selection of final impeller design.

Current State of Knowledge:

These types of tests are routinely performed by impeller manufacturers. Therefore, the current state of knowledge is high.

DDN REQUIREMENT

Data Needed:

Air tests of the impeller at scale 0.2 to 0.4 to characterize the fluid dynamics and harmonics of the impeller, and establish its efficiency.

Data Range/Service Conditions:

Air tests at ambient temperature and pressure

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Design impeller based on existing impeller test data.

Selected Design Approach and Fallback:

Selected approach: Impeller tests in air will be performed prior to selection of final impeller design.

Fallback position: Manufacturers have different families of impellers. The model with the best performance based on the NGNP operating conditions (flow rates, head, etc) will be selected. In the event that the selected impeller does not perform well in the air tests, a different impeller will be selected. Moreover, should the air tests not take place; the impeller will be designed based on existing impeller test data. This could cause the impeller to not be as well optimized as it could have been with the air tests.

Performing air tests of the impeller enables better characterization of the operational performance of the circulator. Additionally, it allows for the aerodynamic and mechanical design of the circulator to be validated ahead of time against the operational requirements of the NGNP. The results of testing in air allow generation of a model to predict performance in the helium environment because the physical phenomenon (ideal gas law) is well understood.

Project Risks:

If testing in air is performed (prior to final impeller design selection) and the results are unsatisfactory, a different family of impeller will be selected and tested. Should the air tests not take place, design based on existing impeller test data (or another fallback option) will be performed.

Due to the high state of knowledge, however, project risks are low.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.1.0b

DDN Revision: 01

DDN Title: Primary Gas Circulator Magnetic and Catcher Bearing Tests in Air

DDN Category: SSCs

DDN Description:

Active magnetic bearings will be used to avoid any lubricating product ingress in the primary circuit.

To validate the performance of the primary gas circulator magnetic and catcher bearings, tests must be performed in air. The tests will use bearing mockups in a configuration having characteristics similar to those of the circulator.

Current State of Knowledge:

The state of knowledge is mature. These tests are routinely performed by manufacturers.

DDN REQUIREMENT

Data Needed:

Magnetic and catcher bearing tests to validate performance of catcher and magnetic bearings

Data Range/Service Conditions:

In air

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

Design bearings based on existing generic information for magnetic and catcher bearings (without testing).

Selected Design Approach and Fallback:

Selected approach: Perform tests in air to validate performance of catcher and magnetic bearings (before installation in the vessel).

Fallback position: If the selected bearings do not pass air testing, different types of bearings could be selected. If air testing does not occur, the bearings will be designed based on existing generic information for magnetic and catcher bearings. This would require more conservative design margins and final confirmation would not be received until after the integrated tests are performed.

Performing testing of bearings prior to installation enables better characterization of the operational performance of the circulator.

Project Risks:

If testing in air is performed (prior to installation) and the results are unsatisfactory, alternate bearing designs will be selected and tested. If preliminary testing of the bearings in air does not occur, the bearings will be designed based on existing generic information (or another fallback option will be selected).

Due to the high state of knowledge, however, project risks are low.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.1.0c

DDN Revision: 01

DDN Title: Primary Gas Circulator Shutoff Valve Testing

DDN Category: SSCs

DDN Description:

The circulator shutoff valve prevents possible reverse flow (potentially hot) from the reactor core onto cold primary structures in case of conduction cooldown situations and also avoids core bypass in shutdown conditions when the SCS is in operation.

Primary gas circulator shutoff valve testing must take place to demonstrate that the circulator starts without stalling under the load imposed by the shutoff valve. The test must be performed under startup, normal and transient conditions.

While testing in helium would be ideal, this is primarily an aerodynamics test. Therefore, testing in air would be acceptable. A decision will be made when circulator design work is initiated and details of this test will be discussed with the circulator vendor.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Air tests of the primary gas circulator shutoff valves. Testing should provide opening and closing speed of the valve, pressure drop across the valve as a function of the valve position relative to the gas flow rate, as well as demonstration of repeated operation without valve failure.

Data Range/Service Conditions:

In air under startup, normal and transient conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Preliminary design

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Perform test in helium
2) Test the valve during startup

Selected Design Approach and Fallback:

Selected approach: Perform testing in air prior to installation.

Fallback position: Perform testing in helium during commissioning. Fallback options will be discussed in detail when a circulator vendor has been selected and a plan will be developed with said vendor.

The tests in air will validate the performance of the valve prior to high temperature testing in conjunction with the circulator. Performing air tests of the impeller enables better characterization of the operational performance of the circulator as it allows for the valve design to be validated ahead of time against the operational requirements of the NGNP. The results of testing in air allow generation of a model to predict performance in the helium environment because the physical phenomenon (ideal gas law) is well understood.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.1.0d

DDN Revision: 01

DDN Title: Primary Gas Circulator – Integrated Full Size Test

DDN Category: SSCs

DDN Description:

The integrated test of a primary gas circulator is not a typical DDN topic but it was determined that it would still be addressed.

Integrated testing will be done in air at the manufacturer's facility as a component confirmatory test and similarity laws to be applied for helium as this is routinely done by manufacturers. The main purpose of this testing in air is final acceptance of the design to make sure that the circulator was assembled properly by the manufacturer.

It is anticipated that detailed design issues will already have been addressed through separate effects tests and scaling analysis.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Integrated testing of a full scale circulator

Data Range/Service Conditions:

In air at manufacturer's facility under normal and accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Medium priority – Following fabrication of the circulator and prior to shipment to NGNP site

DDN IMPORTANCE

Alternatives to DDN Completion:

Perform helium tests in the NGNP during commissioning.

Selected Design Approach and Fallback:

Selected approach: Integrated testing of a full scale circulator in air at the manufacturer's facility.

Fallback position: Helium tests in the NGNP during commissioning.

The integrated test in air will validate the performance of the circulator. Performing air tests enables better characterization of the operational performance of the circulator. Additionally, it allows for the design to be validated ahead of time against the operational requirements of the NGNP. The results of testing in air allow generation of a model to predict performance in the helium environment because the physical phenomenon (ideal gas law) is well understood.

If helium tests in the NGNP fail, repairs will have to be done in the NGNP which would likely incur schedule delays and increase cost.

Project Risks:

If integrated testing in air is performed and the results are unsatisfactory or not obtained, confirmatory testing in air in the NGNP (or another fallback option) will be performed. The impeller design may also have to be reassessed should integrated testing not be successful. Using the above fallback positions could incur schedule delays and cost increases.

However, if air test are performed at the manufacturer's facility, the potential for damage in the NGNP will be negligible.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.5.0a

DDN Revision: 01

DDN Title: Hot Gas Ducts – Elementary Tests of Subcomponents

DDN Category: SSCs

DDN Description:

The hot gas ducts transport the primary helium coolant between the reactor and the steam generator. The design will be selected and defined during conceptual design. Currently, the reference design for the hot gas duct is the metallic concept. The ceramic concept is envisioned as a fallback option.

The need for discrete testing of the individual parts of the hot gas ducts such as spacers, bellows, etc has been identified. Testing of the hot gas duct subcomponents will confirm their adequacy and represents the first step in qualifying the hot gas ducts. In the first stages of the design and until final selection has been made, tests should cover both the metallic and ceramic concepts.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Discrete testing of the hot gas duct subcomponents (specifics to be defined as design matures)

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Add increased design margin
2) Accept the risk of reduced performance

Final confirmation of performance of the subcomponents will be acquired as part of the integrated test.

Selected Design Approach and Fallback:

Selected Approach: Perform discrete testing of the hot gas duct subcomponents.

Fallback position: If discrete testing of the subcomponents does not occur, the fallback position is to accept the risk of reduced performance in which case final confirmation of performance of the subcomponents will be acquired as part of the integrated test. If integrated testing does not provide acceptable results, the subcomponents may have to be reassessed which would incur schedule risks.

The fallback option could incur schedule delays and cost increases if the integrated test is not satisfactory. Performing discrete testing of the subcomponents allows for better characterization of the system. Any potential issues can be solved faster and on a subcomponent level.

Project Risks:

If discrete testing of the hot gas duct subcomponents does not take place or the results of testing are not satisfactory, the integrated test of the hot gas duct will verify performance of the subcomponents. Failure of the integrated test would likely incur schedule delays and cost increases as the design of some subcomponents may have to be reassessed.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.5.0b

DDN Revision: 01

DDN Title: Hot Gas Ducts – Helium Tests on Small Mockup in Test Facility

DDN Category: SSCs

DDN Description:

The hot gas ducts transport the primary helium coolant between the reactor and the steam generator. The design will be selected and defined during conceptual design. Currently, the reference design for the hot gas duct is the metallic concept. The ceramic concept is envisioned as a fallback option.

Helium tests should be performed on a small mockup (1MW or less) in a test facility. The following tests, as a minimum, should be performed: depressurization; pressure loss, heat loss and temperature of the support tube; leak tightness tests of connection areas; fatigue and creep-fatigue tests (bellows, spacers, etc); and potential for ceramic fiber release from insulation during normal operation and transients.

These tests represent the second step to qualifying the hot gas ducts. In the first stages of the design and until final selection has been made, tests should cover both the metallic and ceramic concepts.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Helium testing on small mockup (specifics to be defined later)
The following tests, at a minimum, should be covered:

- depressurization
- pressure loss, heat loss, temperature of the support tube
- leak tightness tests of the connection areas
- fatigue and creep-fatigue tests (bellows, spacers, etc)
- potential for ceramic fiber release from insulation during normal operation and transients

Data Range/Service Conditions:

In helium, under normal operating conditions, under transient conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

<u>DDN IMPORTANCE</u>

Alternatives to DDN Completion:

Increase design margins to accommodate increased risk.

Selected Design Approach and Fallback:

Selected Approach: Perform helium tests on small hot gas duct mockup in test facility.

Fallback position: If the results of helium testing are not satisfactory, the detailed design of the concept will have to be reassessed and design margins increased to accommodate increased risk. If the helium tests are not performed, potential issues with the hot gas ducts would not be detected until the large integrated test which would likely incur schedule delays and cost increases.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

<u>DDN ISSUE</u>

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.5.0c

DDN Revision: 01

DDN Title: Hot Gas Ducts – Tests on Full Scale Mockup in Helium

DDN Category: SSCs

DDN Description:

The hot gas ducts transport the primary helium coolant between the reactor and the steam generator. The design will be selected and defined during conceptual design. Currently, the reference design for the hot gas duct is the metallic concept. The ceramic concept is envisioned as a fallback option.

The potential need for helium tests to be performed on a full scale mockup in a large test facility (around 10 MW) has been identified. Such tests would study the integrated performance of the system. The following tests, as a minimum, should be performed: depressurization; pressure loss, heat loss and temperature of the support tube; leak tightness tests of connection areas; fatigue and creep-fatigue tests (bellows, spacers, etc); and potential for ceramic fiber release from insulation during normal operation and transients.

These tests represent the third step to qualifying the hot gas ducts. In the first stages of the design and until final selection has been made, tests should cover both the metallic and ceramic concepts.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Helium testing on full scale mockup (specifics to be defined later)
The following tests, at a minimum, should be covered:

- depressurization
- pressure loss, heat loss, temperature of the support tube
- leak tightness tests of the connection areas
- fatigue and creep-fatigue tests (bellows, spacers, etc)
- potential for ceramic fiber release from insulation during normal operation and transients

Data Range/Service Conditions:

In helium, under normal operating conditions, under transient conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Selected Approach: Perform helium tests on a full scale hot gas duct mockup in a large test facility.

Fallback position: If the results of helium testing are not satisfactory, the detailed design of the concept will have to be reassessed. If the helium tests are not performed, potential issues with the hot gas ducts would not be detected until testing in the NGNP which would likely incur schedule delays and cost increases.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.6.0a

DDN Revision: 01

DDN Title: Steam Generator – Integrity Testing of Dissimilar Material Welding Joint in Tubes

DDN Category: SSCs

DDN Description:

The NGNP steam generator design selected is the helical coil type with helium flowing on the shell side and water/steam on the tube side. Although final selection will occur during conceptual design, currently, 2 ¼ Cr – 1 Mo steel is envisioned for the outer shell and part of the heat transfer tube while Alloy 800H is envisioned for the rest of the heat transfer tube.

The properties of the bimetallic welds at the evaporator and superheater tube bundle must be characterized in air at high temperature for qualification of the welding process. Tensile strength, creep and fatigue data need to be expanded.

Current State of Knowledge:

Steam generator manufacturers have extensive experience with dissimilar welds.

DDN REQUIREMENT

Data Needed:

Integrity testing of dissimilar material welding joints in steam generator tubes
Properties needed are: tensile strength, creep, fatigue, etc.

Data Range/Service Conditions:

In air at high temperatures

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Low priority – Final design

DDN IMPORTANCE

Alternatives to DDN Completion:

Use a steam generator design without dissimilar welds.

Selected Design Approach and Fallback:

Selected Approach: Use a helical coil steam generator with dissimilar welds. Although final selection will occur during conceptual design, currently, 2 ¼ Cr – 1 Mo steel is envisioned for the outer shell and part of the heat transfer tube while Alloy 800H is envisioned for the rest of the heat transfer tube. Therefore, bimetallic welds are needed between the evaporator and superheater regions.

Fallback position: No dissimilar welds. Use a single tube material (to be determined).

2 ¼ Cr – 1 Mo is envisioned up to the superheater region because of its corrosion resistance. Alloy 800H; on the other hand, performs better in the hottest locations. Therefore, temperatures may get too high in the superheater region to use 2 ¼ Cr – 1Mo and the corrosion properties of Alloy 800H not be strong enough to use the material in wet areas.

Using the fallback position could incur schedule delays and increase cost if the chosen material does not perform well as the only tube bundle material. In that case, tube bundle material selection may have to be reassessed.

Project Risks:

If dissimilar welds integrity testing fails or is not performed and the welding process cannot be qualified, then the steam generator tube bundle design or material may have to be reassessed. This could incur schedule delays and cost increases.

Due to the familiarity of steam generator manufacturers with dissimilar welds, projects risks are low.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.6.0b

DDN Revision: 01

DDN Title: Steam Generator – Circular Hot Header Manufacturability Development

DDN Category: SSCs

DDN Description:

A ring-shaped hot header is envisioned in the steam generator at the hot end. There is high confidence in the manufacturability of the hot header; however, the fabrication method has not been established for the required forging size.

Fabrication testing is therefore required and includes definition of the engineering processes for manufacturing the circular hot header for the helical tube steam generator.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Definition of the engineering processes for manufacturing the circular hot header

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

High/Medium priority – Beginning of final design

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Selected design: Ring-shaped hot header at the hot end of the helical tube steam generator.

Fallback position: A fallback option has not been selected yet. The flat conventional tube sheet currently used in light water reactors could be an option. The fabrication method for the flat conventional tube sheet is already established.

If flat conventional tube sheet design is selected, it would have to be reassessed for NGNP conditions.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.1.6.0c

DDN Revision: 01

DDN Title: Steam Generator – Engineering-Scale Demonstration

DDN Category: SSCs

DDN Description:

The NGNP steam generator design selected is the helical coil type with helium flowing on the shell side and water/steam on the tube side. While the design has not been completed, we anticipate that each steam generator will be on the order of 300 MWt.

An engineering-scale demonstration would be beneficial to reduce performance uncertainties and confirm thermal hydraulic performance, FIV performance, stability and controllability of the steam/water interface, and validation of the ISI equipment for the tubes. It is, however, not required for concept feasibility.

Power testing at one tenth scale will be adequate to meet these objectives.

Current State of Knowledge:

Helical coil steam generators have a long history of being used in operating reactors and reactor designs:

1) Helical coil steam generators have been built and used in the AGRs, Magnox, AVR, FSV (12 x 70MW modules), THTR (6 x 125MW)
2) Large HTGR designs using 500 MW helical coil steam generators (typically 4-6 loops) were developed and submitted to the NRC for licensing in the 70s
3) Modular HTGRs designs such as the MHTGR (350MW steam generators) and the HTR-module (200 MW steam generators) used helical coil steam generators

This experience would be adequate to build the NGNP steam generator. The only difference is that this experience was some time ago, therefore, access to personnel involved in their operation and design is limited. For that reason, it may be beneficial to run a new test.

DDN REQUIREMENT

Data Needed:

Engineering-scale demonstration of the steam generator
The following parameters should be measured: thermal hydraulic performance of the steam generator, flow stability/controllability and water/steam system control, flow-induced vibration behavior of tube bundle, in-service inspection of tubes, etc.

Data Range/Service Conditions:

Under design conditions

At 1/10th scale

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Low priority – During final design since the design has to be known for the test to be performed

DDN IMPORTANCE

Alternatives to DDN Completion:

Build the steam generator prototype, install it in the NGNP and perform confirmatory testing.

Selected Design Approach and Fallback:

Selected Approach: Perform an engineering-scale demonstration of the helical tube steam generator.

Fallback position: Build the steam generator prototype, install it in the NGNP and perform confirmatory testing. If separate engineering tests are not performed, the design may be required to be more conservative and include extensive analysis before installation.

Performing an engineering-scaled demonstration before commissioning allows for better characterization of the operational performance of the steam generator.

Project Risks:

The engineering-scale demonstration would be beneficial but it is not a high priority item. If the engineering-scale demonstration does not take place, the steam generator will be tested during commissioning. Although this presents some amount of risk in the event the tests are not satisfactory, the risks remain low because of the existing state of knowledge and the ability to design this component with adequate margins.

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.1.0

DDN Revision: 01

DDN Title: Helium Purification System – Charcoal Qualification

DDN Category: SSCs

DDN Description:

The Helium Purification System (HPS) controls the purity of the primary helium coolant. This is done to both maximize the lifetime of the reactor components and control circulating activity (by removing fission products). A small fraction of the primary coolant is continuously removed from the primary circuit and directed to filters, cold traps, and charcoal beds to remove impurities.

The type of charcoal used in the HPS will be selected during the commissioning phase. Once selection has been made, the charcoal will need to be qualified. Qualification involves obtaining numerous properties of the charcoal (thermal, physical, mechanical, etc) and some may be determined to be DDNs.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

TBD

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

During commissioning phase

DDN IMPORTANCE

Alternatives to DDN Completion:

Charcoal will be replaced periodically over the lifetime of the plant; therefore, the risk of not performing qualification tests (hence selecting "inappropriate" charcoal) is minimal. The charcoal will be changed out as necessary.

Selected Design Approach and Fallback:

Selected Approach: Perform qualification tests on the selected charcoal.

Fallback position: The optimum charcoal will be picked during the commissioning phase. Charcoal will be replaced periodically over the lifetime of the plant; therefore, the risk of selecting inappropriate charcoal is minimal.
If qualification tests are not performed and the selected charcoal is found to not be the optimal choice, it will be changed out as necessary.

Specifics will be (further) defined as design progresses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.3.0

DDN Revision: 01

DDN Title: Fuel Handling System – Material/Subcomponent Testing

DDN Category: SSCs

DDN Description:

The Fuel Handling System consists of a series of mechanisms and devices capable of transferring fuel and reflector blocks between the reactor core and the near reactor spent fuel storage location.

Specific tests of candidate materials for the Fuel Handling System seal, bearing and lubricant type need to be conducted. Tests and conditions will be specified during design of the system.
Qualification in small scale tests at normal pressure and temperature would likely be appropriate.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Tests of candidate materials for the Fuel Handling System seal, bearing and lubricant (specifics to be determined)

Data Range/Service Conditions:

Small scale tests at normal pressure and temperature conditions.

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Selected approach: Perform small scale tests of the candidate materials for the Fuel Handling System seal, bearing and lubricant.

Fallback position: Select new materials.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.4.0a

DDN Revision: 01

DDN Title: RCCS – Characterization of the Heat Transfer Characteristics of the Surface Treatments for the Reactor Vessel and the Panel Heat Exchanger

DDN Category: SSCs

DDN Description:

The primary function of the Reactor Cavity Cooling System (RCCS) is to protect the reactor cavity concrete from overheating during normal operation. It provides an alternate means of heat removal from the Reactor System to the environment when neither the Main Heat Transport System nor the Shutdown Cooling System is available.

Use of an uninsulated reactor vessel couple with water-cooled panels as a core cooling mechanism for accident conditions has not yet been fully demonstrated. Separate effects tests must be performed to characterize the heat transfer characteristics of the anticipated or proposed surface treatments for the reactor vessel and the panel heat exchanger. Heat transferred to the RCCS panels is removed via natural circulation within the tube panels, piping, and the water storage tank. This heat transfer mechanism requires detailed analytical modeling and may require validation testing. Additionally, the emissivity of the reactor pressure vessel and RCCS panel materials must be fully characterized over the range of conditions experienced during normal and accident operation.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Separate effects tests to characterize the heat transfer characteristics of the surface treatments for the reactor vessel and the panel heat exchanger. Emissivity data is needed as well.

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

Use alternate assumptions about emissivity or large uncertainties about emissivity in the analysis.

Selected Design Approach and Fallback:

Selected approach: Perform separate effects tests to characterize the heat transfer characteristics of the surface treatments for the reactor vessel and the panel heat exchanger.

Fallback position: Use alternate assumptions about emissivity or large uncertainties about emissivity in the analysis.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.4.0b

DDN Revision: 01

DDN Title: RCCS – Optional Large Scale Test

DDN Category: SSCs

DDN Description:

The primary function of the Reactor Cavity Cooling System (RCCS) is to protect the reactor cavity concrete from overheating during normal operation. It provides an alternate means of heat removal from the Reactor System to the environment when neither the Main Heat Transport System nor the Shutdown Cooling System is available.

A large scale demonstration of the capability of the RCCS to release the decay heat from the reactor may be beneficial. This type of test would ensure that important phenomena have not been disregarded. Additionally, it would ensure that the interactions between the different phenomena occurring in the RCCS are understood properly.

AREVA does not have a strong position on the need for a large scale test. While separate effects testing provides most precise information on critical parameters, large scale integrated testing may provide convincing confirmation for regulators. Licensing may be easier if a large scale test is performed.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Optional large scale test of the RCCS.

Data Range/Service Conditions:

Under irradiation, not under irradiation, under normal operating conditions, under accident conditions

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

Rely on detailed analysis and observe the performance of the system during reactor commissioning.

Selected Design Approach and Fallback:

Selected approach: Perform a large scale demonstration of the capability of the RCCS to release the decay heat from the reactor.

Fallback position: If tests are performed but the results are not satisfactory, redesign work will be performed on the RCCS. If the test is not performed, the fallback position is to rely on detailed analysis and observe the performance of the system during reactor commissioning.

Specifics of the test, including selected approach and fallback position, will be (further) defined as design progresses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.4.0c

DDN Revision: 01

DDN Title: RCCS – Characteristic Effects of Particulate and Plateout on Radiation Heat Transfer

DDN Category: SSCs

DDN Description:

The primary function of the Reactor Cavity Cooling System (RCCS) is to protect the reactor cavity concrete from overheating during normal operation. It provides an alternate means of heat removal from the Reactor System to the environment when neither the Main Heat Transport System nor the Shutdown Cooling System is available.

Tests must be performed to determine the effects of particulate, dust, and steam in the reactor cavity on radiation heat transfer. In fact, particulates can scatter radiant energy and act as a participating medium. Additionally, particulates may plateout on the cooler surface of the RCCS panels and reduce emissivity to the panels. Testing will characterize the overall effect of these impurities on the heat transfer from the RPV to the RCCS.

More examination is required during conceptual design to determine which tests will be required.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Effects of plateout and particulates on radiation heat transfer
More examination is required during conceptual design to determine which tests will be required.

Data Range/Service Conditions:

The type of facility needed remains to be determined. Tests will be performed under irradiation, not under irradiation, under normal operating conditions and under accident conditions.

More examination is required during conceptual design to determine which tests (and testing conditions) will be required.

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

<u>DDN IMPORTANCE</u>

Alternatives to DDN Completion:

Use different uncertainty assumptions in overall heat transfer analysis.

Selected Design Approach and Fallback:

Selected approach: Demonstrate, through testing (yet to be defined), the effects of particulate and plateout on radiation heat transfer. More examination is required during conceptual design to determine which tests will be required.

Fallback position: If testing is not performed, use different uncertainty assumptions in overall heat transfer analysis.

Specifics of the tests, including selected approach and fallback position, will be (further) defined as design progresses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

<u>DDN ISSUE</u>

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.5.0a

DDN Revision: 01

DDN Title: Instrumentation – R&D and Qualification of Pt-Rh Thermocouples

DDN Category: SSCs

DDN Description:

Platinum-Rhodium (Pt-Rh) thermocouples are used for high-temperature measurements as they can perform in inert or lightly oxidized environments (as the NGNP environment) with temperatures as high as 1300°C.

The identification of no feasibility issues for the Primary Loop Instrumentation Systems does not preclude the identification of new sensor research and development needs to meet NGNP safety and reliability goals as the design and licensing processes progress.

NGNP will be a test bed for testing and validating HTGR technology. It will include additional instrumentation beyond that required for normal operation in a commercial plant. FOAK instrumentation will be required, and special instrumentation to support future HTGR technology development missions may also be anticipated.

Temperature measurement sensors are currently available up to temperatures seen in the NGNP; however FOAK instrumentation may necessitate developmental testing. Some of the instrumentation in question will not be standard and potentially only used for the first few years of operation for testing purposes only. As design is being developed, use for that kind of testing could be anticipated and will be defined appropriately.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

R&D and qualification of Pt-Rh thermocouples (to be further defined)

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

No preferred or fallback options have been identified yet. It is anticipated that sensors will be used in the core and graphite structures. Specifics will be defined as design progresses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.5.0b

DDN Revision: 01

DDN Title: Instrumentation – Qualification Testing in Helium

DDN Category: SSCs

DDN Description:

The Primary Loop Instrumentation required for plant protection and Plant Control System measurements are commercially available but have not been used at NGNP operating pressures and temperatures. Testing is required to verify acceptable accuracy, sensitivity and lifetime. Demonstration and qualification testing will be performed in helium under simulated plant conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Qualification testing of Primary Loop Instrumentation in helium to verify acceptable accuracy, sensitivity and lifetime.

Data Range/Service Conditions:

In helium at expected reactor startup, normal, shutdown, and off-normal operating conditions.

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

TBD

Selected Design Approach and Fallback:

Selected approach: Qualification testing of Primary Loop Instrumentation in helium to verify acceptable accuracy, sensitivity and lifetime.

Fallback position: If qualification testing results are unacceptable, the instrumentation in question will have to be reassessed and a different instrument or technology may have to be used instead.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.3.5.0c

DDN Revision: 01

DDN Title: Instrumentation – In-Core Neutronics Measurement Sensor R&D for Qualification of CABERNET

DDN Category: SSCs

DDN Description:

Provide instrumentation to get additional neutronics data during operation for further methods qualification. In-core neutronics measurement sensors are only for use during the commissioning period to collect data for additional benchmarking and qualification of CABERNET while the NGNP is running. They are not required to last the lifetime of the plant. Moreover, since the sensors are optional and redundant, their reliability is not required to be as high as that of permanent sensors.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

In-core neutronics measurement sensor R&D for benchmarking and qualification of CABERNET

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Commissioning period

DDN IMPORTANCE

Alternatives to DDN Completion:

Use existing data and/or critical facility tests to benchmark the codes. Using existing commercial instruments cooled to stay within their limits could be another alternative.

Selected Design Approach and Fallback:

Selected approach: Install (new) sensors in the core (hot and cold ends) to obtain neutronic measurements.

Fallback position: If the new sensors do not get installed in the NGNP core, use existing data and/or critical facility tests to benchmark the codes. On the other hand, if the new sensors do not get developed, use existing commercial instruments and cool them to stay within their limits. This can be done by limiting their location to positions that stay within acceptable temperatures (including cooled channels if necessary).

Specific instrumentation required for the startup program will be identified as the program moves forward.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 3.4.1.0

DDN Revision: 01

DDN Title: Reactor Core – Test Block Interface Flow Characteristics

DDN Category: SSCs

DDN Description:

The helium bypass flow is a key parameter and a complex value to determine. Bypass at the interfaces between blocks (tiny gaps and misalignments) and the effects of potential cross flows and axial flows must be characterized under various conditions. Ranges of bypass flow expected in the NGNP will then be established. Such data can be used to develop integrated models to predict overall system behavior. Specifics of the tests will be defined as design progresses.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Tests in helium facility to determine bypass flow at the interfaces between blocks and assess the effects of potential cross flows and axial flows

Data Range/Service Conditions:

Under cold and hot conditions with blocks that simulate irradiated conditions.

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

TBD

DDN IMPORTANCE

Alternatives to DDN Completion:

Use conventional fluid mechanics data and include adequate uncertainties in bypass analysis.

Selected Design Approach and Fallback:

Selected approach: Perform tests (in helium facility) to determine bypass flow at the interfaces between blocks and assess the effects of potential cross flows and axial flows.

Fallback position: Use conventional fluid mechanics data and include adequate uncertainties in bypass analysis to take into account the fact that test data was unavailable.

Specifics of the tests, including selected approach and fallback position, will be (further) defined as design progresses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

N/A

DDN ISSUE

Preparer: Elisa Herd

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.1.1

DDN Revision: 01

DDN Title: Neutronics – Enhancement of Capabilities of CABERNET (Reactor Physics-Thermofluid Dynamic Coupling) for the Calculation of Transient Analyses

DDN Category: Codes/Methods

DDN Description:

CABERNET model enhancement to include short-term transient analysis capability to reactivity events for block type cores.

Current State of Knowledge:
TBD

DDN REQUIREMENT

Data needed:

CABERNET capabilities for transient analyses need to include calculations for reactivity, power, temperature, burnup, and fluence distribution for block type cores (input to fuel performance assessment).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Design with margins for accommodating larger uncertainties.

Selected Design Approach and Fallback:

The current approach to get short-term transient capability to reactivity events is to enhance CABERNET models for the calculation of transient analyses. The fallback position would be to accommodate larger uncertainties in the design.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

<u>DDN ISSUE</u>

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.1.2

DDN Revision: 01

DDN Title: Neutronics – Development of Cross-Section Data for Modeling in NEPHTIS

DDN Category: Codes/Methods

DDN Description:

Cross-section data is needed as input into NEPHTIS. Originally this DDN was written with a 950°C reactor in mind. Give the lower temperature of the NGNP now, existing cross-sections may be adequate.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Improved cross-section data may be needed for NEPHTIS. A review will be performed and some additional cross-sections may be required, but none are identified at this time.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Cross-section data for NEPHTIS is needed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use existing cross-section data
2) Modify design to account for slightly larger uncertainties

Selected Design Approach and Fallback:

If cross-section data cannot be obtained then existing cross-section data can be used or the design will be modified to account for slightly larger uncertainties.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.2.1a

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Modeling of RELAP5-3D

DDN Category: Codes/Methods

DDN Description:

This DDN is required to incorporate capabilities into RELAP5-3D necessary to model the NGNP system.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

RELAP5-3D modeling improvements to incorporate the following capabilities: model water ingress, air ingress, transport and graphite oxidation reactions, modeling HTGR components (improved circulator modeling) and ability to interface with other tools for data output (e.g. output core temperature maps vs. time as input into fuel performance calculations). A more detailed list of code modifications will be developed early in conceptual design once the planning for NGNP transient analysis has been completed.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use the appropriate existing code.

Selected Design Approach and Fallback:

The fallback position of not improving RELAP5-3D models is to use other appropriate existing codes.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.2.1b

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Coupling of CFD Models to RELAP5-3D

DDN Category: Codes/Methods

DDN Description:

Currently, RELAP5-3D is capable of coupling to the FLUENT CFD code. If the role of RELAP5-3D expands, there may be value to the project coupling the CFD code STAR-CD with RELAP5-3D to best utilize our investment in our STAR-CD models for the HTGR.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

RELAP5-3D capability to couple with STAR-CD.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Manually iterate between RELAP5-3D and STAR-CD.

Selected Design Approach and Fallback:

There is a need for RELAP5-3D to couple with STAR-CD to allow boundary conditions of each model to pass to the other. The selected design approach is to add capability to RELAP5-3D to allow this coupling. A fallback position would be to manually iterate between RELAP5-3D and STAR-CD.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.2.2

DDN Revision: 01

DDN Title: Thermal-Hydraulics – STAR-CD Graphite Oxidation Model Development for Water and Air Ingress

DDN Category: Codes/Methods

DDN Description:

There is a need to predict graphite oxidation rates during water and air ingress events to predict impact on graphite strength, off-gas production, and potential fission product release. Therefore oxidation models need to be developed to be used with STAR-CD to predict mass transfer rates and reaction rates of chemical species within graphite, water, and air.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data Needed:

Graphite oxidation model(s) should be implemented in Star-CD for simulation of air ingress and water ingress events under forced circulation and natural circulation conditions.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Prediction of graphite integrity during water and air ingress events is needed as early in the design process as possible, i.e. during preliminary design, to allow for proper design to mitigate the consequences of these ingress events.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Perform testing of representative graphite structures in conditions that simulate water and air ingress events
2) Design with additional oxidation allowance margins

Selected Design Approach and Fallback:

If graphite oxidation models cannot be developed for STAR-CD then additional representative testing would be needed of graphite in conditions that simulate water and air ingress events.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.3.1a

DDN Revision: 01

DDN Title: Fuel – Improvement of the Diffusion and the Coatings Corrosion Modeling in ATLAS

DDN Category: Codes/Methods

DDN Description:

Refinement of ATLAS models is needed for better prediction of how fission products interact with coatings.

Current State of Knowledge:

The best updated models for fission product interaction with coating layers and for fission product diffusion have been implemented in the ATLAS code and checked versus available data.

DDN REQUIREMENT

Data needed:

If improvements in ATLAS models for diffusion and coatings corrosion prediction appear to be needed, new diffusion and corrosion data will have to be obtained with materials representative of NGNP fuel in order to tune the models for fitting with these data.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Development of models needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use ATLAS models as they are.

Selected Design Approach and Fallback:

The ATLAS diffusion and corrosion models will be refined/improved. The fallback position of not improving the ATLAS models is to use the models as they are.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.3.1b

DDN Revision: 01

DDN Title: Fuel – Development of Fuel Hydrolysis Modeling in ATLAS

DDN Category: Codes/Methods

DDN Description:

Fuel hydrolysis modeling needs to be included in ATLAS for fuel performance prediction during water ingress events.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

ATLAS fuel hydrolysis model.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Fuel hydrolysis modeling needs to be complete by the beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use INL fuel hydrolysis models.

Selected Design Approach and Fallback:

An ATLAS fuel hydrolysis model will be developed. The fallback position of not completing the model is to use INL fuel hydrolysis models.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.3.1c

DDN Revision: 01

DDN Title: Fuel – Improvement of the Coated Particle and Compact Irradiation Modeling in ATLAS at Relevant Operating Conditions

DDN Category: Codes/Methods

DDN Description:

Checking and possibly adapting the coated particle and compact irradiation models in ATLAS versus data from the AGR irradiation program will help assess NGNP fuel performance. Calculation of the failure fraction and fission product release rate from a fuel load in normal operation or accident conditions.

Current State of Knowledge:

The most updated models for the irradiation behavior of coated particles and compacts have been implemented in the ATLAS code and qualified versus available irradiation data (data from the former German fuel qualification program and from the recent irradiations in the European HTGR program).

DDN REQUIREMENT

Data needed:

Possible improvements in the ATLAS coated particle and compact irradiation models.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

N/A

Need Date:

Possible improvements in the ATLAS coated particle and compact irradiation models need to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use for the current ATLAS coated particle and compact irradiation models.

Selected Design Approach and Fallback:

The ATLAS coated particle and compact irradiation model will be tuned, if needed, for NGNP fuel. The fallback position is to use current ATLAS coated particle and compact irradiation models.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.3.1d

DDN Revision: 01

DDN Title: Fuel – Heat-Up Experiment Modeling of Irradiated Fuel Particles in ATLAS

DDN Category: Codes/Methods

DDN Description:

ATLAS heat-up modeling predictions have to be compared with experimental heat-up data and might have to be improved following such comparison.

Current State of Knowledge:

ATLAS can model the behavior of HTGR fuel in heat-up accident conditions. It calculates the fission gas release and the failure rate in such conditions as well as in normal operating conditions.

DDN REQUIREMENT

Data needed:

Possible improvement of ATLAS heat-up modeling.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use the ATLAS heat-up model as is.

Selected Design Approach and Fallback:

The fallback position is to use ATLAS code heat-up modeling as it is. If the comparison with experimental data shows unacceptable discrepancies, the modeling will have to be improved.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.3.1e

DDN Revision: 01

DDN Title: Fuel – Development of UCO Models in ATLAS

DDN Category: Codes/Methods

DDN Description:

The ATLAS code currently has no UCO models; therefore these models need to be developed.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

ATLAS UCO models and experimental data for model development.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Models need to be developed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use INL code for prediction of UCO fuel performance.

Selected Design Approach and Fallback:

Develop UCO models. The fallback position of not developing the ATLAS UCO models is to use INL code for prediction of UCO fuel performance.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1a

DDN Revision: 01

DDN Title: FP Transport – Development of Model for Activation Product Assessment in the Primary Circuit

DDN Category: Codes/Methods

DDN Description:

Improved models might be needed for the assessment of product activation in the primary circuit (in particular tritium and ^{14}C). These models will help to predict transport of radio contaminant species from the compact boundary into the graphite blocks and the primary coolant under normal or accident operation.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Experimental data are needed for better understanding of the phenomenology of product transport, improving models and qualifying them.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use appropriate available code
2) Design with additional margins for uncertainties

Selected Design Approach and Fallback:

In order to assess product activation in the primary circuit, models will be developed. For licensing purposes, the fallback position of not developing these models is to use the appropriate available code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1b

DDN Revision: 01

DDN Title: FP Transport – Modeling of Tritium Migration and Control in SG and Secondary Water Loops

DDN Category: Codes/Methods

DDN Description:

DDN is necessary to model release of radionuclides from primary system.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Models for tritium migration and control in SG and secondary water loops.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use a more conservative design approach and margins
2) Use appropriate available code

Selected Design Approach and Fallback:

Models are needed to predict tritium migration and control in SG and secondary water loops. The fallback position of not developing these models is to use the appropriate available code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

<u>DDN ISSUE</u>

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1c

DDN Revision: 01

DDN Title: FP Transport – Modeling of Radio-Contaminant Distribution in the Primary Circuit during Both Normal Operation and Accidental Situations

DDN Category: Codes/Methods

DDN Description:

DDN is necessary to model transport of radionuclides within the primary system including circulating activity, plated-out/deposited activity and purification system.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Models of radio-contaminant distribution in the primary circuit during both normal operation and accidental situations.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use appropriate available code.

Selected Design Approach and Fallback:

To be able to predict radio-contaminant distribution in the primary circuit during both normal operation and accidental situations it is desired to develop the necessary models. The fallback position of not developing these models is to use appropriate available code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1d

DDN Revision: 01

DDN Title: FP Transport – Modeling of Radio-Contaminant Release outside the Primary Pressure Boundary

DDN Category: Codes/Methods

DDN Description:

This DDN is necessary to model release of radionuclides from the primary system.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Models for radio-contaminant release outside the primary pressure boundary.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use appropriate available code.

Selected Design Approach and Fallback:

The selected design approach for predicting radio-contaminant release outside the primary pressure boundary is to develop the necessary models. The fallback position of not developing these models is to use appropriate available code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1e

DDN Revision: 01

DDN Title: FP Transport – Modeling of Radio-Contaminant Releases in the Environment for Accidental Situations

DDN Category: Codes/Methods

DDN Description:

DDN is necessary to model release of radionuclides from the reactor building.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Model for the release of radionuclides from the reactor building.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use appropriate available code.

Selected Design Approach and Fallback:

A model will be developed to get predictions for release of radionuclides from the reactor building. The fallback position of not developing this model is to use appropriate available code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1f

DDN Revision: 01

DDN Title: FP Transport – Development of Fission Product Wash-Off Modeling

DDN Category: Codes/Methods

DDN Description:

A model is needed to predict release of radionuclides from the primary system and from the reactor building due to a water ingress event.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

A fission product wash-off model is needed.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use appropriate INL code.

Selected Design Approach and Fallback:

Development of a fission product wash-off model is the approach used to predict radionuclide release from the primary system and reactor building. The fallback position of not developing this model is to use appropriate INL code.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

<u>DDN ISSUE</u>

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.1g

DDN Revision: 01

DDN Title: FP Transport – Data Collection for Fission Product Aerosols

DDN Category: Codes/Methods

DDN Description:

This DDN is necessary to model release of radionuclides from the core, transport within and release from the primary system, transport within and release from reactor building, as well as transport in the environment

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Modeling is needed for aerosol growth; aerosol and dust dispersion, bounce and breakup; confinement aerosol physics; surface roughness effects; coolant chemical interaction with surfaces; and FP diffusivity, sorbtivity and resuspension.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Data collection for input into models needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Use larger design margins and/or conservative bounding assumptions for design.

Selected Design Approach and Fallback:

The selected design approach is to collect data and develop fission product transport models to release from the core to the environment. The fallback is to use larger design margins and/or conservative bounding assumptions for design.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.2a

DDN Revision: 01

DDN Title: Structural Analysis – Completion of Experimental Databases for Structural Mechanics Codes

DDN Category: Codes/Methods

DDN Description:

Complete HTGR materials database for introduction into structural mechanics codes of specific constitutive laws for HTGR material (graphite).

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Experimental data, design rules for structural HTGR material (graphite).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Structural materials database needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Run tests on either small or full scale mockup of components
2) Use appropriate General Atomics methodology (still requires some data for current graphite)

Selected Design Approach and Fallback:

The goal of getting the material property data and developing the materials models for the structural mechanics codes is to assess component behavior under normal operation and mechanical and thermal loadings under accident conditions. The fallback position is to use appropriate General Atomics methodology (still requires some data for current graphite).

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.2b

DDN Revision: 01

DDN Title: Structural Analysis – Development of Block-Type Core Dynamic Modeling

DDN Category: Codes/Methods

DDN Description:

It is necessary to study seismic behavior of a block-type core during accident conditions.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Numerical model to assess seismic behavior of a block-type core.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Run a full scale partial core mockup test of the block-type core

Selected Design Approach and Fallback:

The goal of developing the models is to assess seismic behavior of a block-type core. The fallback position is to run a full scale partial core mockup test of the block-type core.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.2c

DDN Revision: 01

DDN Title: Structural Analysis – Modeling of Fluid Structure Interaction and Flow-Induced Vibration

DDN Category: Codes/Methods

DDN Description:

It is necessary to understand the effects of fluid structure interaction, such as flow-induced vibration, on key structures and components such as the reactor internals, hot gas duct, steam generator, and compressor to avoid structural failures. Therefore models need to be developed to mitigate the effects of fluid structure interaction or eliminate the oscillatory flow pattern.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Numerical models to predict vibration due to oscillatory fluid structure interaction.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model development needs to be completed by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Run mockup tests
2) Use conventional flow-induced vibration analyses

Selected Design Approach and Fallback:

The selected design approach to understanding fluid structure interaction will be via model development. The fallback position of not getting codes developed is to use conventional flow-induced vibration analyses.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.1.4.2d

DDN Revision: 01

DDN Title: Structural Analysis – Development of LBB Methodology for Gas-Cooled Reactors

DDN Category: Codes/Methods

DDN Description:

A methodology needs to be developed to assess vessel behavior during normal and accident conditions. The proposed safety approach excludes the vessel rupture and thus relies on a leak-before-break (LBB) approach that has not been established for gas-cooled reactors yet. This DDN will support development of the methodology.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

An LBB methodology needs to be established for vessels.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

LBB methodology needs to be established by beginning of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

Perform more detailed analysis to preclude failure of vessel by design.

Selected Design Approach and Fallback:

The proposed methodology for reactor safety analysis is LBB. The fallback would be to perform more detailed analysis to preclude failure of vessel by design.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.1a

DDN Revision: 01

DDN Title: Neutronics – Experimental Data on Representative Fuel Assembly Geometry for Qualification of CABERNET

DDN Category: Codes/Methods

DDN Description:

Experimental data is needed of coupled power and temperature distributions on representative fuel assembly geometry for qualification of CABERNET.
As soon as NEPHTIS and STAR-CD models can be qualified, only the CABERNET coupling model needs qualification and this requires an integral experiment with combined power (flux) and temperature monitoring.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Qualification of CABERNET using coupled power and temperature distributions from experimental data.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification can be performed during commissioning phase.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Change the design to accommodate uncertainty with larger design margins
2) Use limited existing data from more limited qualification (see DDN 4.2.1.1b)
3) Adopt staged qualification approach using initial NGNP operation data for final qualification

Selected Design Approach and Fallback:

Qualifying CABERNET is the selected approach. The fallback position is staged qualification.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.1b

DDN Revision: 01

DDN Title: Neutronics – Partial Data for Qualification of CABERNET

DDN Category: Codes/Methods

DDN Description:

If DDN 4.2.1.1a is not achievable before NGNP then partial qualification data is needed: burn-up measurements on fuel columns after irradiation in HTTR, which can provide a code/experiment comparison on the axial power distribution on a cycle, certainly different with and without temperature feedback.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Partial qualification of CABERNET using HTTR burn-up data.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Partial model qualification can be performed during commissioning phase.

DDN IMPORTANCE

Alternatives to DDN Completion:

Change the design so CABERNET is not needed.

Selected Design Approach and Fallback:

Qualifying CABERNET is the selected approach. The fallback position of not partially qualifying CABERNET is to change the design so CABERNET is not needed.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.1c

DDN Revision: 01

DDN Title: Neutronics – In-Core Measurements for Qualification of Coupled Calculations in CABERNET

DDN Category: Codes/Methods

DDN Description:

In-core measurements of power and temperature distributions in NGNP are needed for qualification of coupled neutronics/thermal-hydraulics calculations in CABERNET, and therefore, for allowing reaching nominal power.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Qualification of CABERNET coupled calculations using in-core measurements.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

CABERNET coupled calculations qualification can be performed during commissioning phase.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code, if in existence, that can be or already is qualified
2) Design with large uncertainty margins

Selected Design Approach and Fallback:

Qualifying CABERNET is the selected approach. The fallback position of not qualifying CABERNET coupled calculations is to design with larger uncertainty margins, because, at this point, no other codes exist.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.2

DDN Revision: 01

DDN Title: Neutronics – New Dedicated Critical Experiments for Qualification of MCNP

DDN Category: Codes/Methods

DDN Description:

A dedicated critical experiment with representative configurations is needed for qualifying MCNP for NGNP core calculations with pin-by-pin power distributions, and control rod and burnable poisons worths.

Current State of Knowledge:

Qualification of MCNP has been strengthened by benchmarking it towards data from available pebble bed experiments (PROTEUS, HTR10 first criticality).
Data are expected from a high temperature zero power experiment performed in the ASTRA facility of the Kurchatov Institute for qualifying the calculation of temperature coefficients with MCNP.

DDN REQUIREMENT

Data needed:

Qualification of MCNP should be extended using data from other relevant critical experiments and maybe through a dedicated critical experiment with two representative configurations of the NGNP core:

- The first configuration will allow getting an asymptotic spectrum representative of the expected NGNP prismatic fuel assembly.
- The second configuration will be representative of the interface between the core and the graphite reflector.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

MCNP qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another Monte Carlo code that can be or already is better qualified than MCNP
2) Use larger design margins to accommodate uncertainties

Selected Design Approach and Fallback:

Qualifying MCNP is the selected approach. The fallback position is to use larger design margins to accommodate uncertainties.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.3a

DDN Revision: 01

DDN Title: Neutronics – Results of Fuel Irradiation Experiments for MONTEBURNS Qualification

DDN Category: Codes/Methods

DDN Description:

Experimental results are needed of fuel compact irradiation experiments at representative burnup, temperature and fluence.

Current State of Knowledge:

MONTEBURNS has been qualified towards data on isotopic composition of irradiated fuel from FSV and HFR-EU1 bis (European program).

DDN REQUIREMENT

Data needed:

Qualification of MONTEBURNS is needed using experimental results. An evaluation is needed to determine the adequacy of the existing qualification.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

MONTEBURNS qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Change the design so MONTEBURNS is not needed
2) Use larger design uncertainties

Selected Design Approach and Fallback:

Qualifying MONTEBURNS is the selected approach. The fallback position of not qualifying MONTEBURNS with experimental data is to use larger design uncertainties.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.3b

DDN Revision: 01

DDN Title: Neutronics – Experimental Results of Decay Heat for MONTEBURNS Qualification

DDN Category: Codes/Methods

DDN Description:

Experimental results are needed of decay heat at short term for representative fuel composition and burnup for qualification of MONTEBURNS.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Qualification of MONTEBURNS is needed using experimental results.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

MONTEBURNS qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Change the design so MONTEBURNS is not needed
2) Use larger design margins

Selected Design Approach and Fallback:

Qualifying MONTEBURNS is the selected approach. The fallback position of not qualifying MONTEBURNS with experimental data is to use larger design margins.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.4

DDN Revision: 01

DDN Title: Neutronics – New Dedicated Critical Experiments for Qualification of NEPHTIS

DDN Category: Codes/Methods

DDN Description:

A dedicated critical experiment with representative configurations is needed for qualifying NEPHTIS for NGNP core calculations with pin-by-pin power distributions, and control rod and burnable poisons worths.

Current State of Knowledge:

NEPHTIS has been qualified by benchmarking against HTTR first criticality data and against MCNP reference calculations.

DDN REQUIREMENT

Data needed:

Qualification of NEPHTIS should be extended using data from other relevant critical experiments and maybe through a dedicated critical experiment with two representative configurations of NGNP core:

- The first configuration will allow getting an asymptotic spectrum representative of the expected NGNP prismatic fuel assembly.
- The second configuration will be representative of the interface between the core and the graphite reflector.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

NEPHTIS qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is better qualified than NEPHTIS
2) Use larger design margins to accommodate uncertainties

Selected Design Approach and Fallback:

Qualifying NEPHTIS is the selected approach. The fallback position is to use larger design margins to accommodate uncertainties.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.1.5

DDN Revision: 01

DDN Title: Neutronics – Results of Fuel Irradiation Experiments for NEPHTIS Qualification

DDN Category: Codes/Methods

DDN Description:

Experimental results of fuel compact irradiation experiments at representative burnup, temperature and fluence are needed.

Current State of Knowledge:

NEPHTIS has been qualified towards data on isotopic composition of irradiated fuel from FSV and HFR-EU1 bis (European program).

DDN REQUIREMENT

Data needed:

Qualification of NEPHTIS is needed using experimental results. An evaluation is needed to determine the adequacy of the existing qualification.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

NEPHTIS qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is better qualified than NEPHTIS
2) Use larger design uncertainties

Selected Design Approach and Fallback:

Qualifying NEPHTIS is the selected approach. The fallback position of not qualifying NEPHTIS with experimental data is to use larger design uncertainties.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.2.1

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Benchmarks against Experimental Data for Qualification of MANTA

DDN Category: Codes/Methods

DDN Description:

Though a significant basis for qualification of the MANTA system transient analysis code exists, additional benchmarks against experimental data should be performed.

Current State of Knowledge:

Global validation of MANTA currently consists of code-to-code benchmarking: comparisons for selected transients with CATHARE from CEA (France), LEDA from EDF (France), ASURA from MHI (Japan), REALY2 from GA (USA) and RELAP5-3D from INL (USA) have already shown good agreement. Qualification against experimental data is also progressing (EVO loop, HE-FUS3 loop and PBMM).

DDN REQUIREMENT

Data needed:

MANTA qualification by benchmarking against experimental data. Some facilities which could provide valuable data have been identified (non exhaustive): namely, HTTR reactor in Japan, HTR10 reactor in China, SBL-30 loop in the USA (SNL). The qualification of component models will follow from the qualification tests of the components. The core model qualification follows from comparison with other codes and experimental results (detailed core calculation).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is better qualified
2) Use MANTA as is with the present level of qualification

Selected Design Approach and Fallback:

Qualifying MANTA is the selected approach. The fallback position of not better qualifying MANTA with experimental data is to use MANTA as is.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.2.2a

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Qualification of STAR-CD for Modeling Conduction Cooldown

DDN Category: Codes/Methods

DDN Description:

STAR-CD needs to be qualified for modeling conduction cooldown.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

The main sources of uncertainty in modeling conduction cooldown include emissivity of surfaces and geometry of gaps between blocks. Elementary tests may be needed to help bound the uncertainties in surface emissivities and gap geometry.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is qualified

2) Change the design so STAR-CD is not needed

Selected Design Approach and Fallback:

Qualifying STAR-CD using experimental data is the selected approach. The fallback position of not qualifying STAR-CD is to use another code that can be or already is qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.2.2b

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Qualification of STAR-CD for Modeling Diffusion, Turbulence and Stratification/Mixing

DDN Category: Codes/Methods

DDN Description:

STAR-CD needs to be qualified for modeling diffusion, turbulence and stratification/mixing (countercurrent flow) on representative mockups in critical areas.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

Turbulent mixing data is needed for qualifying STAR-CD in modeling critical areas such as lower and upper reactor plena, hot gas duct, and core bypass. For mixing in the lower plenum, the INL MIR facility is relevant, but may not be sufficient. Isothermal turbulent mixing can be tested but not the effect of a temperature gradient in helium flowing through the lower plenum.

Also, turbulent shear and mixing data at the flow stream interface is needed for STAR-CD qualification in modeling countercurrent (shear) flow.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is qualified
2) Use larger design margins to accommodate uncertainties

Selected Design Approach and Fallback:

Qualifying STAR-CD using experimental data is the selected approach. The fallback position of not qualifying STAR-CD is to use another code that can be or already is qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.2.2c

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Qualification of STAR-CD for Modeling Oxidation

DDN Category: Codes/Methods

DDN Description:

STAR-CD needs to be qualified for modeling oxidation with selected graphite grades in representative operating conditions.

Current State of Knowledge:

Several predecessor tests were performed with different graphite grades at CEA and FZJ. Also, NACOK experiments were performed within the European RAPHAEL project (coupling of graphite models with thermofluid dynamic behavior).

DDN REQUIREMENT

Data needed:

Qualification of STAR-CD for modeling oxidation is needed. The need for additional data beyond the existing data must be further assessed.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is qualified
2) Change the design, or use larger design margins, so STAR-CD is not needed

Selected Design Approach and Fallback:

Qualifying STAR-CD is the selected approach. The fallback position of not qualifying STAR-CD is to use another code that can be or already is qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.2.3

DDN Revision: 01

DDN Title: Thermal-Hydraulics – Validation of RELAP5-3D Consistent with that Planned for MANTA

DDN Category: Codes/Methods

DDN Description:

Validation of RELAP5-3D is consistent with that planned for MANTA (see DDN 4.2.2.1: Global validation of MANTA currently consists of code-to-code benchmarking: comparisons with CATHARE from CEA (France), LEDA from EDF (France), ASURA from MHI (Japan), REALY2 from GA (USA) and RELAP5-3D from INL (USA) have already shown good agreement. Qualification against experimental data is also progressing (EVO loop, HE-FUS3 loop and PBMM). Nevertheless, additional benchmarks against experimental data are recommended.

Current State of Knowledge:

TBD

DDN REQUIREMENT

Data needed:

RELAP5-3D qualification by benchmarking against experimental data. Some facilities which could provide valuable data have been identified (non exhaustive): namely, HTTR reactor in Japan, HTR10 reactor in China, SBL-30 loop in the USA (SNL). The qualification of component models will follow from the qualification tests of the components. The core model qualification follows from comparison with other codes and experimental results (detailed core calculation).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is qualified
2) Change the design, or use larger design margins, so RELAP5-3D is not needed

Selected Design Approach and Fallback:

Qualifying RELAP5-3D is the selected approach. The fallback position of not qualifying RELAP5-3D with experimental data is to use another code that can be or already is qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.3.1a

DDN Revision: 01

DDN Title: Fuel – Qualification of ATLAS for Modeling Irradiation of Coated Particles

DDN Category: Codes/Methods

DDN Description:

ATLAS needs to be qualified for modeling of irradiation of NGNP fuel.

Current State of Knowledge:

ATLAS has been qualified towards existing irradiation data (for the former German fuel qualification program, from the present European program (HFR-EU1 and HFR-EU1 bis) and has been favorably benchmarked towards other fuel codes (JAEA and European benchmarks).

DDN REQUIREMENT

Data needed:

Qualification of ATLAS is needed for NGNP fuel irradiation modeling at relevant operating conditions (burnup, temperature, fluence).

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be qualified towards NGNP fuel
2) Increase design margins

Selected Design Approach and Fallback:

Qualifying ATLAS towards NGNP fuel is the selected approach. The fallback position of not qualifying ATLAS is to use another code that can be qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.3.1b

DDN Revision: 01

DDN Title: Fuel – Qualification of ATLAS for Modeling Heat-Up Experiment

DDN Category: Codes/Methods

DDN Description:

ATLAS needs to be qualified for modeling heat-up experiment of irradiated fuel particles.

Current State of Knowledge:

ATLAS has been qualified towards data from German heat-up tests and from heat-up tests performed in the European RAPHAEL project.

DDN REQUIREMENT

Data needed:

Qualification of ATLAS is needed for heat-up experiment of irradiated fuel particles modeling.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Use another code that can be or already is qualified
2) Increase design margins

Selected Design Approach and Fallback:

Qualifying ATLAS towards NGNP fuel is the selected approach. The fallback position of not qualifying ATLAS is to use another code that can be qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

DDN SUMMARY

DDN Number: 4.2.4.1

DDN Revision: 01

DDN Title: Experimental Work for Fission Product Transport Model Qualification

DDN Category: Codes/Methods

DDN Description:

Experimental work needs to be carried out to qualify fission product transport models: tritium migration model, radio-contaminant distribution models inside and outside the primary circuit as well as releases into the environment, and fission plateout and product wash-off models.

Current State of Knowledge:

Existing German and US codes can calculate the FP transport with rather large uncertainties. Large scattering of experimental data in similar conditions show that the understanding of the factors influencing FP transport is limited.

DDN REQUIREMENT

Data needed:

Qualification of FP transport models is needed. Experimental work needs to be performed to support the qualification including separate effects tests as well as integrated tests.

Data Range/Service Conditions:

TBD

Accuracy Requirements:

TBD

Special Testing Considerations:

TBD

Need Date:

Model qualification needs to be completed by end of preliminary design.

DDN IMPORTANCE

Alternatives to DDN Completion:

1) Change the design so these models are not needed
2) Use existing US or German codes with appropriate analysis uncertainties

Selected Design Approach and Fallback:

Qualifying FP transport model is the selected approach. The fallback position of not qualifying these models is to use another code that can be qualified.

Project Risks:

TBD

Importance of New Data:

TBD

Schedule Priority:

TBD

Critical Issues:

TBD

DDN ISSUE

Preparer: James Geschwindt

DDN Issue Date: 10/09/2009

APPENDIX B: PREVIOUS LIST OF DDNS FROM REFERENCE [2]

The list of DDNs generated in this document can be found in Section 5.0. It is primarily based on the most recent DDN update effort performed as part of the DDN/PIRT reconciliation [2]. Table B-1 provides the final list of DDNs as found in Table 4-9 of [2]. The table contains section names and numbers, the AREVA DDN number and title, a description of each DDN and notes as applicable.

Table B-1: Table of Most Recent DDNs from the DDN/PIRT Reconciliation Report [2]

Section	AREVA DDN Number	DDN Title	Description	Notes
1	**Fuel**			
1.1	**Fuel Development**			
1.1.1	**Kernel**			
	1.1.1.1	Kernel Materials	Develop advanced carbon source for UCO kernel production. Test materials in pilot-facility fabricating UCO kernels.	
	1.1.1.2	Kernel Manufacturing	Develop advanced kernel wash and dry system to effectively increase throughput of kernel line with no degradation in kernel quality. Develop enhanced sintering for either UCO (large fluidized bed sintering) or UO2 (static bed sintering) with a focus on increased throughput and reduced cost.	
1.1.2	**Coating**			
	1.1.2.1	Coating Materials	Not used	R&D need of coating materials qualification has been included in 1.1.3.1 and 1.1.3.2.
	1.1.2.2	Coating Manufacturing	Investigate largest coating batches size capable in existing 6" coating retort. Determine economic feasibility of using a 6" retort for production.	Acceptability of coatings should initially be based on physical characteristics of the coatings after manufacture. Should a larger coater be required, plan on implementing the R&D of that coater as part of the facility expansion for production.
1.1.3	**Compact**			
	1.1.3.1	Compact Materials	Select graphitic matrix, resin, etc. to produce thermosetting compacts. Demonstrate performance of compacts under normal and off-normal accident conditions.	

Section	AREVA DDN Number	DDN Title	Description	Notes
	1.1.3.2	Compact Manufacturing	Establish compact manufacturing capabilities in the US based on the AREVA process. Develop (or confirm) compact pressures and temperatures to minimize fuel damage. Develop heat treat process to ensure complete graphitization of the matrix material. Perform irradiation tests on compacts to demonstrate performance for nominal and off-nominal operating conditions. Recommend expansion of BWXT fuel line for compacts.	
1.1.4	**Fuel Mass Production**			
	1.1.4.1	Fuel Mass Production	R&D should focus on areas where product uniformity and quality are most at jeopardy. Initial R&D should focus on kernel wash & dry, sintering, coating (assuming larger than 6" coater required), compact matrix formulation, and compact fabrication. Irradiation testing will be required to confirm fuel performance matches performance from the laboratory/pilot facilities. Some chemical processing areas or the process will require significant scale-up to meet production demands.	
1.2	**Fuel Qualification**			
	1.2.1.0	Quality Control Methods	Develop highly reliable instrumentation and data acquisition software to ensure fuel particle quality is built into the fuel. Capture essential data for fuel certification.	

Section	AREVA DDN Number	DDN Title	Description	Notes
	1.2.2.0	Inspection Techniques	Develop QC inspection techniques that directly relate to irradiation performance. Develop techniques for large-scale production capabilities that minimize the quantity of materials that require destructive evaluation to ensure statistically acceptable fuel is produced. Irradiation testing of the compacts to attempt to relate as-measured attributes actually correlated to performance would be necessary to ensure the correct attributes are being measured and characterized.	Techniques to be investigated could be: micro focus x-ray of particles (dimensional inspection of particle layers), mercury porosymetry (buffer density), sink-float (IPyC, SiC, and OPyC density), anisotropy measurements of the IPyC and OPyC layers, leach-burn-leach test or weak irradiation techniques (particle leak tightness), etc. Many QC techniques need to be developed with mass production in mind.
1.3	**Fuel Materials**			
	1.3.1.0	Fuel Oxidation Under Water/Air Ingress	Evaluate the need for additional data for oxidation behavior of the kernel, buffer, IPyC, SiC, OPyC, compact, and Fuel element, including associated property changes, due to interactions with the kernel and fission products as well as air and water during certain accident scenarios. Develop additional data as needed.	
	1.3.2.0	Fuel Compact Properties and FP Interactions	Determine key fuel compact matrix properties, including permeability and tortuosity, which impact fission product transport through the material. Establish an empirical fission product release rate constant for the matrix material. Determine fuel element thermal conductivity.	
	1.3.3.0	FP Speciation During Mass Transfer	Determine chemical speciation of fission products within the primary system and the confinement for differing potential atmospheres, including those encountered during water or air ingress events.	

Section	AREVA DDN Number	DDN Title	Description	Notes
2	**Materials Development and Qualification**			
2.1	**All Materials**			
	2.1.1.0	Tribology	Perform tribology tests on expected couples of materials in representative HTR conditions.	This type of tests requires dedicated facilities.
2.2	**Metallic Materials**			
2.2.1	**RPV High Temperature Materials**			
	2.2.1.1	Not used.		
2.2.2	**IHX Materials**			
	2.2.2.1	Not used.		
2.2.3	**Reactor Internal Materials**			
	2.2.3.1	Reactor Internal Materials	For Alloy 800H and Mod 9Cr1Mo: - Emissivity measurement under likely representative state of surface (as-machined and oxidized after machining) including expected changes over the expected component lifetime. - Corrosion behavior under representative primary helium environment. - Irradiation creep, embrittlement and effects on material properties, including ductility and dimensional change. For extension of 800H coverage in ASME III-NH the following items are needed: - Long term tests at temperature higher than 760°C - Material properties tests at transient temperatures seen by control rods. - Extension of allowables to cover 60 years lifetime.	Efforts in progress to extend coverage of alloy 800H up to ASME III-NH. Modified 9Cr1Mo is also a candidate if temperatures are kept below 750°C. Needs for mod 9Cr1Mo are already covered in the R&D needs for the vessel system.

Section	AREVA DDN Number	DDN Title	Description	Notes
2.2.4	**RPV Low Temperature Materials**			
	2.2.4.1	RPV Low Temperature Material	Study: - Effect of irradiation. - Creep during high temperature, short duration (100h) excursions - Corrosion in helium environment. - Emissivity (in air and helium, and considering emissivity degradation).	
	2.2.4.2	Field Fabrication of Vessels	Because of vessel size, must address field fabrication process control and property control, including welding, postweld heat treatment, section thickness and preservice inspection.	
2.3	**Ceramic Materials**			
2.3.1	**Control Rods**			

Section	AREVA DDN Number	DDN Title	Description	Notes
	2.3.1.1	Control Rod Sheaths	Study: - Thermal-physical properties (K, CTE, Cp). - Mechanical properties including multiaxial strength. - Fracture properties. - Fatigue properties. - Behavior under oxidized atmosphere and oxidation effects on properties. - Codification. - Materials envisioned so far are C/C or C/SiC composites. - Test and irradiate component mock-ups (e.g. sample joints) - Development of qualified fabrication and qualification/verification methods.	

Section	AREVA DDN Number	DDN Title	Description	Notes
	2.3.1.2	Control Rods (solid ceramic control rod without sheaths)	Study: - Thermal-physical properties (K, CTE, Cp). - Mechanical properties including multiaxial strength. - Fracture properties. - Fatigue properties. - Behavior under oxidized atmosphere and oxidation effects on properties. - Codification. - Materials envisioned so far are C/C or C/SiC composites. - Test and irradiate component mock-ups (e.g. sample joints) - Development of qualified fabrication and qualification/verification methods.	

Section	AREVA DDN Number	DDN Title	Description	Notes
2.3.2	**Upper Core Restraints**			
	2.3.2.1	Upper Core Restraints	Study: - Thermal-physical properties (K, CTE, Cp). - Mechanical properties including multiaxial strength. - Fracture properties. - Fatigue properties. - Behavior under oxidized atmosphere and oxidation effects on properties. - Codification. - Materials envisioned so far are C/C or C/SiC composites. - Test and irradiate component mock-ups (e.g. sample joints) - Fabrication and qualification/verification methods.	
2.3.3	**Top Plenum Shroud**			
	2.3.3.1	Not used.		
2.3.4	**Hot Gas Duct Liners**			
	2.3.4.1	Not used.		
2.3.5	**Core Support Insulation Blocks**			
	2.3.5.1	Not used.		

Section	AREVA DDN Number	DDN Title	Description	Notes
2.3.6	**Ceramic Insulation**			
	2.3.6.1	Ceramic Insulation	Study: - Thermal-physical properties (K, CTE, Cp). - Behavior under high temperature and irradiation conditions. - Behavior under oxidation.	

Section	AREVA DDN Number	DDN Title	Description	Notes
2.4	**Graphite Materials**			
	2.4.1.0	Graphite	Study: - Thermal-physical properties (K, CTE, Cp, emissivity). - Mechanical properties including multiaxial strength. - Microstructural characteristics (permeability, tortuosity, pore structure) - Fracture properties. - Fatigue properties. - Irradiation effects on properties including irradiation induced dimensional change, irradiation induced creep, changes in thermal conductivity, changes in CTE, and annealing out of thermal conductivity changes at high temperature. - Behavior under oxidized atmosphere including oxidation effects on properties. - Tribology. - Codification including fracture models. - Graphite oxidation from water ingress. - Graphite oxidation from air ingress. Develop ASME and ASTM codes and standards for graphite essential for timely application of graphite for NGNP reactor. Graphite qualification.	Grades presently under consideration are PCEA, NBG17 and/or NBG18.

Section	AREVA DDN Number	DDN Title	Description	Notes
	2.4.2.0	Graphite/Fission Product Interactions	Study the interactions between graphite components and fission products including FP transport through the fuel block, sorbtivity of graphite, fluence effect on transport in graphite, FP speciation in carbonaceous material and during mass transport, absorption and deabsorption on dust. Assess impacts of chemical forms of fission products on transport, holdup and chemical reactivity. Explore development of an effective release rate coefficient (empirical constant) as an alternative to first principles modeling.	
3	**Components Testing**			
3.1	**Helium Loop**			
	3.1.1.0	Primary Gas Circulators	Component qualification tests: - Air tests of the impeller (at scale 0.2 to 0.4). - Helium tests of Magnetic and Catcher bearings. - Tests of the circulator shutoff valve. - Tests and/or evaluations of age-related impeller failure modes (creep, fatigue) - Integrated tests near full-scale of the whole machine should be required on a large He loop, in air at the manufacturer's site or during the NGNP commissioning phase.	
	3.1.2.0	Not used.		
	3.1.3.0	Not used.		
	3.1.4.0	Not used.		

Section	AREVA DDN Number	DDN Title	Description	Notes
	3.1.5.0	Hot Gas Ducts	Demonstrate that no significant hot streaks should be expected with the V-shaped metallic concept. Qualification should be performed in 3 steps: - Elementary tests to characterize the fiber conditions, assembly techniques, spacers, etc. - Tests on a small mock-up in a test facility of about 1 MWt or less to validate the fiber specification and the ceramic spacer specification (if possible in He). - Tests on a full scale mock-up in a big test facility in He (around 10 MW). Test should at least cover: - Depressurization tests. - Pressure loss, heat loss, temperature of the support tube (in He conditions). - Leak tightness tests of the connection areas. - Fatigue and creep-fatigue tests (e.g. bellows, V-shape spacers, etc). - Potential for ceramic fiber release from insulation during normal operation and transients.	The reference design for the primary and secondary hot gas duct is the V-shaped metallic concept. The ceramic concept is envisioned as a fall back option for the primary hot gas duct. In the first stages of the design, tests should cover both the metallic and ceramic design (pending the confirmation of the feasibility of the metallic design).
	3.1.6.0	Steam Generator	Test during commissioning stage of: thermal-hydraulic performance, flow induced-vibration, and flow stability and controllability of water and steam system. Test integrity of dissimilar material welding joint in tubes (alloy 800H/ 2.25 Cr - 1 Mo).	
3.2	**PCS**			
3.2.1	**Brayton Cycle**			
	3.2.1.1	Not used.		

Section	AREVA DDN Number	DDN Title	Description	Notes
	3.2.1.2	Not used.		
	3.2.1.3	Not used.		
	3.2.1.4	Not used.		
3.2.2	**HRSG**			
	3.2.2.1	Not used.		
3.2.3	**Steam Cycle**			
	3.2.3.1	Not used.		
3.2.4	**Process Steam Supply System**			
	3.2.4.1	Reboiler	TBD - place holder in case future testing is required	
3.3	**Other Systems and Subsystems**			
	3.3.1.0	Helium Purification System	Selection and qualification of appropriate charcoal (during commissioning phase). Size various components for the desired flow rates.	
	3.3.2.0	Not used.		
	3.3.3.0	Fuel Handling System	The Fuel Server system needs to be designed based on the current system concept. Key activities should include: - Mechanical design of the shield enclosure. - Design of the robotic fuel cart. - Development of the control software.	The Fuel Server System has been described only as a design concept at this point. Testing of the Fuel Server, beyond initial component testing, should be included in the testing program developed for the complete Fuel Handling System.

Section	AREVA DDN Number	DDN Title	Description	Notes
	3.3.4.0	RCCS	Characterization of the heat transfer characteristics of the anticipated or proposed surface treatments for the reactor vessel and the panel heat exchanger will need to be accomplished. A large scale (e.g., representative height) demonstration of the capability of the RCCS to release the decay heat for the reactor may be beneficial.	Use of an uninsulated reactor vessel coupled with water-cooled panels as a core cooling mechanism for accident conditions has not been fully demonstrated. Basic physics of conduction cooldown heat transfer to RCCS and RCCS operation are straightforward. Separate effects tests provide direct path to critical data (e.g., surface emissivities). AREVA does not have a strong position on need for large scale test. While separate effects testing provides most precise information on critical parameters, large scale integrated testing may provide convincing confirmation for regulators. Licensing may be easier if large scale test is performed.

Section	AREVA DDN Number	DDN Title	Description	Notes
	3.3.5.0	Instrumentation	Examples of R&D which might be envisioned: - Neutron flux detectors – Some R&D and qualification efforts may be desirable to select detector technology and verify adequate sensitivity and lifetime. - Temperature Measurements – Standard thermocouples used in nuclear plants today are capable of measuring operating temperatures up to 1200ºC. Monitoring accident conditions may require the use of Pt-Rh thermocouples for operation at higher temperatures. These types of thermocouples are not used today and limited data about their reliability in nuclear environments exists. R&D may be needed to qualify Pt-Rh thermocouples for use in the NGNP, particularly if measurement of temperatures within the core is desired. Qualification testing is required in helium at expected normal and off-normal pressures, temperatures, flows and moisture levels. Further needs should arise together with the definition of the monitoring strategy.	NGNP will be a test bed for testing and validating HTR technology. Therefore, NGNP will include additional instrumentation beyond that required for normal operation in a commercial plant. Specific FOAK instrumentation will be required, and special instrumentation to support future HTR technology development missions may also be anticipated. For example, specific instrumentation might be required for operation at high temperature. The detail of this instrumentation (in particular the operating conditions) will be a function of the type of testing and experiments envisioned and will depend also on the monitoring strategy.
4	**Computer Codes, Methods Development and Qualification**			
4.1	**Code Development**			
4.1.1	**Neutronics**			
	4.1.1.1	CABERNET (=NEPHTYS/STAR-CD)	Enhancement of capabilities for the calculation of transient analyses.	This is a coupled neutronics/TH code.
	4.1.1.2	NEPHTYS		

Section	AREVA DDN Number	DDN Title	Description	Notes
4.1.2	**Thermal-Hydraulic**			
	4.1.2.1	RELAP5-3D	Several areas with regard to both modeling and validation are identified in the report INEEL/EXT-04-02293. Validation beyond that identified in INEEL/EXT-04-02293 and consistent with that planned for MANTA should be pursued. The INL has recognized a need to couple Computation Fluid Dynamics models to RELAP5-3D. Currently, RELAP5-3D is capable of coupling to the FLUENT CFD code. If the role of RELAP5-3D expands, there may be value to the project coupling the CFD code STAR-CD with RELAP5-3D to best utilize our investment in our STAR-CD models for the VHTR.	Reactor system analysis code. Unique capability to model: a) water ingress and b) air ingress. Unique capability to interface with other computation tools.
	4.1.2.2	STAR-CD	Develop graphite oxidation model for water and air ingress transients on reactor internal structures.	Mass transfer, reaction kinetics, air ingress, water ingress
4.1.3	**Fuel**			
	4.1.3.1	ATLAS	Improve the diffusion and the coatings corrosion modeling. Coated particle irradiation at relevant operating conditions (burnup, temperature, fluence). Heat-up experiment of irradiated fuel particles. Develop UCO models.	

Section	AREVA DDN Number	DDN Title	Description	Notes
4.1.4	**Other Codes**			
	4.1.4.1	FP Transport	Models for: - The assessment of product activation in the primary circuit (in particular tritium and 14C). - Investigation of tritium migration and control in SG and secondary water loops. - Radio-contaminants distribution in the primary circuit, making distinction between circulating activity, plated out / deposited activity and purification system, during both normal operation and accidental situations. - Radio-contaminants releases outside the primary pressure boundary. - Radio-contaminants releases in the environment for accidental situations. - Fuel hydrolysis. - Fission product wash-off. Experimental work required for model qualification and for the actual qualification effort. Data collection needed to support modeling of aerosol growth; aerosol and dust dispersion, bounce and breakup; confinement aerosol physics; surface roughness effects; coolant chemical interaction with surfaces; and FP diffusivity, sorbtivity and resuspension. Recommended to develop a mechanical analysis code for the NHS.	

Section	AREVA DDN Number	DDN Title	Description	Notes
	4.1.4.2	Structure Analysis	Introduction in structural mechanics codes of specific constitutive laws for HTR material (graphite, visco-plastic behavior of Ni base alloys): completing the experimental databases and developing numerical models. Seismic behavior of a block type core: development of a block type core modeling and experimental determination of input data for the model through tests on a vibration table. Fluid structure interaction and flow induced vibrations. LBB methodology for gas cooled reactors.	The proposed safety approach excludes the vessel rupture and thus relies on a leak-before-break (LBB) approach that has not been established for gas cooled reactors yet.
	4.1.4.3	Chemistry Effects Of Steam/Water	Need data to determine necessity and preferential approach to any modeling effort. Effects of water ingress from small and large SG breaks on graphite oxidation, pressure increase, fission product mobilization, fuel hydrolysis.	

Section	AREVA DDN Number	DDN Title	Description	Notes
4.2	**Code Qualification**			
4.2.1	**Neutronics**			
	4.2.1.1	CABERNET (=NEPHTYS/STAR-CD)	Experimental data of coupled power and temperature distributions obtained on representative fuel assembly geometry. If not achievable before NGNP: - Partial qualification data (e.g. burn-up measurements on fuel columns after irradiation in HTTR, which can provide a code/experiment comparison on the axial power distribution on a cycle, certainly different with and without temperature feedback). - Additional power margins will be necessary for initial operation of NGNP, to account for the uncertainty on the coupled neutronics-thermo-fluid dynamics calculation. - Need to provide in-core measurements of power and temperature distributions in NGNP for qualification of coupled calculations and therefore for allowing reaching nominal power. - R&D needs for developing appropriate sensors for in-core measurements (never performed in HTRs).	Coupled neutronics/TH code This code qualification can be performed during commissioning phase.
	4.2.1.2	MCNP	Dedicated critical experiments, with an asymptotic spectrum representative of the expected prismatic fuel assembly and core, with full access to pin-by-pin power distributions, and control rod and burnable poisons worths are needed. Experimental data of neutronic characteristics (spectrum, fission and capture rates) at the interface between a prismatic fuel assembly and a graphite reflector assembly.	Data from FSV and HTTR first criticality testing can be applicable to MCNP code qualification.

Section	AREVA DDN Number	DDN Title	Description	Notes
	4.2.1.3	MONTEBURNS	Experimental results of fuel irradiation experiments (compacts or pebbles) at representative burnup, temperature and fluence. Experimental results of decay heat at short term (<100 hours) for representative fuel composition and burnup.	
	4.2.1.4	NEPHTYS	Benchmarking for annular HTR core geometries. Approach for qualification currently consists of comparisons against Monte-Carlo reference calculations and benchmarking against the few available experimental data (FSV, HTTR). Thus new dedicated critical experiments, with an asymptotic spectrum representative of the expected prismatic fuel assembly and core, with full access to pin-by-pin power distributions, and control rod and burnable poisons worths are needed. Experimental data of neutronic characteristics (spectrum, fission and capture rates) at the interface between a prismatic fuel assembly and a graphite reflector assembly.	
4.2.2	**Thermal-Hydraulic**			
	4.2.2.1	MANTA	Additional benchmarks against experimental data are required. Some facilities which could provide valuable data have been identified (non exhaustive): namely, HTTR reactor in Japan, HTR10 reactor in China, SBL-30 loop in the USA (SNL). The qualification of component models will follow from the qualification tests of the components. The core model qualification follows from comparison with other codes and experimental results (detailed core calculation).	Global validation of MANTA currently consists of code-to-code benchmarking: comparisons with CATHARE from CEA (France), LEDA from EDF (France), ASURA from MHI (Japan), REALY2 from GA (USA) and RELAP5-3D from INL (USA) have already shown good agreement. Qualification against experimental data is also progressing (EVO loop, HE-FUS3 loop and PBMM).

Section	AREVA DDN Number	DDN Title	Description	Notes
	4.2.2.2	STAR-CD	Qualification of conduction cooldown models on representative geometry, materials and temperature. Qualification of countercurrent flow and diffusion models. Qualification of turbulence and stratification/mixing on representative mock-ups in critical areas (lower and upper reactor plena, hot gas duct, core bypass). Qualification of oxidation models with selected graphite grades in representative operating conditions.	Several predecessor tests performed with different graphite grades can be applied for STAR-CD qualification.
4.2.3	**Fuel**			
	4.2.3.1	ATLAS	Coated particle irradiation at relevant operating conditions (burnup, temperature, fluence); heat-up experiment of irradiated fuel particles.	