Phenomena Identification and Ranking Technique (PIRT) Panel Meeting Summary Report

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CONTENTS

1. Introduction

Section 644(b) of the Energy Policy Act of 2005 (EPAct) states: "Not later than 3 years after the date of enactment of this Act, the Secretary and the Chairman of the Nuclear Regulatory Commission shall jointly submit to the appropriate committees of the Senate and the House of Representatives a licensing strategy for the prototype nuclear reactor, including –

> 1) a description of ways in which current licensing requirements relating to light-water reactors need to be adapted for the types of prototype nuclear reactor being considered by the Project;
>
> 2) a description of analytical tools that the Nuclear Regulatory Commission will have to develop to independently verify designs and performance characteristics of components, equipment, systems, or structures associated with the prototype nuclear reactor;
>
> 3) other research or development activities that may be required on the part of the Nuclear Regulatory Commission in order to review a license application for the prototype nuclear reactor; and
>
> 4) an estimate of the budgetary requirements associated with the licensing strategy."

As a result of the tasks included in the EPAct, a working group was formed that consisted of personnel from the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC) and the Idaho National Laboratory (INL). This group, the "NGNP Licensing Strategy Working Group," was given the task of developing the report to Congress addressing the four areas listed above.

2. Objective

NRC, in collaboration with DOE and the working group, conducted the Phenomena Identification and Ranking Technique (PIRT) exercises to identify safety-relevant phenomena for NGNP, and to assess and rank the importance and knowledge base for each phenomenon. The overall objective was to provide NRC with an expert assessment of the safety-relevant NGNP phenomena, and an overall assessment of R&D needs for NGNP licensing. The PIRT process was applied to five major topical areas relevant to NGNP safety and licensing: 1) thermofluids and accident analysis (including neutronics), 2) fission product transport, 3) high temperature materials, 4) graphite, and 5) process heat for hydrogen cogeneration.

3. Overview of PIRT process

PIRT is a systematic way of gathering information from experts on a specific subject, and ranking the importance of the information, in order to meet some decision-making objective, e.g., determining what has highest priority for research on that subject.

The PIRT process results in lists of phenomena which are associated with a particular subject (a specific figure-of-merit). The phenomena can actually be the condition of a particular reactor/system/component, a physical or engineering approximation, a reactor parameter, or anything else that might influence the figure-of-merit. The process proceeds by ranking these phenomena using some scoring criteria in order to help determine what is most important. That ranking, as well as the rationale for the ranking along with the information obtained to explain the ranking, can assist in decision making. The PIRT methodology brings into focus the phenomena that dominate an issue, while identifying all plausible effects to demonstrate completeness. [1]

An important part of the process is to also identify the uncertainty in the ranking, usually by scoring the knowledge base for the phenomenon. Again the rationale for the scoring is an important product of the elicitation. When a phenomenon is identified as being important but the corresponding knowledge level is low it is an indication that more effort must be applied, e.g., more research support. [1]

4. Structure of NGNP PIRT Panels

The expert panels were organized around the five areas listed in Section 1 (above). NRC and DOE, personnel developed lists of acknowledged experts in each of the fields represented by the five panel topics and invitations were extended to the recommended panelists. Panel participants included 25 experts from Argonne National Laboratory (ANL), INL, Oak Ridge National Laboratory (ORNL), Sandia National Laboratory (SNL), Savannah River National Laboratory (SRNL), Commissariat à l'énergie atomique (CEA), Institut de Radioprotection et de Sûrenté Nucléaire (IRSN), Massachusetts Institute of Technology (MIT), Texas A&M, University of Manchester (UK), and University of Wisconsin. In addition, gas reactor technical experts from Areva, General Atomics, Technology Insights, and Westinghouse were invited to provide design information to the panelists, but were not allowed to vote during panel deliberations.

The panels were organized as follows:

- **Thermal-fluidics Panel** – The objectives of the thermofluids and accident analysis PIRT were to identify safety-relevant phenomena for normal plant operation and postulated accident scenarios, and then rank them for their importance with regard to established evaluation criteria or figures of merit (FOMs). The PIRT panel focused on the thermal fluid aspects of the events, but considered neutronic behavior as well where appropriate.
    - ♦ Panel Chair: Syd Ball – ORNL
    - ♦ Mike Corradini – U. of Wisconsin
    - ♦ Randall Gauntt – SNL
    - ♦ Genvieve Geffraye – CEA
    - ♦ Yassin Hassan – Texas A&M
    - ♦ Dave Moses – ORNL
    - ♦ Tom Wei – ANL
    - ♦ Richard Schultz - INL

- **High Temperature Materials Panel** – The objectives of the high temperature panel were to assess material behavior under both normal and accident conditions with respect to structural integrity and performance (such as strength, creep, fatigue, and corrosion/erosion properties).
  - Panel Chair: Bill Corwin – ORNL
  - Ron Ballinger – MIT
  - Saurin Majumdar – ANL
  - Kevan Weaver – INL
- **Graphite Panel** – The objectives of the graphite panel were to assess graphite behavior under both normal and accident conditions with respect to structural integrity and performance.
  - Panel Chair: Tim Burchell – ORNL
  - Rob Bratton – INL
  - Barry Marsden – U. of Manchester
- **Process Heat & Hydrogen Panel** – The objectives for the process heat PIRT focused on phenomena involved with coupling a hydrogen generation plant to the reactor, mainly those that could affect reactor, not hydrogen plant, safety. Particular phenomena were identified for their role in postulated accident sequences, primarily in terms of external event challenges to the reactor.
  - Panel Chair: Charles Forsberg – ORNL
  - Max Gorensek – SRNL
  - Steve Herring – INL
  - Paul Pickard – SNL
  - Steve Wright – SNL
- **Fission Product Transport Panel** – The objectives of the fission product transport PIRT were to categorize potential sources of fission product release and, assuming various release scenarios, identify and rank the primary phenomena involved, as well as the knowledge bases, with respect to the respective FOMs.
  - Panel Chair: Bob Morris – ORNL
  - Martin Kissane – IRSN
  - Robert Morris – ORNL
  - Dave Petti – INL
  - Dana Powers – SNL
  - Bob Wichner – Consultant

5. Conduct of Meetings

Two sets of meetings were held in Rockville, MD. The first meetings were held on February 27 & 28, 2007, and the second meetings were held on April 16 through 18, 2007. Handouts and overhead slides from these meetings are available upon request.

February PIRT Meetings

The first meetings were designed to introduce the panel participants to the NRC's PIRT process and to initiate the first steps in that process. The meetings opened with a PIRT overview (Sud Basu/NRC) and a series of presentations provided by the three principal gas reactor vendors (Areva, General Atomics, and Westinghouse) that covered each design's safety characteristics. Syd Ball (ORNL) then provided an additional overview of gas reactor safety characteristics. The afternoon of the first day and most of the second day was spent by the individual panels identifying gas reactor phenomena (associated with each panel's respective area) and figures of merit. The second day closed with a short session where each panel chair summarized the panel's progress.

April PIRT Meetings

The second set of meetings allowed the panel members to reconvene and discuss phenomena that were identified during the first meeting. In addition, the remaining steps in the PIRT process were performed. The meetings opened with a review of the PIRT process (with emphasis on the remaining steps to be performed) and a summary of the results from the first meeting (Sud Basu/NRC). The two days were spent by the individual panels completing the remaining steps in the NRC PIRT process. The third day closed with a short session where each panel chair summarized the panel's results.

Additional Panel Meeting

The Thermal-fluidics Panel was unable to complete their deliberations during the April meetings. Therefore, a supplemental meeting was held during the week of May 1, 2007, at ORNL. This meeting was organized by Panel Chair Syd Ball.

6. Current Status

PIRT evaluations were done using the nine-step PIRT process developed by the NRC. Consideration of a wide range of postulated accidents was based in part on review of licensing and design experience, as well as on detailed accident analysis for designs similar to NGNP (but without the process heat component).

During the PIRT meetings, phenomena with average or consensus rankings of high importance (H) with a corresponding low knowledge level (L) were flagged (H, L) as the major candidates for further consideration. In some other cases, phenomena ranked (H, M) or (M, L), where M is medium, were given consideration as well. In a very few cases, phenomena ranked (H, H) or (M, M) were identified also for consideration, only to indicate that in these cases there was a divergence of expert opinions. The list of phenomena in each of the major topical areas is provided in the attached tables. Please note that the results from the High Temperature Materials Panel and the Graphite Panel have been consolidated into one table.

Subsequent to the PIRT meetings, each of the panel members developed the underlying bases for their identification and ranking of phenomena. Input was provided to each respective panel chair that was responsible for organizing the panel's results and for providing those results to the NRC facilitators.

The products of the PIRT activities are documented in five individual PIRT reports, and summarized in a main report. The individual reports are undergoing internal review and the main report is in preparation. These reports will be published as NUREG reports with a tentative publication date of September 2007.

7. References

1. D. J. Diamond, Brookhaven National Laboratory, "Experience Using Phenomena Identification and Ranking Technique (PIRT) for Nuclear Analysis," presented at *PHYSOR-2006 Topical Meeting*, Vancouver, British Columbia, Canada, September 10-14, 2006.

The following attachments are included as supporting information in these areas:

- Phenomena Ranking Tables for each of the panel topics.
- Agendas for the February and April PIRT meetings.
- NRC introductory presentation slides given at the start of the April PIRT meeting.

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R&D Phenomena Table for a Generic High Temperature Gas Reactor

Thermofluids, Accident Analysis, and Neutronics

System/component	Phenomena	Importance	Knowledge
Reactor vessel	Flow and thermal properties for mixed gases in vessel	High	High
Reactor core	Heat transfer correlations for mixed gases in core	Medium	Medium
Reactor cavity	RCCS performance with "gray gas" in cavity	Medium	Low
Reactor core	Fuel performance with oxygen attack	High	Medium
Core support	Core support structures oxidation	High	Medium
Reactor core	Core oxidation	High	Medium
Reactor cavity	RCCS gas stratification and mixing	Medium	Medium
Cavity/confinement	Confinement-to-reactor cavity air ingress	High	Medium
Reactor cavity	Cavity structural integrity during blowdown	Medium	Medium
Reactor cavity	Cavity filtering performance	High	Medium
Reactor vessel	Molecular diffusion from cavity to vessel	High	Medium
Reactor vessel	Chimney effects and air ingress	Medium	Medium
Reactor vessel	Thermal stratification/ mixing in the lower plenum	High	Medium
Reactor core	Core effective thermal conductivity	High	Medium
Reactor core	Decay heat and distribution vs. time	High	Medium
Reactor core	Heatup accident fuel performance modeling	High	Medium
Reactor vessel	Hydrodynamics of dust suspension	High	Medium
Reactor cavity	Pressure pulse in confinement	High	Medium
Vessel/cavity	Reactor vessel and cavity air circulation and heat transfer	High	Low
Reactor core	Reflectors conductivity and annealing	High	Medium
Reactor core	Core barrel emissivity	High	Medium
Reactor vessel	Inlet plenum stratification & plumes	High	Medium
Reactor cavity	RCCS spatial heat loadings, heat removal	High	Medium
Reactor vessel	Radiant heat transfer from core to vessel head	High	Medium
Reactor core	Core coolant flow and properties	High	Medium
Reactor core	Core coolant bypass flow	High	Low
Reactor core	Core flow distribution changes due to graphite irradiation	Medium	Low

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R&D Phenomena Table for a Generic High Temperature Gas Reactor Thermofluids, Accident Analysis, and Neutronics

System/component	Phenomena	Importance	Knowledge
Reactor core	Core flow distribution changes due to core barrel geometry changes and core block stability	Medium	Medium
Reactor vessel/core	Pebble bed core wall interface effects on bypass flow	High	Low
Reactor core	Pebble flow	High	Medium
Reactor components	Shutdown cooling system startup transients during core heatup	High	Medium
Reactor core	Power and flux profile during normal operation	High	Low
Reactor core	Reactivity-temperature feedback coefficients	High	Low
Reactor core	Fuel performance modeling	High	Low
Core/vessel/confinement/environment	Ag-110m release and plateout	High	Low
IHX loop/ confinement bypass	Fission product transport through IHX loop (part of confinement bypass)	High	Medium
Reactor vessel and components	Ingress of molten salt into primary system and RPV; riser and lower plenum fill	High	Medium
Reactor vessel	Molten salt to core support/vessel heat transfer	High	Medium
Reactor vessel	Reactor cavity to vessel air ingress	High	Medium
Reactor cavity	RCCS heat transfer characteristics	High	Medium
Reactor cavity	RCCS fouling	High	Medium
IHX loop/ confinement bypass	Helium transport through IHX loop (part of confinement bypass)	Medium	Medium
Reactor vessel	Outlet plenum flow distribution	High	Low
Core/vessel	Side reflector/core barrel/vessel heat transfer	Medium	Medium
Components	Thermal shock in SCS due to startup flow transient	Medium	Medium
Reactor core	Reactivity insertion due to pebble core compaction	Medium	Medium
Reactor core	Reactivity insertion due to steam/water ingress	High	Medium
Reactor core	Control and scram rods, and reactor shutdown worth	High	Medium
Reactor core	Xenon and Samarium buildup	Medium	Medium
Reactor core	Coolant flow restart during ATWS	Medium	Low

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R&D Phenomena Table for a Generic High Temperature Gas Reactor High Temperature Materials and Graphite

System/component	Phenomena	Importance	Knowledge
Reactor vessel	Long-term thermal aging of Gr. 91 material	High	Medium
Reactor vessel	Short-term high temperature thermal aging Gr. 91 material	Medium	Medium
Reactor vessel	Crack initial and subcritical crack growth Gr. 91 material	High	Low
Reactor vessel	Radiation degradation of Gr. 91 material	High	Low
Reactor vessel	Emissivity degradation due to loss of desired surface layer properties	High	Low
Reactor vessel	Transient creep in Gr. 91 and LWR materials	Medium	Medium
Reactor vessel	Creep during normal operations Gr. 91 material	Medium	Low
Reactor vessel	Field fabrication process control	High	Low
Reactor vessel	Properties control in heavy sections	High	Low
Vessel internals	Radiation induced degradation of control rods	Medium	Medium
Vessel internals	Oxidation of control rods	Medium	Medium
Vessel internals	Structural design methodology limitation for C-C composites for control rods and RPV internals	High	Low
Vessel internals	Change in emissivity of RPV internals	High	Low
Vessel internals	Radiation induced creep of RPV internals	High	Low
Vessel internals	Radiation induced embrittlement of RPV internals	Medium	Medium
Vessel internals	Environmental and radiation degradation of RPV internals (non-metallic)	High	Low
Vessel internals	Oxidation of RPV internals	Medium	Medium
Reactor components	Isolation valve failure	High	Low
Reactor cavity	Inadequate heat removal	High	High
Power conversion vessel & components	Missile failure	Medium	Medium
Power conversion vessel & components	Creep, creep crack growth, thermal loading, fatigue	Medium	Medium
Power conversion vessel & components	Primary coolant contamination	Medium	Medium
Intermediate heat exchanger	Creep, fatigue, subcritical crack growth	High	Low

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R&D Phenomena Table for a Generic High Temperature Gas Reactor
High Temperature Materials and Graphite

System/component	Phenomena	Importance	Knowledge
Intermediate heat exchanger	Design methodology limitation for structures and components	High	Low
Intermediate heat exchanger	Manufacturing phenomena, inspection and testing	High	Low
Intermediate heat exchanger	Water or chemical ingress/attack	Medium	Medium
Other components	Primary coolant contamination in circulators	Medium	Medium
Other components	Creep, fatigue, subcritical crack growth	Medium	Medium
Other components	Aging fatigue, environmental degradation of piping	High	Low
Other components	Creep, fatigue, subcritical crack growth	Medium	Medium
Reactor core and components	Statistical variation of non-irradiated graphite properties	High	Medium
Reactor core and components	Consistency in graphite properties over the reactor life	High	Medium
Reactor core and components	NDE techniques for detection of flaws in graphite	Medium	Medium
Reactor core and components	Fatigue of graphite core components	Medium	Medium
Reactor core and components	Irradiation induced dimensional changes in graphite	High	Medium
Reactor core and components	Irradiation induced creep	High	Low
Reactor core and components	Irradiation induced thermal conductivity changes	High	Medium
Reactor core and components	Irradiation induced changes in elastic constants	High	Medium
Reactor core and components	Irradiation induced changes in CTE	High	Low
Reactor core and components	Irradiation induced changes in mechanical properties	High	Low
Reactor core and components	Annealing of graphite thermal conductivity	Medium	Medium
Reactor core and components	Graphite dust generation	Medium	Low

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R&D Phenomena Table for a Generic High Temperature Gas Reactor
High Temperature Materials and Graphite

System/component	Phenomena	Importance	Knowledge
Reactor core and components	Tribology of graphite in helium environment	High	Medium
Reactor core and components	Degradation of thermal conductivity of graphite	High	Medium
Reactor core and components	Graphite spalling	High	Low
Reactor core and components	Channel distortion	Medium	Medium
Reactor core and components	Increased bypass coolant flow channels by breaks	Medium	Medium
Reactor core and components	Effect on chronic chemical attack on graphite properties	Medium	Medium

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R&D Phenomena Table for a Generic High Temperature Gas Reactor Process Heat Applications

System/component	Phenomena	Importance	Knowledge
Intermediate heat exchanger	Blowdown effects, large mass transfer, and pressurization of primary and secondary sides due to IHX failure	High	Medium
Process heat exchanger	Fuel and primary system corrosion due to PHX failure	High	Medium
Process heat components	Cyclic loading due to temperature transients	Medium	Medium
Reactor core	Reactivity spike due to neutron serialization	High	Medium
Other components	Turbo machinery response due to mass addition to reactor	Medium	Medium
Reactor core and internals	Chemical attack of TRISO layers and graphite	High	Medium
Intermediate heat exchanger	Loss of heat sink and loading of IHX	High	Medium
Intermediate heat exchanger	Radiologic release through IHX loops and plant	Medium	Medium

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R&D Phenomena Table for a Generic High Temperature Gas Reactor
Fission Product Transport and Dose

System/component	Phenomena	Importance	Knowledge
Reactor core	Material and structural properties of graphite	High	Medium
Reactor core	Graphite geometry and dimensional changes due to air ingress	High	Medium
Reactor core	Thermofluids properties	High	Medium
Reactor core/vessel	Gas composition for oxygen potential and chemical activity	High	Medium
Reactor vessel	Gas flow path	High	High
Reactor core/vessel	FP Plate-out and dust distribution under normal operation	High	Low
Reactor core/vessel	Matrix permeability and tortuosity	High	Low
Reactor core/vessel	Fission product transport through matrix	High	Low
Reactor core	Fuel block permeability, tortuosity	High	Medium
Reactor core	Fission product transport through fuel block	High	Medium
Reactor core/vessel	Sorbtivity of graphite	High	Medium
Reactor core/vessel	Fluence effect on transport in graphite	High	Medium
Reactor core/vessel	Air/steam attack on graphite	High	Medium
Reactor core/vessel	Fission product Speciation in carbonatious material	High	Low
Reactor vessel	Fission product Speciation during mass transfer	High	Medium
Reactor core/vessel	Dust generation	High	Medium
Reactor vessel	Fission product absorption in dust	High	Medium
Reactor vessel/ components	Tritium generation and circulating coolant inventory	High	Medium
Vessel/confinement	Ag-110m generation, transport	High	Low
Vessel/confinement	Aerosol growth	High	Low
Vessel/confinement	Surface roughness effect on aerosol deposition	Medium	Medium
Vessel/confinement	Coolant chemical interaction with surfaces	High	Medium
Vessel/confinement	FP diffusivity, sorbtivity in non-graphite surfaces	High	Low
Vessel/confinement	Aerosol/dust deposition	High	Medium
Vessel/confinement	Aerosol dust bounce, breakup during deposition	High	Medium

Draft

R&D Phenomena Table for a Generic High Temperature Gas Reactor
Fission Product Transport and Dose

System/component	Phenomena	Importance	Knowledge
Vessel/confinement	Resuspension of fission products	High	Low
Confinement	Confinement aerosol physics	High	Medium
Vessel/confinement	Fission product and aerosol wash-off	High	Medium
Other components	Failure modes of auxiliary systems (e.g. gas cleanup, holdup, refueling)	Medium	Medium
Confinement	Radiolysis effects in confinement	High	Medium
Confinement	Combustion of dust in confinement	High	Medium
Confinement	Confinement leakage path, release rate through penetrations	High	Medium
Other components	Cable pyrolysis, fire	High	Medium
Reactor core	Recriticality (slow)	High	Medium
Reactor core	Fuel-damaging reactivity insertion accidents	High	Medium

First NGNP PIRT Meeting
Doubletree Hotel, Rockville
February 27-28, 2007

Day#1 (Tuesday, Feb. 27)

8:30	Opening remarks	F. Eltawila (NRC)
8:40	Introduction to NGNP PIRT	S. Basu (NRC)
9:10	Overview of NGNP	T. Cook (DOE)
9:30	Industry presentation by Westinghouse	C. Kling (WEC)
10:00	Industry presentation by AREVA	F. Shahrokhi (AREVA)
10:30	BREAK	
10:45	Industry presentation by General Atomics	J. Parme (GA)
11:15	Modular HTGR safety and accident characteristics	S. Ball (ORNL)
12:30	LUNCH BREAK	
1:30	PIRT Breakout Sessions (4 parallel sessions)	PIRT Chairs

a. Panel Chairs' presentations
b. Individual member presentations (optional)
c. Initial PIRT development
d. Issue identification for group discussion

5:30 ADJOURN

Day #2 (Wednesday, Feb. 28)

8:30	PIRT Breakout Sessions continued	PIRT Chairs
12:30	LUNCH BREAK	
1:30	PIRT Breakout Sessions continued	PIRT Chairs
3:00	Meeting wrap-up	

a. PIRT Chairs' reports
b. Discussion
c. NRC assessments and guidance
d. Date and location for the final PIRT meeting

4:00 ADJOURN

Second NGNP PIRT Meeting
Doubletree Hotel, Rockville
April 16 - 18, 2007

Day#1 (Monday, April 16)

1.	9:00	Opening Remarks	NRC/DOE
2.	9:10	Summary of the First NGNP PIRT Meeting	S. Basu (NRC)
3.	9:30	Panel Summaries	
		Thermofluids and Accident Analysis	S. Ball (ORNL)
		High Temperature Materials	K. Weaver (INL)
		Graphite	T. Burchell (ORNL)
		Process Heat Applications	C. Forsberg (ORNL)
		Fission Products	R. Morris (ORNL)
4.	10:30	BREAK	
5.	11:00	PIRT Breakout Sessions	PIRT Chairs
6.	12:00	LUNCH	
7.	1:00	PIRT Breakout Sessions (continued) Interaction between panels	PIRT Chairs
8.	5:00	ADJOURN	

Day #2 (Tuesday, April 17)

1.	8:30	PIRT Breakout Sessions continued	PIRT Chairs
2.	12:00	LUNCH	
3.	1:00	PIRT Breakout Sessions continued Interaction between panels	PIRT Chairs
4.	3:00	BREAK	
5.	3:30	PIRT Breakout Sessions continued	PIRT Chairs
6.	5:30	ADJOURN	

Day #3 (Wednesday, April 18)

1.	8:30	PIRT Breakout Sessions continued	PIRT Chairs
2.	10:30	BREAK	
3.	11:00	PIRT Breakout Sessions continued Interaction between panels	PIRT Chairs
4.	12:00	LUNCH	
5.	1:00	PIRT Wrap-Up a. PIRT Chairs' reports b. Discussion	
6.	3:00	ADJOURN	

PIRT Meeting 2 – NRC Introduction – Sudhamay Basu

SECOND NGNP PIRT

Sudhamay (Sud) Basu, NRC

Summary of the First NGNP PIRT

- Issue defined (Step 1)
  - NGNP is a new design (VHTR, dual mission)
  - Experience base (design, operation)
  - Knowledge base (data, tools, etc.)
- Objectives defined (Step 2)
  - Identify safety-relevant phenomena, rank importance, and assess knowledge base
  - Major topical areas covered
    - Thermofluidics and accident analysis (including neutronics)
    - High temperature materials including graphite
    - Process heat and hydrogen co-generation
    - Fission product transport and dose

Summary of the First NGNP PIRT

- Hardware and Scenarios specified (Step 3)
  - Identify NGNP hardware/plant including components (e.g., reactor vessel, core, internals, IHX, etc.)
  - Identify conditions (accident and otherwise) to which plant and components are exposed
- Evaluation Criteria (FOM) established (Step 4)
  - Top level regulatory criteria (e.g., dose limit) common to all panels
  - Criteria at subsidiary levels established by individual panels; criteria may be different for panels but all derivatives of top level regulatory criteria

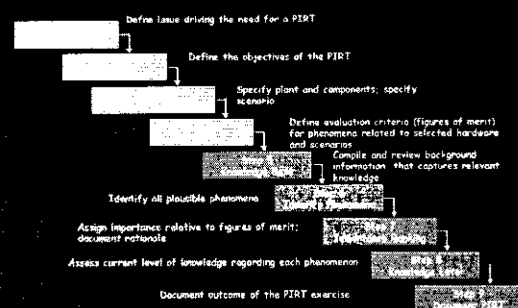
Evaluation Criteria (FOM)

FOM Level	TF	H.T. Mat'l	Graphite	Process	FPT
Level 1 (regulatory)	Dose	Dose	Dose	Dose	Dose
Level 2 (system)	Fuel failure fraction	System/ structure integrity	Coolable geometry	Structure integrity	Cumul. FP release history
Level 3 (component)	RPV P&T limits	RPV integrity	Reactivity control	Equipment integrity	
Level 4 (sub-component)	Coolant activity level	Heat transfer capability		Chemical corrosion	

Summary of the First NGNP PIRT

- Existing Knowledge Base discussed (Step 5)
  - Background information capturing relevant knowledge
    - HTGR legacy information
    - Industry resources
    - Ongoing international activities
- Relevant Phenomena identified (Step 6)
  - All plausible phenomena without importance ranking
  - Connectivity between phenomena, scenarios, and hardware

PIRT Process Flow Chart



PIRT Premise

- PIRT provides for identification and ranking of safety-significant phenomena
- Some phenomena are more important than others; some phenomena are not as important
- Once phenomena are ranked by importance, research needs can be prioritized to address highly-ranked important phenomena with least knowledge base

Remaining PIRT Process

- Step 6 - Phenomena Identification (revisited)
  - Panel re-examines the list of plausible phenomena for completeness
  - Staff input solicited and provided for panel consideration
  - Interaction between panels for consistency

Remaining PIRT Process

- Step 7 - Phenomena Importance Ranking
  - Basis for ranking
    - Influence on safety, measured with respect to established evaluation criteria or FOM
    - Improved understanding needed for making decisions of interest
  - Ranking scale and rationale
    - HIGH (H) if phenomenon has controlling influence on FOM or improved understanding critical for making decisions
    - MEDIUM (M) if moderate influence on FOM or improved understanding important for making decisions
    - LOW (L) if minimal influence on FOM or current understanding adequate for making decisions

Remaining PIRT Process

- Step 8 - Knowledge Assessment
  - Definition
    - Understanding of physical phenomena
    - Associated experimental data base, models, or analytical tools
  - Assessment ranking and rationale
    - KNOWN (K)/HIGH (H) if the knowledge base of a phenomenon is adequate for modeling, analytical representation, or making decisions of interest
    - PARTIALLY KNOWN (PK)/MEDIUM (M) if the knowledge base is incomplete for the above purposes
    - UNKNOWN (U)/LOW (L) if none or hardly any knowledge exists by way of physics, data, or model

Phenomena Ranking Template

Phenomena	Safety relevance	Importance ranking	Rationale	Knowledge assess	Rationale
Radiation heat transfer	Heat load to upper head	High (H) medium (M) or low (L)	Relative contribution to heat load	Known, partially known, or unknown	Existing data tools, etc.
Thermal aging	RPV integrity	H, M, or L	------	------	------
Hydrogen blast effect	Structure integrity	H, M, or L	------	------	------
FP and dust plate-out	FP and dust transport	H, M or L	------	------	------

Remaining PIRT Process

- Step 9 - Documentation
  - PIRT objectives
  - Process description
  - Discussion of hardware, scenarios, evaluation factors (FOM)
  - Listing of plausible phenomena
  - Individual scoring of phenomena importance and knowledge assessment
  - Collective (panel) scoring
  - Detail discussion of scoring rationale
  - Supporting reference materials