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MODIFIED PHENOMENA IDENTIFICATION AND RANKING TABLE (PIRT) FOR UNCERTAINTY ANALYSIS

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ABSTRACT

This paper describes a methodology of characterizing important phenomena, which is also part of a broader research by the authors called “Modified PIRT”. The methodology provides robust process of phenomena identification and ranking process for more precise quantification of uncertainty. It is a two-step process of identifying and ranking methodology based on thermal-hydraulics (TH) importance as well as uncertainty importance. Analytical Hierarchical Process (AHP) has been used for as a formal approach for TH identification and ranking. Formal uncertainty importance technique is used to estimate the degree of credibility of the TH model(s) used to represent the important phenomena. This part uses subjective justification by evaluating available information and data from experiments, and code predictions.
The proposed methodology was demonstrated by developing a PIRT for large break loss of coolant accident LBLOCA for the LOFT integral facility with highest core power (test LB-1)

1. INTRODUCTION

The USNRC has revised the ECCS licensing rules to allow the use of best estimate computer codes [1]. But this requires explicit quantitative assessment of the uncertainties of the TH calculations in the licensing and regulatory processes. To support this licensing revision, the USNRC and its contractors developed the code scaling, CSAU to demonstrate the feasibility of a best estimate plus uncertainty approach [2]. The PIRT process, a step in the CSAU, was developed to identify important processes and phenomena in the transient scenarios considered. It was originally formulated to support the best estimate plus uncertainty licensing option. Through further development and application, the PIRT process has shown additional utility as a robust means to establish safety analysis computer code phenomenological requirements in their order of importance to such analyses [3]. The process tries to identify and rank phenomena and processes based on their TH importance. For the purpose of uncertainty analysis, this step is necessary but not adequate. The phenomena may be important from the TH as well as uncertainty point of views. That is our degree of knowledge about phenomena and credibility of models must be characterized, and when possible quantified. Experience with TH phenomena shows that certain phenomena and their uncertainties contribute significantly to the TH code output and uncertainty on the output.

This paper describes a methodology of identifying and characterizing important phenomena, which is also part of a broader research for developing an integrated uncertainty methodology for TH computational codes by the authors. This methodology provides a robust process of PIRT for more objective quantification of uncertainty. It is a two-step process of identifying and ranking methodology based on TH importance as well as TH uncertainty importance. Traditional PIRTs consider only TH importance. We will rank and screen phenomena based on both TH importance of phenomena but also importance of TH phenomena uncertainty. The proposed methodology was demonstrated by developing a PIRT for large break loss of coolant accident (LBLOCA) for the LOFT integral facility with highest core power (test LB-1) [4].

NOMENCLATURE

AHP	Analytic Hierarchical Process
CSAU	Code Scaling, Applicability and Uncertainty Evaluation
CFT	Critical Flow Test
ECCS	Emergency Core Cooling System
FFTBM	Fast Fourier Transform Based Method
GRS	Gesellschat Fur Anlagen- und Reaktorsicherheit
INEEL	Idaho National Engineering Laboratory
ITF	Integrated Test Facility
LBLOCA	Large Break Loss of Coolant Accident
LOCA	Loss of Coolant Accident
MCMC	Markov Chain Monte Carlo
PDF	Probability Distribution Function
PIRT	Phenomena Identification and ranking Table
PWR	Pressurized Water Reactor
SBLOCA	Small Break Loss of Coolant Accident
SET	Separate Effect Test
TH	Thermal-Hydraulics
UMAE	Uncertainty Analysis Methodology based on Accuracy Extrapolation
USNRC	United States Nuclear Regulatory Commission

2. PIRT OBJECTIVES

In a risk-informed regulatory environment, best-estimate and formal characterization of all available information helps the decision makers better appreciate the ranges of uncertainty. It also shows the impact uncertainty might have on the decision. It should include conceptual level as well as modeling and computation. Nuclear power plant with its surrounding environment as selected portion of reality demonstrates many phenomena in case of any transient occurred. With many phenomena involved, TH analyses involve many sources of uncertainty. All sources of uncertainties should be ideally considered in the analysis explicitly, but this is neither practical nor necessary to evaluate all processes and components in detail. PIRT is a helpful tool to identify and rank phenomena in case of many phenomena involved in the nuclear power plants scenarios. Figure 1 discusses the idea behind the PIRT process. PIRT can be used to support several important decision-making processes. PIRT development becomes difficult if multiple reactor types or accident scenarios are considered simultaneously [3]. Therefore PIRT is developed for a specific plant design and scenario. Both the occurrence of phenomena and processes and the importance of phenomena and processes are plant and scenario specific. The ranking process is designed to direct the examination of importance to those processes having the most significant effect on the figure of merit. Traditional PIRT considers the effects of an input phenomenon on the magnitude of the output. It is a necessary step but does not carefully examine the knowledge and information about the phenomena. The knowledge on various phenomena results on the models and correlation developed. Credibility of models is directly related on our understanding of the reality of the phenomena and the portion captured in the analysis. Ref. [5] presents a discussion on the philosophical grounds of notions such as reality, modeling, models, and their relation.

3. PIRT PROCESS

Reference [3] explains in detail the steps for PIRT process. The steps in a typical PIRT were illustrated in Fig. 1 of the reference. The steps are summarized as following:

1. Define objectives of the process (PIRT process is conditioned on the objectives).
2. Identify plant design and the scenario type.
3. Define parameters of interest or figure of merit as phenomena have different impacts on different parameters.
4. Partition transient scenario into convenient time phases and plant design into subsystems and components.
5. Identify plausible phenomena by phase and component
6. Develop a ranking for identified components and phenomena by expert judgment and discussions or by using pairwise AHP methodology.
7. Perform sensitivity analysis to confirm the results from the previous steps.
8. Define screening criteria if only important phenomena remain for the next step analysis (e.g., TH uncertainty analysis).

As these are all steps toward constructing a PIRT table, some of the steps are controversial and will be discussed in this article. As part of the research leading to the development of the method proposed in this paper, extensive literature review was conducted to evaluate the merits and limitation of the PIRT method with the objective of incorporating the best features into a new more comprehensive method.

3.1 Phenomena Definition

Phenomena are defined differently in various applications. As a matter of definition, the term “phenomena’ as used in this research and consistent with other PIRT processes should be taken to mean “phenomena, process, component functions, behavior, conditions, and status”. All of the following examples are identified as phenomena even though only the first one is truly phenomena: flashing, break mass flow, decay heat, steam generator pressurizer level, accumulator temperature, initial core power, , and primary-to secondary heat transfer.

There is no consensus on the list of phenomena considered in TH studies. Early PIRT processes considered mostly actual phenomena as in original CSAU [2]. Phenomena in AP600 PIRT [6] are more detailed in which actual phenomena, as well as process, component functions, behavior, conditions, and status were considered. AREVA [7] and

Westinghouse/EPRI PIRT [8] consider initial condition and their impact on figure of merit. A recent PIRT study for a NPP with high burn-up {9] approached the process by identifying the phenomena in four categories of plant transient analysis, integral tests transient fuel rod analysis, and separate effect tests category. Types of phenomena are different in each category.

3.2 Identification of Phenomena

In the process of identification procedure, the scenario is examined in its operational time periods. For each period, each component is examined to identify the various processes and phenomena. There are different ways to divide the scenario period to different phases. There is consensus to divide LBLOCA to the three operational phases of blowdown, refill, and reflood. It is different in case of SBLOCA and other operational transients. Short descriptions of each phase with identification of phenomena are given in following sections. The idea is identifying the phenomena occurring in important components for each phase. Figure 1 illustrates importance of phenomena by their TH and uncertainty importance. It is obvious that screening is dependent on regulation, type of analysis, and resources available.

Table 1 shows a comparison table of some of the recently completed PIRTs. They are all for LBLOCA in similar 4 loop PWR NPP. Marked phenomena are common in the studies. It clearly shows how different are the tables for similar transient scenario. This is a serious issue in PIRT process. Development of comprehensive phenomena matrix including all phenomena, process, component functions, behavior, conditions (including initial and boundary), and status helps for PIRT developers to reach a consensus list of phenomena for similar scenarios in same NPP designs. OECD-Nuclear Energy Agency [9] had initiated developing such matrices but it is limited to actual phenomena. A total of 67 phenomena were identified. Completion of phenomena matrix, as a handbook for expert, will improve consistency of PIRTs done by different expert groups.

3.3 Ranking and Screening Process

"Primary evaluation criteria (or criterion) are normally based in regulatory safety requirements such as those related to restrictions in peak clad temperature (PCT)" [3]. Ranking and screening depends on analysis objective, regulatory requirements, availability of resources. Some of studies consider only high-ranked phenomena, but others consider medium and high phenomena. It is different in two-step PIRT as every phenomenon possesses two ranks. Figure 1 illustrates two-dimension importance. High-high combination is an option for decision making, while medium and high combinations should be other alternatives. It was decided that the low, medium, and high rank scheme should be adopted based upon past experience with the PIRT process for both TH and uncertainty ranking process.

High = the phenomenon or process has dominant impact on the primary evaluation criterion,

Medium = the phenomenon or process has moderate influence on the primary evaluation criterion.

Low = the phenomenon or process has small effect on the primary evaluation criterion.

4. THE TWO-STEP PIRT PROCESS

A methodology of characterizing important phenomena, called "Modified PIRT" is used this research. This methodology provides robust process of PIRT for more precise quantification of uncertainty. It is a two-step process of identifying and ranking methodology based on TH importance as well as uncertainty importance. We will rank and screen phenomena based on both TH and uncertainty importance. Experience with TH phenomena show that phenomena with TH and uncertainty importance contribute significantly to output uncertainty than rather TH importance alone or just uncertainty importance. It is not the general case and there are exemptions. Analytical Hierarchical Process (AHP) has been used for as a formal approach for TH identification and ranking. AHP is a powerful tool for ranking of alternatives and attributes of a decision, especially when limited experts are available. Formal uncertainty importance technique is used to estimate the degree of credibility of the TH model(s) used to represent the important phenomena. This part uses subjective justification by evaluating available information and data from experiments, and code predictions.

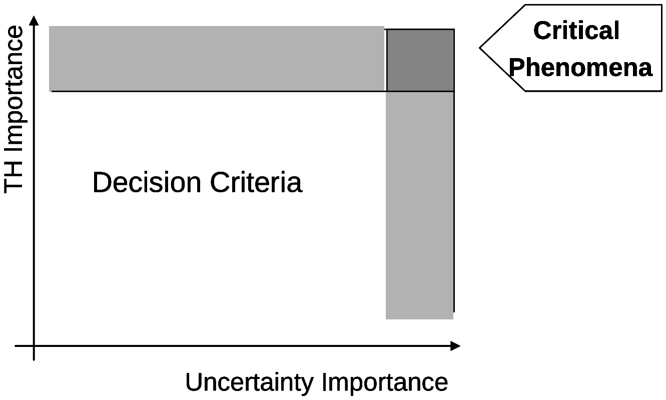


FIGURE 1: TH IMPORTANCE VS. UNCERTAINTY IMPORTANCE IN CHOSEN CRITERIA

Table 1 shows some phenomena with their TH and uncertainty importance. By uncertainty importance, we mean how credible the developed models are by predicting the phenomena precisely. For example, decay heat power was considered high in its TH importance due to its impact on PCT itself. The phenomenon is well-known and correlations are well developed to predict it. Therefore, low uncertainty was assigned to it to demonstrate high confidence of the phenomena model used in TH codes. TH importance has impact on output's mean value while uncertainty importance affects the variation. There are different qualitative and quantitative approaches to assign ranks to phenomena. Ranking of high, medium, and low was used in some studies and others used ranking on 1 to 9 where 9 is highest importance and 1 is the lowest.

TABLE 2: SOME PHENOMENA WITH THEIR TH AND UNCERTAINTYRANK

Uncertainty / TH	High	Medium	Low
High	Spacer Grid Rewetting and Droplet Breakup	Rewet CCFL	Decay Heat Power
Medium	Time of Burst?	Rod-to-Spacer Grid Local Heat Transfer	Cladding Phase Change
Low	Rod-to-Rod Mechanical Interactions	Cladding Oxidation (ID&OD)	Fuel Relocation

4.1 TH RANKING-AHP METHOD

Analysts have a high capability to determine the relative importance of two items, when the number of items does not exceed four-five. As the number of items in a group increases beyond 4 or five, the ranking capability decreases at an increasing rate. Accordingly, AHP methodology has been developed to organize large ranking problems into subsets that capitalize human abilities to work with [11]. AHP is a systematic, logical approach developed by T.L. Saaty [11] to reduce complex issues into manageable pieces. The decision maker can sort through the variables and determine to what degree a particular variable will influence the final decision. With more than 67 {10] actual phenomena and many others processes, status, and conditions considered as phenomena identified in LOCA scenarios in NPPs, AHP approach with such capability help justify LOFT LBLOCA PIRT. AHP was very useful for LOFT LBLOCA PIRT because of few experts available.

The AHP methodology was used for ranking of phenomena based on their TH importance. Phenomena were compared in a pairwise manner to find their relative importance on the output or any other figure of merit. Examples are tabulated in the Table 8. The UMD-AHP software was used for computation of TH ranks for every component and system considered. List of all of them were shown in Table 4-6

4.2 UNCERTAINTY RANKING-EXPERT JUSTIFICATION

Formal uncertainty importance technique is used to estimate the degree of credibility of the TH model(s) used to represent the important phenomena. This part uses subjective justification by evaluating available information and data from experiments, and code predictions. High rank signifies sufficient knowledge about phenomena which leads to development of precise model(s) and correlation (s) and low rank indicate poor knowledge.

5. LOFT APPLICATION

The LOFT (Loss-of-Fluid Test) facility is a 50-MWt pressurized water reactor (PWR) with instrumentation to measure and provide data on the thermal hydraulic conditions throughout the system. The unique feature of the facility is its UO2 powered core. The facility is scaled to represent a 1/60-scale model of a typical 1000-MWe commercial four-loop PWR. Three PWR primary-coolant loops are simulated by a single intact loop in LOFT scaled to have the same volume-to-power ratio. A broken loop in LOFT simulates the fourth PWR primary-coolant loop where a break may be postulated to occur. Detail description of the facility may found in Ref. [12] and other LOFT facility documents.

PIRT for LBLOCA-LOFT is built for the purpose of uncertainty analysis of the transient scenario calculation by the TH code, RELAP5/MOD3.3.

5.1 Scenario Description

LOFT LOCA Test LB-1 is a 200% cold leg break test. Table 3 gives the measured initial conditions for the test. A detailed description of the test is given in Reference [13]. The transient sequence of events for Test LB-1 is shown in Table 4. Reactor power was tripped on a low pressure in the experiment. However, the pressure set point for tripping the reactor power for this test was higher than the other tests (49.3 MW) and thus a higher loop flow. The high pressure injection was assumed inactivated for this test. The intact loop pumps were disconnected from the fly wheel at the time of pump trip.

Computational analysis and experimental data indicate that a PWR-LBLOCA involves three phases or periods, based on trends of changes in the liquid inventories of the vessel, the core, and the lower plenum. The three periods are: Blowdown, Refill and Reflood. PIRT results from a Westinghouse 4 loop PWR NPPs PIRT results [14] and results from [9] and list of 67 phenomena identified by [10]were used as starting point for developing PIRT for scenario.

TABLE 3: LOFT MEASURED INITIAL CONDITIONS FOR TEST LB-1 [12]

Parameter	*LB-1*
Reactor Power (MW)	*49.3*
Low Pressure Scram Set Point (MPa)	*14.5*
Intact-loop Mass Flow (kg/s-m2)	*305.8*
Hot-leg Pressure (MPa)	*14.77*
Hot-leg Temperature (K)	*586.1*
Cold-leg Temperature (K)	*556.6*
Pump Speed (rad/s)	*209*
Pressurizer Steam Volume (m^3)	*0.38*
Pressurizer Liquid Volume (m)	*0.55*
Steam-generator Pressure (MPa)	*5.53*
Steam-generator Mass Flow (kg/s)	*25.4*
Accumulator Pressure (MPa)	*4.21*
Accumulator Temperature (K)	*305*
Accumulator Initial Level (m)	*2.31*
Accumulator Level at End of Discharge (m)	*1.75*
Accumulator Liquid Level Change (m)	*0.56*
Accumulator Liquid Volume Discharged (m^3)	*0.76*
Accumulator Initial Gas Volume (m^3)	*0.65*
Accumulator Initial Gas/Liquid Fraction	*0.85*

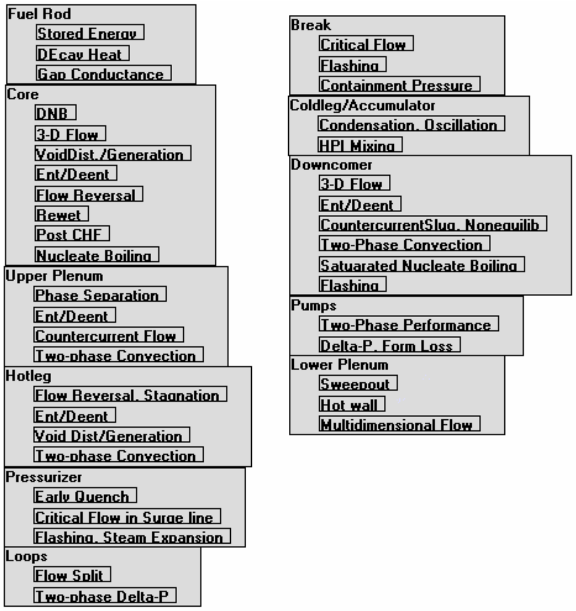
Table 4: LOFT LB-1 LBLOCA transient sequence of events [13]

LOFT Test LB-1 Sequence of Event Timing		
Event	*Measured*	*Code Results*
Break initiated (s)	*0*	*0*
Reactor scrammed (s)	*0.13*	*0.13*
Primary-coolant pumps tripped (s)	*0.63*	*0.63*
Pressurizer emptied (s)	*Instrument failure*	*15.5*
Accumulator A injection initiated (s)	*17.4*	*14*
Reflood Tripped On (s)	*NA*	*0*
HPIS injection initiated (s)	*NA*	*NA*
LPIS injection initiated (s)	*24.8*	*24.8*
Maximum cladding temperature (°K)	*1170*	*1050*

5.2 Blowdown Phase

The phase begins with the break initiation and ends when the accumulator injection initiates in the intact loops, a period of approximately 12 seconds. Table 4 shows complete list of identified phenomena during this phase. Details of the phase sequence of events are found in Refs. [2, 14]

TABLE 4: IDENTIFICATION TABLE FOR BLOWDOWN PHASE



Fuel Rod
- Stored Energy
- DEcay Heat
- Gap Conductance

Core
- DNB
- 3-D Flow
- VoidDist./Generation
- Ent/Deent
- Flow Reversal
- Rewet
- Post CHF
- Nucleate Boiling

Upper Plenum
- Phase Separation
- Ent/Deent
- Countercurrent Flow
- Two-phase Convection

Hotleg
- Flow Reversal, Stagnation
- Ent/Deent
- Void Dist/Generation
- Two-phase Convection

Pressurizer
- Early Quench
- Critical Flow in Surge line
- Flashing, Steam Expansion

Loops
- Flow Split
- Two-phase Delta-P

Break
- Critical Flow
- Flashing
- Containment Pressure

Coldleg/Accumulator
- Condensation, Oscillation
- HPI Mixing

Downcomer
- 3-D Flow
- Ent/Deent
- CountercurrentSlug, Nonequilib
- Two-Phase Convection
- Satuarated Nucleate Boiling
- Flashing

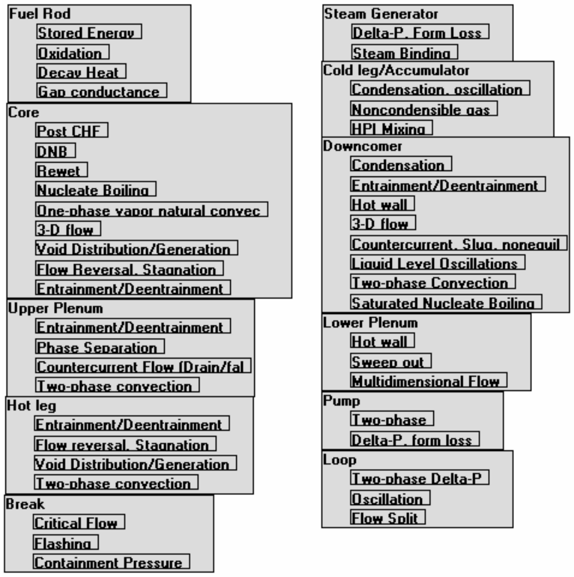
Pumps
- Two-Phase Performance
- Delta-P, Form Loss

Lower Plenum
- Sweepout
- Hot wall
- Multidimensional Flow

5.3 Refill

The phase begins with the accumulator injection and ends when the mixture level in the lower plenum reaches the core inlet, a period of approximately 20 seconds. Table 5 shows complete list of identified phenomena during this phase. Details of the phase sequence of events are found in [2, 14]

TABLE 5: PHENOMENA IDENTIFICATION TABLE FOR REFILL PHASE



Fuel Rod
- Stored Energy
- Oxidation
- Decay Heat
- Gap conductance

Core
- Post CHF
- DNB
- Rewet
- Nucleate Boiling
- One-phase vapor natural convec
- 3-D flow
- Void Distribution/Generation
- Flow Reversal, Stagnation
- Entrainment/Deentrainment

Upper Plenum
- Entrainment/Deentrainment
- Phase Separation
- Countercurrent Flow (Drain/fal
- Two-phase convection

Hot leg
- Entrainment/Deentrainment
- Flow reversal, Stagnation
- Void Distribution/Generation
- Two-phase convection

Break
- Critical Flow
- Flashing
- Containment Pressure

Steam Generator
- Delta-P, Form Loss
- Steam Binding

Cold leg/Accumulator
- Condensation, oscillation
- Noncondensible gas
- HPI Mixing

Downcomer
- Condensation
- Entrainment/Deentrainment
- Hot wall
- 3-D flow
- Countercurrent, Slug, nonequil
- Liquid Level Oscillations
- Two-phase Convection
- Saturated Nucleate Boiling

Lower Plenum
- Hot wall
- Sweep out
- Multidimensional Flow

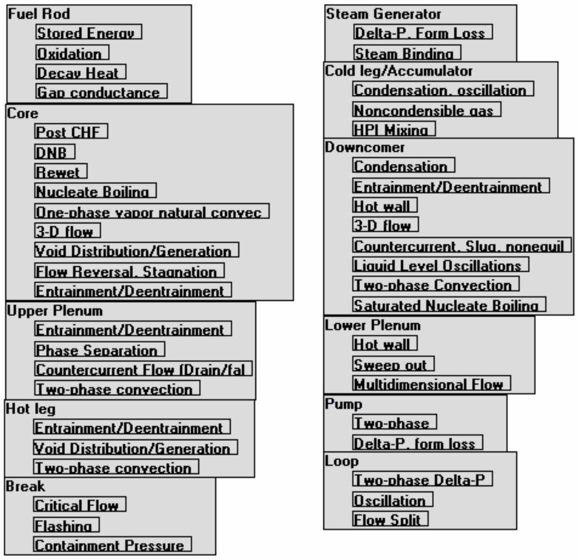
Pump
- Two-phase
- Delta-P, form loss

Loop
- Two-phase Delta-P
- Oscillation
- Flow Split

5.4 Reflood

The phase begins when the liquid mass in the core starts to increase and ends when the whole core is quenched and submerged again, a period lasting 20 to 300 s. Table 6 shows complete list of identified phenomena during this phase. Details of the phase sequence of events are found in [2, 14]

TABLE 6: IDENTIFICATION OF PHENOMENA TABLE FOR REFLOOD PHASE



Fuel Rod
- Stored Energy
- Oxidation
- Decay Heat
- Gap conductance

Core
- Post CHF
- DNB
- Rewet
- Nucleate Boiling
- One-phase vapor natural convec
- 3-D flow
- Void Distribution/Generation
- Flow Reversal, Stagnation
- Entrainment/Deentrainment

Upper Plenum
- Entrainment/Deentrainment
- Phase Separation
- Countercurrent Flow (Drain/fal
- Two-phase convection

Hot leg
- Entrainment/Deentrainment
- Void Distribution/Generation
- Two-phase convection

Break
- Critical Flow
- Flashing
- Containment Pressure

Steam Generator
- Delta-P, Form Loss
- Steam Binding

Cold leg/Accumulator
- Condensation, oscillation
- Noncondensible gas
- HPI Mixing

Downcomer
- Condensation
- Entrainment/Deentrainment
- Hot wall
- 3-D flow
- Countercurrent, Slug, nonequil
- Liquid Level Oscillations
- Two-phase Convection
- Saturated Nucleate Boiling

Lower Plenum
- Hot wall
- Sweep out
- Multidimensional Flow

Pump
- Two-phase
- Delta-P, form loss

Loop
- Two-phase Delta-P
- Oscillation
- Flow Split

5.5 Results Discussion

Results of final screening for purpose of uncertainty analysis is shown in Table 10. The decision criteria was chosen as medium and higher for both TH and uncertainty importance. Normalized TH ranks were converted to low, medium, and high ranks accordingly. The application is for demonstration only and more TH expertise would be needed for definitive confirmation of the results. Final results are shown in Table 9. Initial conditions are not considered in this application due to limited TH expertise available but they should be considered as important part of conditions influencing on the figure of merit (PCT).

6. CONCLUSION

A methodology of characterizing important phenomena, called "Modified PIRT" was developed and demonstrated on LOFT LBLOCA transient. It provides robust process of PIRT for more precise quantification of uncertainty. It is part of a broader research by the authors and will be implemented on general methodology for a comprehensive methodology of TH computational codes uncertainty analysis.

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TABLE 1: LBLOCA PIRT COMPARISON OF 3 STUDIES OF AREVA, ORIGINAL CSAU, AND WESTINGHOUSE/EPRI; GRAY AREA ARE COMMON PHENOMENA IDENTIFIED IN THE PIRT STUDIES

AREVA	Original CSAU	Westinghouse/EPRI
Dominant PIRT Parameters	**Break Flow**	**Plant Initial Conditions**
1.Break Flow	1. Mass Flow	1. RCS Average Fluid Temperature
2.Entrainment	**Stored Energy an Fuel Response**	2. RCS Pressure
3.Axial Power Distribution	1. Gap Conductance	3. Accumulator Fluid Temperature
4.Interfacial Heat Transfer	2. Peaking Factor	4. Accumulator Pressure
5.Core Multi-Dimnesional Flow	3. Fuel Conductivity	5. Accumulator Volume
6.ECCS Bypass	4. Fuel/ Fluid HT	6. Safety Injection Temperature
7.Steam Binding	5. Clad Conductivity	7.Accumulator Line Resistance
8.Spacer Effects	6. Fuel and Clad Heat Cap	**Plant Initial Core Power Distribution**
9.Cold Leg Condensation	7. Pellet Power Distribution	1.Nominal Hot Assembly Peaking Factor
10.Void Distribution	**ECCS Bypass**	2.Nominal Hot Assembly Average Relative Power
11. Accumulator Nitrogen Discharge	1. ECC Flow Deversion	3. Average relative power, lower third of core
12.Heat Transfer	**Steam Binding**	4. Average relative power, middle third of core
13.Upper Tie Plate CCFL	1. Liquid Mass Flow	5. Average relative power, outer edge of core
Treated Plant Parameters	2. Evaporation	**Thermal-Hydraulics Physical Models**
1.Core Power	3. Entrainment	1.Critical Flow Modeling (CD)
2.Pressurizer Pressure	4. De-entrainment	2. Broken Loop Resistance
3.Pressurizer Level	**Pump 2-Phase Flow**	3. Blowdown and reflood heat transfer
4.Accumulator Volume	1. Mass Flow	4. Minimum Film Boiling Temperature
5.Accumulator Pressure	2. Pressure	5. Condensation Modeling
6.Containment/Accumulator Temperature	3. Core Power	6. Break Type
7.Containment Volume	4. Disolved Nitrogen	7. ECCS Bypass
8.Initial Flow Rate	5. Non-Condensible Gas Partial Pressure	8. Entrainment and Steam Binding
9.Initial Operating Temperature		9. Effect of Nitrogen Injection
10.Offsite Power Availability		**(d) Hot Rod physical Models**
11.Deisel Start		1. Local Hot Spot Peaking Factor
		2. Fuel Conductivity
		3. Gap Heat Transfer Coefficient
		4. Fuel Conductivity after Burst
		5. Fuel Density after Burst (Fuel Relocation)
		6. Cladding Reaction Rate
		7. Rod Internal Pressure
		8. Burst Temperature
		9. Burst Strain

Table 78: Partial PIRT calculation results

LOFT PIRT Development		Uncertainty Importance	TH Rank During Phase		
Component	**Phenomena**	**Models**	**Blowdown**	**Refill**	**Reflood**
Fuel Rod	Stored Energy	Low	0.735	0.532	0.068
	Decay Heat	Low	0.058	0.185	0.363
	Oxidation	Medium	*	0.097	0.319
	Gap Conductance	Medium	0.207	0.185	0.249
Core	Post-CHF heat Transfer	High	0.171	0.245	0.092
	Rewet	Medium	0.283	0.051	0.016
	Reflood Heat Transfer plus quench	High	*	*	0.199
	3-D flow	Medium	0.021	0.098	0.128
	Void generation/distribution	Low	0.105	0.178	0.132
	Entrainment/Deentrainment	Medium	0.032	0.082	0.102
	Nucleate Boiling	Medium	0.114	0.045	0.031
	Flow Reversal, Stagnation	Medium	0.082	0.043	0.016
	DNB	Low	0.191	0.048	0.023
	One-phase vapor natural convection	Low	*	0.201	0.202

TABLE 8: AHP PROCESS DEMONSTRATION

Upper Plenum	Phase Separation	Ent./Deent.	2-Phase Convection	Countercurrent Flow
Phase Separation	1	3	1	9
Ent./Deent.	0.333	1	0.333	1
2-phase Convection	1	3	1	9
Countercurrent Flow	0.111	1	0.111	1

TABLE 9: LOFT LOBLOCA PIRT RESULTS

High TH/Uncertainty Importance Phenomena
Critical Flow
Rewet
Entrainment/Deentrainment
Post-CHF Heat Transfer
Core 3-D Flow
Pump Two-Phase Flow
Non-Condensable Gases
Steam Binding
Conductive/ Convective Heat Transfer