NextEra Energy Seabrook, LLC
(Seabrook Station, Unit 1)
License Renewal Application

NRC Staff Answer to Motion for Summary Disposition of Contention 4B

ATTACHMENT 4B-C

ELECTRIC POWER RESEARCH INSTITUTE

MAAP4 Applications Guidance

Desktop Reference for Using MAAP4 Software, Revision 2

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PORTIONS TRANSLATED

2
INTRODUCTION TO MAAP4

The Modular Accident Analysis Program Version 4 (MAAP4) is a computer code that simulates the response of light water reactor (LWR) power plants during severe accidents. Given a set of initiating events and operator actions, MAAP4 predicts the plant's response as the accident progresses. The code is used to do the following:

- Predict the timing of key events (for example, core uncovery, core damage, core relocation to the lower plenum, and vessel failure)
- Evaluate the influence of mitigative systems, including the impact of the timing of their operation
- Evaluate the effects of operator actions
- Predict the magnitude and timing of fission product releases
- Investigate uncertainties in severe accident phenomena

MAAP4 results are primarily used to determine Level 1 and 2 success criteria and accident timing for probabilistic risk assessments (PRAs). They are also used for equipment qualification analyses, fission product large early release frequency (LERF) determinations, integrated leak rate test evaluations, emergency planning and training, simulator verification, analyses to support plant modifications, generic plant issue assessments (for example, significance determinations), and other similar applications.

MAAP4 is an integral code. It treats the full spectrum of important phenomena that could occur during an accident, simultaneously modeling those that relate to the thermal hydraulics and to the fission products. It also simultaneously models the primary system and the containment and reactor/auxiliary building.

Parallel versions of MAAP4 support boiling water reactors (BWRs) and pressurized water reactors (PWRs), and there are also unique versions for CANDU, VVER, and ATR reactor designs. Although much of the information presented in this section and in other parts of this report is applicable to all versions of the MAAP4 code, the information primarily applies to the BWR and PWR versions. These two versions contain the same core model, containment and reactor/auxiliary building model, fission product model, and input and output schemes. They have distinct primary system models and engineered safeguards models. The code is applicable to both current and advanced LWR designs, with models that represent the passive features of the latter.

MAAP4 requires two input files. The first is the parameter file, which contains plant-specific information, output specifications, and user-controlled phenomenological parameters. The second is the sequence input file, which specifies the accident initiators, operator actions, and sequence control times (that is, end time and print interval). After processing the information in the two files, the code predicts the sequence of events and corresponding plant conditions. It generates approximately 25 output files, including a synopsis of the sequence, a summary of events, tables of time-dependent results in a form suitable for plotting, and tabulated results that provide the details of the plant's status at selected times. The input and output files are described in more detail in Section 3 of this report.

2.1 MAAP Development History and the MAAP Users Group

MAAP was originally developed for the Industry Degraded Core Rulemaking (IDCOR) program in the early 1980s by Fauske & Associates, LLC (FAI). At the completion of IDCOR, ownership of MAAP was transferred to the Electric Power Research Institute (EPRI), which was charged with maintaining and improving the code. Starting in the late 1980s, the MAAP3B version became widely used, first in the United States and then worldwide, to support success criteria determination, human action timing evaluations, and Level 2 analyses for individual plant examinations (IPEs). IPEs were used to identify plant vulnerabilities and to facilitate an increased understanding of severe accident phenomena. Therefore, the code has been applied to numerous containment designs and sequences for approximately 20 years.

The code was updated to the current version, MAAP4, in the mid-1990s. It extended MAAP's capabilities for accident management evaluations, primarily with refined core and lower plenum models. Other improvements include a generalized node and junction containment model and models that represent unique features of advanced LWRs. As part of the development process, MAAP4 was reviewed by a committee of independent experts to ensure that it is state-of-the-art and applicable for accident management evaluations. The development of MAAP4 was sponsored by several organizations, including EPRI and the U.S. Department of Energy (DOE). EPRI licenses MAAP4 to utilities, vendors, and research organizations, including universities.

The majority of MAAP4 users are members of the MAAP Users Group (MUG). The MUG provides direction and funding for code maintenance, enhancements, and benchmarking; facilitates information transfer through biannual meetings and the issuance of various communications on code problems and best practices; and supports industry and regulatory acceptance. As of April 2009, the MUG membership consists of approximately 50 organizations from 12 countries. FAI is the maintenance contractor for the code, and ERIN Engineering and Research, Inc. performs an independent review of maintenance activities.

The code has been developed and is maintained under FAI's quality assurance program, which is in compliance with U.S. 10CFR50 Appendix B and ISO 9001 quality assurance requirements.

2.2 Phenomena Modeled in MAAP4

MAAP4 treats the spectrum of physical processes that could occur during an accident. Level 1 PRA phenomena include the following:

- Gas and water flow
- Natural circulation

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MAAP BENCHMARKS

The MAAP4 code has been extensively benchmarked, and information about the benchmarks has been presented and published in a variety of forums. To facilitate an assessment of the abilities of the code to model Level 1 phenomena based on the results of the benchmarks, the documentation of relevant benchmarks was collected and reviewed by a team of MAAP4 experts.[8] The benchmarks were gathered from the MAAP4 User's Manual, technical journals, conference proceedings, MUG meeting presentations, and technical reports. More than 30 benchmarks were collected; they fall into the following categories:

- Comparisons to plant events (PE entries)
- Comparisons to integral codes (IC entries)
- Comparisons to integral experiments (IE entries)
- Comparisons to separate effects experiments (SE entries)

7.1 Method for the Review of the MAAP Benchmarks

The team of experts—each member having extensive experience with the development and application of MAAP3B and MAAP4 as well as extensive knowledge of severe accident phenomena and plant response—reviewed the individual benchmarks in two stages. The first stage consisted of a preliminary review of the documentation of each benchmark to determine if 1) it contains adequate information on the method and results so that conclusions could be drawn and 2) the code was used in an appropriate manner (for example, not in a regime determined to be outside the range of applicability according to the limitations posted on the MAAP4 web site). The major code models—primary system thermal hydraulics, steam generator thermal hydraulics, core heat-up, and containment thermal response—evaluated by each benchmark were identified. Similarly, significant code capabilities validated by each benchmark were identified. These include critical flow through valves and breaks, ECCS injection, condenser heat transfer, voiding in the core, and hot leg natural circulation (HLNC).

The second stage consisted of an in-depth review of each of the benchmarks that met the preliminary criteria to determine the agreement between the MAAP4 results and the corresponding data and comparative analyses. The team studied the documented information and discussed the strength of the benchmark, the specific results, the conclusions drawn by the authors, and so on. To provide a framework for the collective assessment of the code's capabilities, the review was structured to 1) rate the degree of agreement between the sets

[8] The team consisted of Jeff Gabor and Barbara Schlenger-Faber of ERIN, Chan Paik and Robert Reeves of FAI, and Marc Kenton of Erigo Technologies.

of comparative results and 2) capture pertinent information on code performance, limitations, and options for modeling particular phenomena.

The degree of agreement for the major code models is based on the following representative quantities. They were selected because of their importance to the success criteria and human reliability components of PRA analysis:

- BWR primary system thermal hydraulics: primary system pressure and water level in the vessel
- PWR primary system thermal hydraulics: primary system pressure, water level in the pressurizer, and water level in the vessel
- Steam generator thermal hydraulics: secondary side pressure and water level in the steam generators
- Core heat-up (generic to BWR and PWR): maximum core temperature
- Containment thermal response (generic to BWR and PWR): containment pressure

The team jointly rated the agreement for each of the major models as well as the overall degree of agreement as *very good*, *good*, *fair*, *qualitative*, or *inconclusive*. No *poor* agreements were identified. By necessity, the rating process was qualitative rather than quantitative. Consideration was given to whether the uncertainties associated with the documented sequence definitions and boundary conditions tended to be greater than those associated with the modeling approaches and phenomenological uncertainties.

The team also assessed the validation of the specific code capabilities as *validated by explicit results* or *qualitative or indirect validation*. No *inconclusive* or *negative* validations were identified.

Details about each of the benchmarks are assembled in Appendix F and include the following:

- Identifying information: authoring organizations, plant types (BWR, PWR, containment type, and so on), PRA levels, sequence types, time frames of the analyses, and MAAP code versions
- Agreement for major code models: elaboration and observations
- Validation of significant code capabilities: elaboration and observations
- Exemplified limitations and precautions
- Issues for further code development and user support
- Notes and recommendations for the users
- Conclusions drawn by the authors of the benchmark
- Documentation: reference citations

The entries in Appendix F have a consistent format; only the applicable or available details are included for each individual benchmark.

7.2 Benchmark Review Results

Tables 7-1 and 7-2 list the benchmarks that met the preliminary criteria of the first stage of the review process and contain the summary results from the team's in-depth review. The first table contains the degree of agreement for the major code models and the overall code. The second table contains the extent of the validation of the significant code capabilities.

Compilations of the degree of agreement for the major code models and the validation of the code capabilities are presented in Tables 7-3 and 7-4, respectively. Compilations of the benchmarks as a function of sequence type are presented in Tables 7-5 and 7-6 for BWRs and PWRs, respectively. Because not all of the benchmarks are of the same technical caliber and because some contain multiple independent sequences while others contain variations of a base sequence, the compilations should be viewed as general versus rigorous.

7.3 Conclusions from the Benchmark Review

Three sets of conclusions were drawn from the review of the benchmarks. First, the compilations in Tables 7-3 through 7-6 were examined to identify particular areas in which additional benchmarks would be beneficial for filling in gaps in the overall matrix of major code models, code capabilities, and sequences that are supported by benchmarks. Recommendations for additional benchmarks based on this examination of the number and level of agreement of the existing benchmarks are as follows:

- Major code models: steam generator thermal hydraulics for OTSGs
- Significant code capabilities: drywell/fan cooler heat and mass transfer
- BWR sequences:
  - SLOCAs and MLOCAs
  - Stuck-open SRVs with discharge to the suppression pool
  - ATWS conditions
- PWR sequences:
  - LLOCAs
  - SGTRs (These are in part supported by the SLOCA benchmark sequences, but additional benchmarks that focus on the secondary side response would be of value because of the complex coupling of the primary and secondary sides and the importance of SGTRs in Level 1 analysis.)
  - Mid-loop operation

Second, specific details of the benchmarks assembled in Appendix F that affect code applications were collected. These details include limitations, precautions, notes and recommendations for users, and issues for further code development and user support. They are listed in Section 8 along with additional items known to the team and the code maintenance contractor.

Table 7-1
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models						Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	
			BWR	PWR				
Plant event (PE1)	TMI-2 LOFW; B&W	Very good given uncertainty in boundary conditions	—	Good	Fair (OTSG, one-region model)	Indirect support	Qualitative	MAAP4 User's Manual and conference proceedings
Plant event (PE2)	Davis-Besse LOFW; B&W	Fair	—	Fair to good	—	—	—	MAAP4 User's Manual
Plant event (PE3)	Oyster Creek LOFW; BWR with isolation condenser	Very good given uncertainty in boundary conditions	Good	—	—	—	—	MAAP4 User's Manual
Plant event (PE4)	Prairie Island SGTR; WLD	Good	—	Good	—	—	—	MAAP4 User's Manual
Plant event (PE5)	Maanshan SBO; WLD	Good	—	Good to very good	—	—	—	Presentation to the NRC

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models						Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	
			BWR	PWR				
Plant event (PE6)	Oconee plant trip; B&W	Good	—	Very good with code change to model plants with hot water in dome	—	—	—	Presentation to the MUG
Plant event (PE7)	LOOP and plant trip in 1992 MAAP3B Qualification Studies; Westing-house four-loop	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report
Integral code–compared to CENTS (IC1)	SBO and LOFW with F&B; CE	Good	—	Good	Fair to very good (U-tube, two-region model)	—	—	Conference proceedings

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models						Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	
			BWR	PWR				
Integral code–compared to SR5 (IC2)	LOFW and S/MLOCAs; U.S. EPR	Good	—	Good to very good[a]	Fair to good (U-tube, one-region model)	Fair to very good	—	Conference proceedings
Integral code–compared to TRACG02 (IC3)	LOOPs with LLOCAs; BWR	Good	Good	—	—	Fair	—	GE technical report
Integral code–compared to RELAP5 (IC4)	SBO with F&B for Palisades; CE	Good	—	Fair to good	Good (U-tube, one-region model)[a]	—	—	Erigo letter report and presentations to the MUG
Integral code–compared to SR5 and MELCOR (IC5 1 of 2)	LLOCA for Kuonsheng; BWR	Good	Fair to good	—	—	Good	—	Journal paper and doctoral dissertation

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models							Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)		
			BWR	PWR					
Integral code–compared to SR5 and MELCOR (IC5 2 of 2)	SBO for Maanshan; WLD	Good	—	Fair to good	Good (U-tube, region model not specified)	Good	—		Journal paper and doctoral dissertation
Integral code–compared to CENTS (IC6)	MLOCA for Palo Verde; WLD	Inconclusive	—	Inconclusive	Inconclusive (U-tube, region model not specified)	—	—		Presentation to the MUG
Integral code–compared to CATHARE (IC7)	S/M LOCAs; EDF/ Framatome PWR 900	Good	—	Good to very good	Very good (U-tube, one-region model)	—	—		EDF technical report
Integral code–compared to SR5 and MELCOR (IC8)	TMLB' (SBO with no RCP seal leak); WLD	Good	—	Fair to good	Good (U-tube, one-region model)	Indirect support	—		Journal paper

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models: Overall Code	Primary System Thermal Hydraulics (pressure and water level): BWR	Primary System Thermal Hydraulics (pressure and water level): PWR	SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	Principal Sources of Documentation for the Benchmark
Integral code–compared to RELAP5 (IC9)	LOOP with F&B for Millstone; CE	Good	—	Fair to good	Good (U-tube, one-region model)	Good	—	Presentation to the MUG
Integral code–compared to MELCOR (IC10)	TMLB, LLOCAs and SLOCA; WLD SBO, transients, and LLOCA; BWR	Good	Not available	Good	—	—	—	Conference proceedings
Integral code–compared to SAFE (IC11)	Transients, SLOCA, and MSLB in 1992 MAAP3B Qualification Studies; BWR	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models: Overall Code	Primary System Thermal Hydraulics (pressure and water level): BWR	Primary System Thermal Hydraulics (pressure and water level): PWR	SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	Principal Sources of Documentation for the Benchmark
Integral code–compared to RELAP and RETRAN (IC12)	Transients, failed-open PORV, SGTRs, SLOCAs, and MSLB in 1992 MAAP3B Qualification Studies; Westing-house four-loop	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report
Integral experiments (IE1)	BETHSY LOFWs with F&B and SLOCA; EDF/ Framatome PWR 900	Very good	—	Very good	Very good (U-tube, one- and two-region models)	—	—	Presentation to the MUG
Integral experiments (IE2)	IIST SBO; WLD	Very good	—	Very good	Very good (U-tube, one-region model)	Very good	—	Conference proceedings

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models						Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	
			BWR	PWR				
Integral experiments (IE3)	MB-2 LOFWs, MSLBs, and MSLB with SGTR; WLD	Very good	—	—	Very good (U-tube, two-region model)	—	—	Conference proceedings
Integral experiment (IE4)	OSU SLOCAs and failed-open PORVs; AP600	Very good	—	Very good	Very good (U-tube, two-region model)	—	—	Conference proceedings
Integral experiment (IE5)	Waltz Mill containment; generic	—	—	—	—	—	Fair	MAAP4 User's Manual
Integral experiment (IE7; see Table 7-2 for IE6)	CSTF containment; generic	—	—	—	—	—	Very good	MAAP4 User's Manual
Integral experiment (IE8)	HDR containment; generic	—	—	—	—	—	Very good	Journal paper and conference proceedings
Integral experiment (IE9)	ISP-35 containment; generic	—	—	—	—	—	Very good	Conference proceedings

Table 7-1 (continued)
Collected Benchmarks and Agreement for the Major Code Models Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier, Sequences, and Plant Type	Agreement for Major Code Models						Principal Sources of Documentation for the Benchmark
		Overall Code	Primary System Thermal Hydraulics (pressure and water level)		SG Thermal Hydraulics (pressure and water level)	Core Heat-Up (core temperature)	Containment Thermal Response (pressure)	
			BWR	PWR				
integral experiment (IE10)	Semiscale: SLOCAs, LOOPs, and SGTRs in 1992 MAAP3B Qualification Studies for PWR	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report
Integral experiment (IE11)	FIST: LOFWs and MLOCA in 1992 MAAP3B Qualification Studies for BWR	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report
Integral experiment (IE12)	MIST: SLOCAs in 1992 MAAP3B Qualification Studies for B&W	Generally but not specifically applicable; good agreement with MAAP3B	—	—	—	—	—	EPRI technical report

[a] One exception to the agreement is suspected to be the result of input differences.

[b] The exception to the agreement is a minor limitation in MAAP4 related to condensation in the steam generators.

Table 7-2
Collected Benchmarks and Validation of Significant Code Capabilities Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier and Plant Type	Capabilities					Principal Sources of Documentation for the Benchmark
		Critical Flow Model	ECCS Injection	Condenser Heat Transfer	Voiding in Core	HLNC	
Plant event (PE3)	Oyster Creek LOFW; BWR with isolation condenser	—	—	BWR isolation condenser validated	—	—	MAAP4 User's Manual
Plant event (PE4)	Prairie Island SGTR; WLD	—	PWR hardwired model validated	—	—	—	MAAP4 User's Manual
Integral code–compared to CENTS (IC1)	SBO and LOFW with F&B; CE	Qualitative support (PORV flow)	PWR generalized model validated	—	—	—	Conference proceedings
Integral code–compared to SR5 (IC2)	LOFW and S/MLOCAs; U.S. EPR	Qualitative support (safety valve flow); validated (break flow)	—	—	—	—	Conference proceedings
Integral code–compared to TRACG02 (IC3)	LOOPs with LLOCAs; BWR	Validated (break flow)	BWR model validated	—	—	—	GE technical report

Table 7-2 (continued)
Collected Benchmarks and Validation of Significant Code Capabilities Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier and Plant Type	Capabilities					Principal Sources of Documentation for the Benchmark
		Critical Flow Model	ECCS Injection	Condenser Heat Transfer	Voiding in Core	HLNC	
Integral code–compared to RELAP5 (IC4)	SBO with F&B for Palisades; CE	Qualitative support (PORV flow)	PWR generalized model validated	—	—	—	Erigo letter report and presentations to the MUG
Integral code–compared to CENTS (IC6)	MLOCA for Palo Verde; WLD	Validated (break flow)	—	—	—	—	Presentation to the MUG
Integral code–compared to CATHARE (IC7)	S/M LOCAs; EDF/ Framatome PWR 900	Validated (break flow)	—	—	—	—	EDF technical report
Integral code–compared to SR5 and MELCOR (IC8)	TMLB' (SBO with no RCP seal leak); WLD	Qualitative support (PORV flow)	—	—	—	—	Journal paper

Table 7-2 (continued)
Collected Benchmarks and Validation of Significant Code Capabilities Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier and Plant Type	Capabilities					Principal Sources of Documentation for the Benchmark
		Critical Flow Model	ECCS Injection	Condenser Heat Transfer	Voiding in Core	HLNC	
Integral code–compared to RELAP5 (IC9)	LOOP with F&B for Millstone; CE	Validated (PORV flow)	PWR validated (model not specified)	—	—	—	Presentation to the MUG
Integral experiment (IE1)	BETHSY LOFWs with F&B and SLOCA; EDF/ Framatome PWR 900	Validated (break and PORV flow)	PWR generalized model validated	—	Qualitative support	—	Presentation to the MUG
Integral experiment (IE3)	MB-2 LOFWs, MSLBs, and MSLB with SGTR; WLD	Validated (break flow)	—	—	—	—	Conference proceedings
Integral experiment (IE4)	OSU SLOCAs and failed-open PORVs; AP600	Validated (break and PORV flow)	PWR validated (passive systems)	—	—	—	Conference proceedings

Table 7-2 (continued)
Collected Benchmarks and Validation of Significant Code Capabilities Related to Level 1 Phenomena

Benchmark Type (entry in Appendix F)	Identifier and Plant Type	Capabilities					Principal Sources of Documentation for the Benchmark
		Critical Flow Model	ECCS Injection	Condenser Heat Transfer	Voiding in Core	HLNC	
Integral experiment (IE5)	Waltz Mill containment; generic	—	—	PWR ice condenser validated	—	—	MAAP4 User's Manual
Integral experiment (IE6)	PNL ice containment; WICE	—	—	PWR ice condenser validated	—	—	MAAP4 User's Manual
Separate effects experiment (SE1)	THTF; generic	—	—	—	Validation of void fraction subroutine	—	MAAP4 User's Manual
Separate effects experiments (SE2)	Westing-house 1/7* scale; PWR	—	—	—	—	Validation of HLNC subroutine	MAAP4 User's Manual and EPRI technical report
Separate effects experiment (SE3)	Marviken and FAI blowdown; PWR	Validated (PORV flow, also pressurizer model)	—	—	—	—	MAAP4 User's Manual

Table 7-3
Compilation of the Agreement for the Major Code Models Related to Level 1 Phenomena[a]

Major Code Model	Number of Benchmarks Reviewed by Experts	Agreement[b]						
		Very Good	Good to Very Good	Good and Fair to Very Good	Fair to Good	Fair	Quali-tative or Indirect	Incon-clusive
Overall code for BWR analysis	4	1	—	3	—	—	—	—
BWR primary system thermal hydraulics	3	—	—	2	1	—	—	—
Overall code for PWR analysis	18	5	—	11	—	1	—	1
PWR primary system thermal hydraulics	17	4	3	4	5	—	—	1
PWR steam generator thermal hydraulics	13	5 U-tube	—	5 U-tube	1 U-tube	1 OTSG	—	1 U-tube
Core heat-up (generic to BWR and PWR)	8	1	—	4	—	1	2	—
Containment (generic to BWR and PWR)	5	3	—	—	—	1	1	—

[a] Does not include the MAAP3B benchmarks that are generally but not specifically applicable (good agreement obtained with MAAP3B).

[b] No poor agreement with the benchmarks was identified for any of the major code models.

Third, all of the assembled benchmark information was reviewed to determine in an overall sense either that MAAP4 is an appropriate tool for Level 1 analysis or that there are significant issues that adversely affect the adequacy of the code for such applications. It was concluded that the benchmarks support the use of MAAP4 for Level 1 analysis as long as users are aware of and follow the guidance in the other sections of this report, particularly Sections 3–6 and 8, and the corresponding appendices.

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