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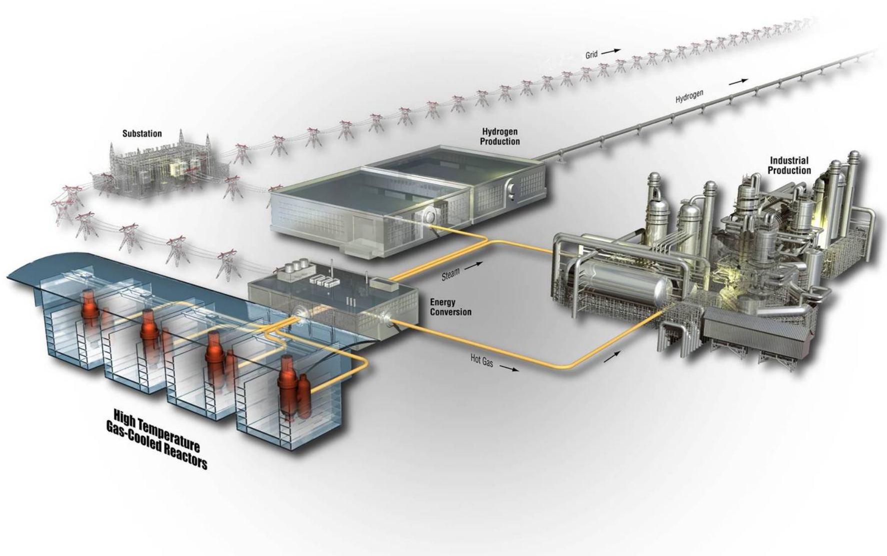
Charter

Project No. 23843

NGNP Moisture Ingress Assessment Committee Charter



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NGNP MOISTURE INGRESS ASSESSMENT COMMITTEE CHARTER	Identifier: CTR-310 Revision: 0 Effective Date: 12/06/2010	Page: i of iv

NGNP Project	~~Plan~~ Charter	eCR Number: 587425

Approved by:

W H Landman Jr — 11/30/10

W. H. Landman, Jr.
NGNP Project Engineer — Date

Phillip A. Mills — 12/01/10

P. M. Mills
Acting Engineering Director, NGNP — Date

Syd Ball — 23 Nov. 2010

S. J. Ball
Moisture Ingress Assessment Chair — Date

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	12/06/2010	All	Newly issued document

SUMMARY

This charter identifies the roles, responsibilities, authorities, and accountabilities for a Committee to assess the impacts of water ingress on a prismatic block high temperature gas reactor and document that assessment.

CONTENTS

1. INTRODUCTION

1.1 Background

The *Energy Policy Act of 2005*, Public Law 109-58, required the Secretary of the U.S. Department of Energy (DOE) to establish the Next Generation Nuclear Plant (NGNP) Project to manage the research, development, design, construction, and operation of a prototype plant that would use process heat to generate electricity and/or produce hydrogen. The NGNP Project would be supported by the research and development (R&D) activities of the Generation IV Nuclear Energy Systems initiative.

DOE selected the high temperature gas-cooled reactor (HTGR) as the reactor concept to be used for the NGNP. Preconceptual designs for the NGNP were developed by three reactor suppliers. The characteristics of these designs are summarized in Table 1.

Table 1. Key operating parameters from preconceptual NGNP designs (INL 2007).

Condition or Feature	AREVA	General Atomics	Westinghouse
Power output (MWth)	565	550 to 600	500
Reactor type	Prismatic block	Prismatic block	Pebble-bed
Core outlet temperature (°C)	900	up to 950	950
Core inlet temperature (°C)	500	490	325
Cycle Configuration	Indirect cycle[a]: parallel hydrogen process and power conversion	Direct power conversion cycle[b]: parallel indirect hydrogen process	Indirect cycle: series hydrogen process and power conversion

a. Indirect cycle uses an intermediate heat exchanger to isolate the radioactively contaminated primary fluid from the power or hydrogen generation processes.

b. Direct power conversion cycle uses the primary coolant in the power conversion unit.

At a meeting of the NGNP senior advisory group (SAG) in October of 2008 (SAG 2008), it was agreed that two designs would be pursued:

- An indirect configuration with a pebble bed reactor and a gas-to-gas intermediate heat exchanger as shown in Figure 1
- An indirect configuration with a prismatic block reactor and steam generator as shown in Figure 2.

The group also agreed that the reactor outlet gas temperature would be in the range of 750 to 800°C.

Additional studies performed in 2009 (Geschwindt 2009; Carosella 2009; WEC 2009) resulted in the operating parameters shown in Table 2. Although the latest 2009 design concept for the pebble bed reactor employed an intermediate heat exchanger, the team was considering the use of a steam generator in the primary loop. This idea was presented to the SAG in July 2009 (SAG 2009).

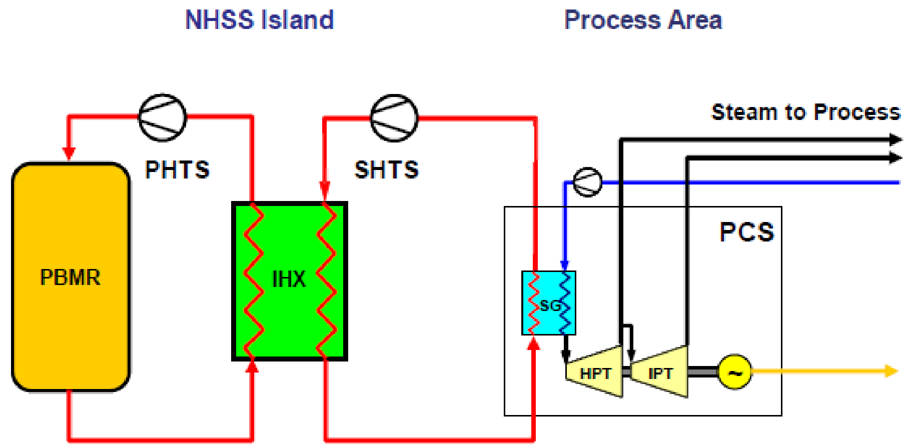

Figure 1. Pebble bed reference configuration (October 2008).

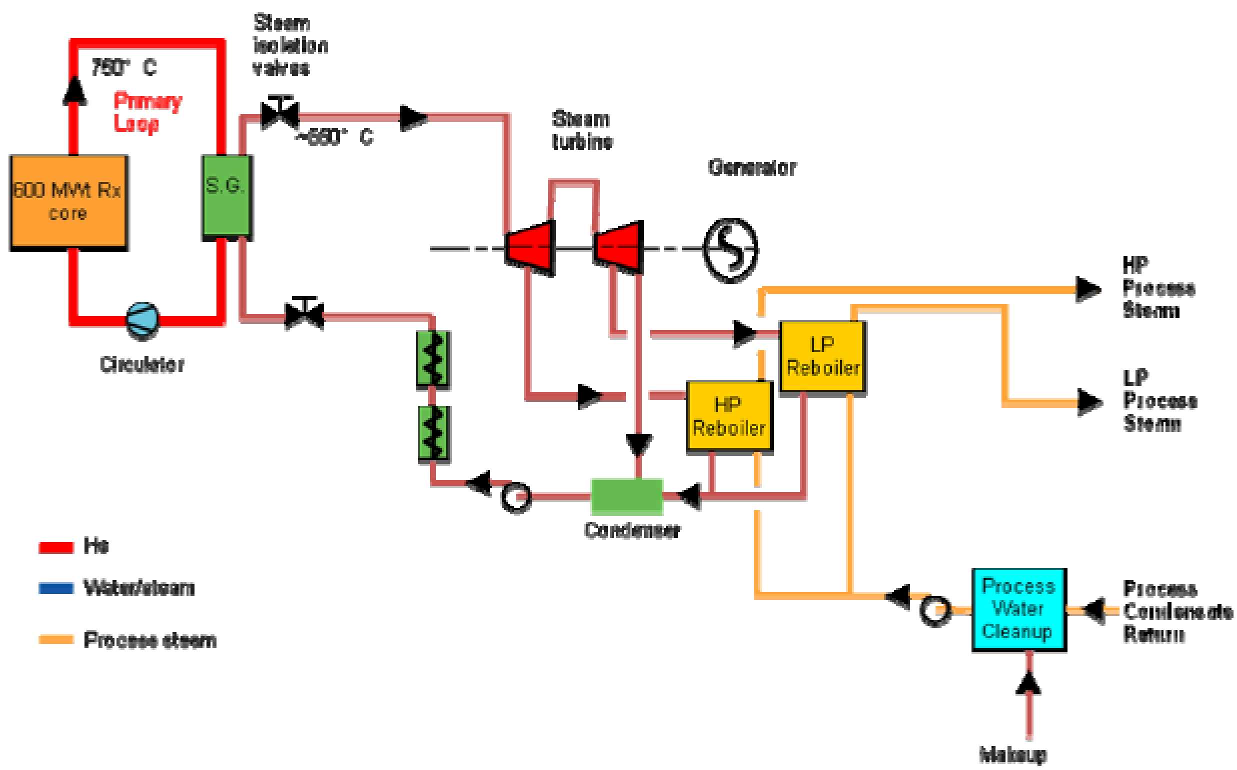

Figure 2. Prismatic block reference configuration (October 2008).

Table 2. Key operating parameters for the 750°C NGNP designs.

Condition or Feature	AREVA	General Atomics	Westinghouse
Power output (MWth)	565	600	500
Reactor type	Prismatic	Prismatic	Pebble bed
Core outlet temperature (°C)	750	750	750
Core inlet temperature (°C)	325	322	280
Coolant pressure (MPa)	6	7	9
Cycle Configuration	Indirect Rankine (Steam)	Indirect Rankine (Steam)	IHX to Rankine (Steam)

As part of an effort to assess the safety performance of the NGNP and to identify the analytical tools and additional research that would be needed to support the safety analyses, design, and licensing efforts, the Phenomena Identification and Ranking Table (PIRT) process was applied to various aspects of the NGNP fuel (NUREG/CR-6844 2004) and several areas of the NGNP design, including accident and thermal fluids analysis, fission product transport and dose, high temperature materials, graphite, and process heat for hydrogen co-generation (NUREG/CR-6944 2008). The NGNP design PIRT was conducted at about the same time as the preconceptual designs were being developed and was based on those configurations. As discussed previously, these designs did not include a steam generator in the primary loop but there was some valuable discussion of water ingress that is included in Appendix A of Volume 2 of NUREG/CR-6944. Given the current configurations in Table 2 and the indications that the pebble bed reactor concept might also employ a steam generator, the NGNP Project intends to develop an assessment of the impacts of a water/steam ingress event on the HTGR to better understand the needs for additional R&D, analytical tools, and experiments to validate the codes.

1.2 Purpose

This document charters the establishment of the NGNP Moisture Ingress Assessment Committee (hereafter called the Committee) to evaluate the effects of water or steam ingress into the NGNP primary coolant system and reactor core. Given that the maturity level of preconceptual designs and subsequent design efforts is limited, the evaluation will address the issues in a more qualitative fashion. It is likely that a more formal PIRT effort will be performed when more design details and analyses are available.

1.3 Objectives

The objectives of the Committee are to:

- Identify causes and describe scenarios of water/steam ingress postulated events
- Assess the knowledge base for the effects of water/steam ingress on the core physics, fission product transport, and the long and short-term corrosion effects on graphite, fuel, and other structural materials and components
- Assess the capability and availability of analytical tools to analyze water/steam ingress events
- Provide rankings according to importance and knowledge base leading to recommendations for additional R&D, code development, and any additional experiments needed to support the analytical work associated with water/steam ingress events.

2. APPROACH

The Committee will follow the nine-step PIRT process summarized in Appendix A to the extent practical. Additional details on the PIRT process are provided by Wilson and Boyack (1998).

Based on previous experience, a method for prioritizing recommendations from this assessment will be needed. It is therefore proposed that the technique used by the Pebble Bed Modular Reactor (PBMR) project be applied as discussed in Appendix B. This proposal will be discussed prior to the Committee meeting.

The Committee will focus its attention on identifying the research efforts and analytical tools needed to support design confirmation and licensing issues and experiments needed to support the analyses.

The Committee will also identify specific phenomena, including but not limited to:

- Reactivity effects (increase for under-moderated core)
- Reduction of control/shutdown rod worth
- Pressure increase in primary helium system
- Pressure relief valve actions
- Graphite oxidation/corrosion
- Fission product release and transport
- Explosive gas mixtures within the reactor vessel or reactor building.

Even though both prismatic block and pebble bed reactor HTGR concepts are being considered for the NGNP, the Committee will focus on the prismatic block configuration for the NGNP HTGR. The South African government's recent decision to cancel funding of its PBMR leads to some uncertainty as to the future design of the pebble bed reactor. The prismatic block reactor design will be based on General Atomics' Modular High Temperature Gas-cooled Reactor (MHTGR) design for which General Atomics submitted a Preliminary Safety Information Document (PSID) in the late 1980s, with additional information to be provided by General Atomics. The MHTGR is a 350 MWth prismatic block HTGR with a single steam generator in the primary loop. The designs were considered to be modular so any given site may employ more than one reactor/steam generator system. Even though no presentations are currently planned for the pebble bed reactor, time will be devoted to discussing the similarities and differences between it and the prismatic block reactor.

The potential scenarios to be considered will be determined by the Committee but they will likely include long-term steady-state considerations and transients such as pressurized and depressurized loss-of-forced convection coupled with water ingress.

3. ORGANIZATION

This Committee is intended to inform the R&D and Methods groups. The level of design maturity is not considered sufficient to support a detailed PIRT for licensing support so the composition of the Committee will include independent subject matter experts and reactor supplier personnel.

3.1 Review Group Members

The members of the Committee and their designated functions are listed in Appendix C.

3.2 Voting Membership

All members of the Committee will be voting members.

4. ROLES AND RESPONSIBILITIES

The roles and responsibilities for the Committee are identified below.

4.1 Chair

The Chair for the Committee will provide overall direction for committee members and coordinate their efforts in developing the advanced material, the introductory talks at the meeting, and the final report.

The Chair will attend and direct the meeting of the Committee.

4.2 Members

Committee members will be responsible for reviewing background materials (to be provided later) prior to the Committee meeting and making introductory presentations (as appropriate) on applications of their specialty.

Members will participate in the assessment process and provide their expert opinions.

Members will be responsible for developing the report sections summarizing their input and assessments.

4.3 Administrative Assistance

Administrative assistance will be provided by the NGNP project.

5. MEETINGS, REPORTS, AND OTHER MATTERS

5.1 Meetings

One 2-day meeting is anticipated for this assessment effort. The meeting agenda has not been finalized, but it is expected that part of the first day will consist of presentations to the full committee by the reactor supplier experts on pertinent design features safety analyses and by the subject experts on specific phenomena impacted by the water or steam ingress. The effort on the remainder of the first day and the second day will focus on the assessment process and the initial drafting of the report.

The meeting is tentatively scheduled for the week of February 7, 2011, in Salt Lake City, UT. The date, time, and location of the meeting will be confirmed. Pre-meetings (telecons) for reporting status and resolving issues will be called as required.

5.2 Changes to Charter

Changes to this charter may be made based on a consensus of committee members.

6. RECORDS

6.1 Products

The Committee will produce a report documenting the moisture ingress assessment process and results. The report will include prioritized recommendations for future R&D and methods development. It will not include cost and schedule estimates for the proposed R&D.

The committee report will be issued as an INL external report following a review process resolving and incorporating recommended changes by the committee members. The milestone for issuing this report is March 31, 2011.

The Committee Chair will coordinate report preparation.

7. REFERENCES

Ball, S. J., and S.E. Fisher, 2008, "Next Generation Nuclear Plant Phenomena Identification and Ranking Tables (PIRTs)," NUREG/CR-6944, Nuclear Regulatory Commission, March 2008

Carosella, D. P., 2009, "Nuclear Heat Supply System Point Design Study for NGNP Conceptual Design," General Atomics 911167, April 21, 2009.

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Morris, R. N., et al., "TRISO-Coated Particle Fuel Phenomenon Identification and Ranking Tables (PIRTs) for Fission Product Transport Due to Manufacturing, Operations, and Accidents." NUREG/CR-6844, 2004, U.S. Nuclear Regulatory Commission, July 2004.

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U. S. Department of Energy, "Preliminary Safety Information Document for the Standard MHTGR," HTGR-86-024, including amendments through 1989.

Westinghouse Electric Company, LLC, 2009, "NGNP: Intermediate Heat Exchanger Development and Trade Studies," NGNP-NHS-HTS-RPT-M-0004. September 2009.

Williams, P. M. et al., *Pre-Application Safety Evaluation Report for the MHTGR*, NUREG-1338 (Draft), U.S. Nuclear Regulatory Commission, 1988.

Wilson, G. E., and B. E. Boyack, 1998, "The Role of the PIRT Process in Experiments, Code Development, and Code Applications Associated with Reactor Safety Analysis," *Nuclear Engineering and Design*, Vol. 186, pp. 2–37.

8. APPENDIXES

Appendix A, NGNP Water/Steam Ingress Conceptual PIRT Process and Objectives

Appendix B, Prioritization Approach for Committee Recommendations

Appendix C, Committee Members and Functions

Appendix A
NGNP Moisture Ingress Assessment Process and Objectives

The Phenomena Identification and Ranking Table (PIRT) is a prescriptive process used by the Nuclear Regulatory Commission (NRC) designed to support decision making that will be used as a model for this assessment process to the extent practical. The process consists of nine distinct steps.

Step 1: Define the issue that is driving the need for a PIRT.

Step 2: Define the specific objectives for the PIRT.

Step 3: Define the hardware and the scenario for the PIRT.

Step 4: Define the evaluation criterion.

Step 5: Identify, compile, and review the current knowledge base.

Step 6: Identify plausible phenomena, i.e., PIRT elements.

Step 7: Develop importance ranking for phenomena.

Step 8: Assess knowledge level for phenomena.

Step 9: Document PIRT results.

The design maturity and applicability of the safety-related analyses is limited at this stage, so this assessment will be somewhat qualitative. The following process steps, taken from the NRC guidelines, will be applied to the extent that the information is available.

Step 1: Issue Definition

The issue is to identify the needs for research and development and analytical code development and verification, as they relate to phenomena associated with water ingress to the NGNP reactor core and primary coolant system.

Step 2: PIRT Objectives

The primary objective of the Next Generation Nuclear Plant (NGNP) water/steam ingress assessment effort is to identify phenomena associated with the ingress of water or steam into the NGNP core and primary system during normal operations, transients, and postulated accidents, and to determine the relative importance of these phenomena to the expected consequences. This involves an evaluation of the knowledge base associated with the identified phenomena to aid in informing the development of the analytical tools and technical bases to perform safety analyses and regulatory reviews, and to scope out other research and development needs to support NGNP licensing. The NGNP technology envelope contains modular high temperature gas-cooled reactors (HTGR), including pebble bed and prismatic core designs, the steam generators, and, to the extent that they impact reactor core and primary coolant system, the balance of plant designs.

As far as this water/steam ingress assessment is concerned, the focus will be on evaluating the thermal-fluids and neutronic phenomena, effects of the water or steam on the materials (especially graphite) within the core and primary coolant system, and impact of the water/steam ingress on the fission product transport and its consequences.

Thermofluidics and Accident Analysis – The objectives are to (1) identify accident scenarios for HTGRs and determine their risk importance, (2) develop figures of merits for accident analyses, (3) determine important phenomena affecting accident progression, and (4) identify and assess the adequacy of supporting experimental databases for developing models and analysis tools.

High Temperature Materials including Graphite – The objectives are to (1) identify and rank potential degradation mechanisms for the HTGR materials under normal operating, transient, and accident conditions, (2) identify important parameters and dependencies that affect the degradation processes, (3) assess material performance requirements to assure safety, including needs for additional codes and standards, and (4) assess material properties databases and identify new data needs, where appropriate.

Fission Product Transport and Consequence Analysis – Assess fission product transport and the consequences of the fission product release evaluated in NUREG/CR-6944 as they would be impacted by the introduction of water or steam. Items to be considered include (1) identifying effects of water/steam ingress on fission product release and transport processes in HTGRs, (2) evaluating the adequacy of existing models and databases for fission product release and transport in HTGRs, and (3) assessing the adequacy of models and databases for consequence analysis.

Step 3: Hardware and Scenario

This assessment will be based on the design of the Modular High Temperature Gas Reactor (MHTGR) that was developed by General Atomics and others. The design and safety basis are provided in the Preliminary Safety Information Document that was submitted to the NRC. The hardware to be discussed will include the reactor vessel (primary pressure boundary for nuclear reaction and heat generation), steam generator, major components in the primary coolant system, and containment or confinement barriers (ultimate barrier to prevent fission product release to the environment). As noted previously, the effect of water/steam ingress on fuel has been addressed in NUREG/CR-6844.

Water ingress scenarios will be developed based on the existing safety analysis work and include pressurized loss of forced circulation, depressurized loss of forced circulation, reactivity insertion because of water ingress, hydrogen explosion, graphite oxidation, environmental degradation of materials and components, etc.

Step 4: Evaluation Criteria

NRC customarily specifies evaluation criteria (figures of merit) for light water reactors (e.g., core damage frequency, large early release frequency, peak cladding temperature, coolable core geometry, etc.) for which there is a large regulatory experience data base. For HTGRs, defining equivalent criteria will pose a challenge. For this assessment, the committee will establish a common understanding of what the evaluation criteria should be for HTGRs (e.g., equivalent to core damage frequency, peak cladding temperature, etc., or dose at site boundary).

Step 5: Current Knowledge Base

For the NGNP moisture ingress assessment, this step will involve familiarization of the committee members with the current knowledge base on HTGR technology with particular focus on safety-relevant physical processes associated with hardware and the scenario identified in Step 3 above. The MHTGR Preliminary Safety Information Document (PSID) provides an overview of the plant design and accident scenarios and will serve as resource material. Additional documents will also be provided. In the course of the assessment exercise, the committee will review the resource materials and provide an assessment of the knowledge base.

Step 6: Phenomena Identification

The committee will identify plausible phenomena for each hardware and scenario identified in Step 3 above. The objective is to develop a preliminary list of phenomena which, in the collective opinion of the committee, are relevant to safety. In developing the list, the committee is expected to create a phenomenological hierarchy starting at the system level and proceeding through component and subcomponent levels and so on. Importance ranking of these phenomena will be done in the next step. However, the committee should recognize that the lowest level of hierarchical decomposition be consistent with the data and modeling needs from a regulatory perspective.

Step 7: Importance Ranking

In this step, the committee will develop importance ranking and rationale for the phenomena identified in Step 6. The process will consist of individual and independent ranking by committee members, discussion of individual rankings considering the rationale, and collective ranking based on the discussion. Importance is ranked relative to the evaluation criteria adopted in Step 4. A qualitative ranking of High, Medium, and Low proved to be sufficient in past PIRT exercises and is adopted for the present exercise.

Step 8: Knowledge Level

The committee will assess the level of knowledge regarding each phenomenon identified in Step 6 and for which importance ranking is assigned in Step 7. Again, the process will consist of individual and independent assessment including the rationale and collective assessment based on the discussion. A qualitative ranking—Known (adequate knowledge), Partially Known (incomplete knowledge), and Unknown (no or hardly any knowledge)—was used in past exercises, and is adopted for the present exercise. [Note: the Importance Ranking and Knowledge Level assessment process may be revised if the PBMR's prioritization approach (Appendix B) is adopted.]

Step 9: Documentation

The objective of this step is to provide sufficient coverage and depth in the documentation so that a knowledgeable reader can understand what was done (process) and the outcomes (results). At a minimum, the documentation should include background materials, assessment objectives, tables of identified phenomena, their importance and knowledge level ranking, and associated text describing the process of phenomena identification and rationale of the ranking process.

Appendix B
Prioritization Approach for Committee Recommendations

FOR DISCUSSION

From: Peter Robinson, *PBMR safety analysis software development and V&V*, Safety Aspects of Modular HTGRs, IAEA, Beijing, Oct. 2007 PBMR's PIRT -Next Iteration(excerpts)

- PBMR has completed one iteration of the PIRT
- We want to confirm the first iteration and build on what we learned
  - Revise ranking bins:
    - Difficult to decide what to do with "Medium" bins
    - Too many combinations of uncertainties were available to adequately recommend action resolution.

Table B-1. PBMR PIRT status decision chart.

Status	Rank (High/Low)	Confidence in Rank (Sure/Unsure)	Confidence in Value (Sure/Unsure)	Symptom	Action Required
8	High	Unsure	Unsure	Phenomenon is perceived as significant but is not well known.	High priority requirement for analysis and validation.
7	High	Sure	Unsure	Phenomenon is significant and confidence in value is low.	High priority requirement for validation.
6	High	Unsure	Sure	Phenomenon is significant and the confidence in rank is low.	High priority requirement for analysis.
5	High	Sure	Sure	Phenomenon is significant and well known.	Should be well represented in the model. Should be readily validated.
4	Low	Unsure	Unsure	Phenomenon is not significant but not well known.	Requires analysis and validation to determine rank and value.
3	Low	Sure	Unsure	Phenomenon is not significant and the confidence in value is low.	Low priority requirement for validation.
2	Low	Unsure	Sure	Phenomenon is not significant and the confidence in rank is low.	Low priority requirement for analysis.
1	Low	Sure	Sure	Phenomenon is well known and is not significant.	May be modeled without validation.

Appendix C
NGNP Moisture Ingress Assessment Committee Membership

DRAFT FOR DISCUSSION

Name	Function	Organization
S. J. Ball	Committee Chair Accident sequences	ORNL
R. R. Schultz	Modeling and Experiments	INL
W. E. Windes	Graphite	INL
J. Kendall	Fuel and fission product transport	Global Virtual LLC
Lew Lommers	Reactor Design and Safety Analysis	AREVA
Yassin Hassan	Methods	Texas A&M
TBD	Observer	Nuclear Regulatory Commission