Westinghouse Non-Proprietary Class 3

WCAP-17573-NP-A
Revision 1

April 2015

PROJ0797

Westinghouse SMR Small Break LOCA Phenomena Identification and Ranking Table

Westinghouse

WCAP-17573-NP-A
Revision 1

Westinghouse SMR Small Break LOCA Phenomena Identification and Ranking Table

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April 2015

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Westinghouse Electric Company LLC
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February 27, 2015

Mr. James A. Gresham, Manager
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Westinghouse Electric Company, LLC
Suite 428, 1000 Westinghouse Drive
Cranberry Township, PA 16066

SUBJECT: WESTINGHOUSE ELECTRIC COMPANY'S FINAL TOPICAL REPORT SAFETY EVALUATION FOR WCAP-17573, REVISION 1, "WESTINGHOUSE SMALL MODULAR REACTOR SMALL BREAK LOSS OF COOLANT ACCIDENT PHENOMENA IDENTIFICATION AND RANKING TABLE"

Dear Mr. Gresham:

The U.S. Nuclear Regulatory Commission (NRC) staff prepared a final Topical Report Safety Evaluation (TRSE) for WCAP-17573, Revision 1, "Westinghouse Small Modular Reactor Small Break Loss of Coolant Accident Phenomena Identification and Ranking Table," in support of the Westinghouse Small Modular Reactor (W-SMR) design pre-licensing activities submitted by Westinghouse Electric Company (WEC).

The staff found that the Licensing Topical Report (LTR) WCAP-17573, Revision 1, is acceptable for referencing in licensing applications for the W-SMR to the extent specified and under the limitations delineated in the LTR and in the enclosed final TRSE. This final TRSE defines the basis for NRC's acceptance of the LTR.

If NRC criteria or regulations change, such that the acceptability of the TRSE conclusion is invalidated, WEC and/or the applicant referencing the TRSE will be expected to revise and resubmit its respective documentation, or submit justification for continued applicability of the TRSE without revision of the respective documentation.

The staff requests that WEC publishes the accepted version of WCAP-17573, Revision 1 within one to three months of receipt of this letter. The accepted proprietary and non-proprietary versions of the LTR shall incorporate this letter and the enclosed TRSE, and by adding an "-A" (designated accepted) following the LTR identification number. Also, the accepted versions must contain historical review information, including all NRC requests for additional information (RAIs) and WEC's responses to these RAIs. This may be in the form of an appendix or a summary change table referencing the RAIs and responses.

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Prior to placing the public version of this document in the public document room, the staff requests that WEC perform a final review of the TRSE for proprietary or security-related information not previously identified. If WEC believes that any additional information meets the criteria, please identify such information line by line and define the basis pursuant to the criteria established in Title 10 of the *Code of Federal Regulations* Part 2, Section 390.

If after a 10–day period, WEC does not request that all or portions of the TRSE be withheld from public disclosure, the TRSE will be made available for public inspection through the NRC Public Document Room and the Publicly Available Records component of NRC's Agencywide Documents Access and Management System and placed on the NRC's public web page for this application.

Should you have any questions or comments concerning this matter, please contact Arlon Costa at 301-415-6402 or via e-mail address at Arlon.Costa@nrc.gov.

Sincerely,

/RA/

Anna H. Bradford, Chief
Advanced Reactors and Policy Branch
Division of Advanced Reactors and Rulemaking
Office of New Reactors

Project No. 0797

Enclosures:
1. Safety Evaluation Report (Non-Proprietary)
2. Safety Evaluation Report (Proprietary)

Prior to placing the public version of this document in the public document room, the staff requests that WEC performs a final review of the TRSE for proprietary or security-related information not previously identified. If WEC believes that any additional information meets the criteria, please identify such information line by line and define the basis pursuant to the criteria established in Title 10 of the *Code of Federal Regulations* Part 2, Section 390.

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Should you have any questions or comments concerning this matter, please contact Arlon Costa at 301-415-6402 or via e-mail address at Arlon.Costa@nrc.gov.

Sincerely,

/RA/

Anna H. Bradford, Chief
Advanced Reactor and Policy Branch
Division of Advanced Reactors and Rulemaking
Office of New Reactors

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Letter to James A. Gresham from Anna H. Bradford dated February 27, 2015

SUBJECT: WESTINGHOUSE ELECTRIC COMPANY'S FINAL TOPICAL REPORT SAFETY EVALUATION FOR WCAP-17573, REVISION 1, "WESTINGHOUSE SMALL MODULAR REACTOR SMALL BREAK LOSS OF COOLANT ACCIDENT PHENOMENA IDENTIFICATION AND RANKING TABLE"

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FINAL SAFETY EVALUATION REPORT
FOR THE
LICENSING TOPICAL REPORT
WCAP-17573-NP, REVISION 1
WESTINGHOUSE SMALL MODULAR REACTOR
SMALL BREAK LOCA PHENOMENA
IDENTIFICATION AND RANKING TABLE
PROJ0797

Office of New Reactors
Division of Advanced Reactors and Rulemaking
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
ACRS	Advisory Committee on Reactor Safeguards
ADS	Automatic Depressurization System
AOV	Air Operated Valve
AOO	Anticipated Operational Occurrence
ATWS	Anticipated Transient Without Scram
BAST	Boric Acid Storage Tank
CCA	Code Capability Assessment
CCFL	Counter Current Flow Limitation
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CHR	Critical Heat Flux
CMT	Core Make-up Tank
CRDM	Control Rod Drive Mechanism
CSAU	Code Scaling, Applicability and Uncertainty
CV	Containment Vessel
CVCS	Chemical and Volume Control System
DBA	Design Basis Accident
DCA	Design Certification Application
DC	Direct Current
DCD	Design Control Document
DEGB	Double Ended Guillotine Break
DNBR	Departure from Nucleate Boiling Ratio
DVI	Direct Vessel Injection
ECCS	Emergency Core Cooling System
EM	Evaluation Model

EMDAP	Evaluation Model Development and Assessment Processes
ERI	Energy Research, Inc.
ESF	Engineered Safety Feature
FoM	Figure-of-Merit
GSI-191	Generic Safety Issue 191
HX	Heat Exchanger
ICP	In-Containment Pool
IET	Integral Effects Test
IFBA	Integral Fuel Burnable Absorber
IVR	In-Vessel Retention
LB	Large Break
LOCA	Loss-of-Coolant Accident
LOOP	Loss-of-Offsite Power
LTR	Licensing Topical Report
LWR	Light Water Reactor
MB	Medium Break
MSHIM	Mechanical Shim
MSIV	Main Steam Isolation Valve
NCG	Non-Condensable Gas
NRC	Nuclear Regulatory Commission
NRO	Office of New Reactors
OCP	Outside Containment Pool
PAR	Passive Autocatalytic Recombiner
PCT	Peak Cladding Temperature
PIRT	Phenomena Identification and Ranking Table
PRHR	Passive Residual Heat Removal
PWR	Pressurized Water Reactor
PSI	Pound per Square Inch
PSIA	Pound per Square Inch Absolute

PXS	Passive Core Cooling System
RAI	Request for Additional Information
RCP	Reactor Coolant Pump
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RES	Office of Nuclear Regulatory Research
RFLB	Recirculation Feedwater Line Break
RG	Regulatory Guide
RPV	Reactor Pressure Vessel
RSLB	Recirculation Steam Line Break
SB	Small Break
SCV	Sump Coupling Valve
SDIV	Steam Drum Isolation Valve
SG	Steam Generator
SGDV	Steam Generator Depressurization Valve
SER	Safety Evaluation Report
SET	Separate Effects Test
SIT	Sump Injection Tank
SRP	Standard Review Plan
SSC	Systems, Structures and Components
TER	Technical Evaluation Report
W-SMR	Westinghouse Small Modular Reactor
UHS	Ultimate Heat Sink

1. INTRODUCTION

Westinghouse Electric Company, LLC (Applicant) previously planned[1] to submit its Westinghouse Small Modular Reactor (W-SMR) design to the United States Nuclear Regulatory Commission (NRC) for certification. As part of the pre-application phase, the Applicant submitted the Licensing Topical Report (LTR) WCAP-17573-P, "Westinghouse SMR Small Break LOCA Phenomena Identification and Ranking Table," to the NRC for review and approval (Ref.1).

The design of the W-SMR involves an integral configuration in which all primary system components (i.e., reactor core, internals, steam generators (except for steam drum), pressurizer, and control rod drive mechanisms) are inside the reactor pressure vessel (RPV). As a result, large pipe penetrations are not present in the RPV thereby eliminating the potential for Large/ Medium Break Loss-of-Coolant Accidents (LBLOCAs/MBLOCAs).

The LTR provides detailed documentation of the Phenomena Identification and Ranking Table (PIRT) developed by the Applicant under Small Break LOCA (SBLOCA) conditions in the W-SMR. The Applicant's purpose of the PIRT development is to identify phenomena of importance during a SBLOCA in the W-SMR in order to determine the technical adequacy and applicability of the Westinghouse evaluation model and the corresponding experimental database. Therefore, the PIRT process identified those phenomena as being highly important during a SBLOCA in the W-SMR but either were not included in the Applicant's Emergency Core Cooling System (ECCS) evaluation model or lacked a firm experimental basis to support further improvements to the ECCS evaluation model and the planned testing program.

After receiving the Applicant's LTR, the NRC's Office of Nuclear Regulatory Research (RES) formed and convened an independent PIRT panel consisting of NRC staff and consultants. The panel developed an independent SBLOCA PIRT for the W-SMR based on its own discussions and deliberations. The NRC staff issued several Requests for Additional Information (RAIs) to the Applicant during the independent PIRT development process. The Applicant's responses to these RAIs further informed the NRC/RES panel members about the specifics of the W-SMR design, the expected evolution of SBLOCA events, and Westinghouse's documented analysis results. This information was used by the panel members during the NRC's independent PIRT development process.

1.1 Background

This safety evaluation report is intended to document the NRC staff's findings based on the PIRT panel's review of the LTR (Ref.1) and Westinghouse's responses to various RAIs. The regulatory criteria used to guide the review are discussed below. Section 2 of this report provides a brief summary of the technical information provided by the Applicant in the LTR. Section 3 describes the safety evaluation performed by the reviewers, including a discussion of the responses to various RAIs. The overall regulatory evaluation and conclusions of the present review are given in Section 4.

The LTR (Ref.1) provides detailed documentation of the PIRT developed by the Applicant for the SBLOCA in the W-SMR. The Applicant's PIRT results are intended to form the basis for the further development of the Westinghouse evaluation model and the planned experimental testing program for the W-SMR.

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[1] See Response to NRC Regulatory Issue Summary 2013-18 (ML14041A015).

A LOCA, as defined in Title 10 of the *Code of Federal Regulations* (CFR), Section 50.46(c)(1), "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors" (Ref.2), is a hypothetical accident that would result from the loss of reactor coolant, at a rate in excess of the capability of the reactor coolant makeup system, from breaks in pipes in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system.

There are five specific acceptance criteria for the ECCS identified in 10 CFR 50.46(b):

- *The calculated maximum fuel element cladding temperature shall not exceed 2200°F (1204°C; 1477K).*

- *The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation.*

- *The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.*

- *Calculated changes in core geometry shall be such that the core remains amenable to cooling.*

- *After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.*

On September 16, 1988, the NRC amended the requirements of 10 CFR 50.46 so that these regulations reflect the improved understanding of ECCS performance during LOCA that was obtained through the extensive research performed since the issuance of the original requirements in January 1974. Paragraph 50.46(a)(1) permits licensees or applicants to use either the conservative approach in Appendix K to 10 CFR Part 50 or a realistic[2](or "best-estimate") evaluation model as explained in Regulatory Guide 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance." (Ref.3)

If the realistic LOCA calculation approach is selected, 10 CFR 50.46 requires that "the evaluation model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a loss-of-coolant accident. Comparisons to applicable experimental data must be made and uncertainties in the analysis method and inputs must be identified and assessed so that the uncertainty in the calculated results can be estimated." (Ref.3)

Regulatory Guide (RG) 1.157 (Ref.3) provides details of the NRC's expectations of an evaluation model that is used for realistic LOCA calculations and meets the requirements set

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[2] For the purpose of Regulatory Guide 1.157, the terms "best-estimate" and "realistic" have the same meaning. Both terms are used to indicate that the techniques attempt to predict realistic reactor system thermal-hydraulic response. "Best-estimate" is not used in a statistical sense in Regulatory Guide 1.157.

forth in 10 CFR 50.46. The NRC's regulatory position for best estimate calculations in RG 1.157 (Section C.1) (Ref. 3) states that, "*A best estimate model should provide a realistic calculation of the important parameters associated with a particular phenomenon to the degree practical with the currently available data and knowledge of the phenomenon.*" As a result, it is important to determine the phenomena of importance and their current state of knowledge for LOCA scenarios used to show ECCS effectiveness.

RG 1.203, "Transient and Accident Analysis Methods," describes the NRC guidance on the evaluation model development process. A key element of the process is the development of a credible PIRT that forms the basis for the evaluation model development and assessment. The evaluation model development process laid out in RG 1.203, which includes the PIRT development process, derives from the Code Scaling, Applicability and Uncertainty (CSAU) effort of the NRC (Ref.4). The original concept for development and application of the PIRT during the CSAU effort was aimed at a LBLOCA in a pressurized water reactor (PWR). The application was considered to be successful and demonstrated the utility of the PIRT for the selecting and developing an ECCS performance evaluation model. Over the years, the PIRT methodology has been applied to several different scenarios, including SBLOCAs in PWRs.

The NRC staff conducted an audit in four phases at the Westinghouse Electric Company (WEC)'s Twinbrook offices during the following days: April 17, 2013, May 2, 2013, August 13, 2013, and October 24, 2013. The audit exit briefing was held on November 20, 2013 (Ref.13).

2. SUMMARY OF TECHNICAL INFORMATION

The LTR (Ref.1) documents the PIRT for an SBLOCA scenario in the W-SMR. The LTR includes sections that discuss the following subjects:

- W-SMR Plant Description
- SBLOCA PIRT Development Methodology and Approach
- SBLOCA Scenario PIRT Results
- Summary and Conclusions of the PIRT Process

Information contained in these sections of the LTR is summarized and briefly discussed in Sections 2.1 through 2.4 that follow. Note that only the information considered by the reviewers as being most pertinent to the LTR review, and not all the sub-sections present in the LTR, is summarized below.

2.1 Brief Description of the W-SMR Plant Design

LTR Section 1.1 includes an overview of key components of the W-SMR plant. The description of the W-SMR components, including the passive core cooling system, is supplemented with several figures. A schematic diagram of the W-SMR plant is shown in Figure 2.1. In addition, LTR Table 1-1 lists and describes the important W-SMR components. The breakdown of the components in Table 1-1 is used in the PIRT.

[

]a,c[3]

a,c

[

[3] Brackets and lettering denote information being withheld per 10 CFR 2.390.

[4] AP1000® is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

]a,c

LTR Section 1.4 lists the objectives of the SBLOCA PIRT as:

- To develop the functional requirements for the evaluation model for safety (LOCA) analyses for the SMR, and
- To develop a test matrix to provide the required evaluation model assessment database.

The review of the content of Section 1.1 of the LTR is provided in Section 3.1 of the present Safety Evaluation Report (SER).

2.2 SBLOCA PIRT Development Methodology and Approach

2.2.1 PIRT Methodology

The approach followed by the Applicant to arrive at the SBLOCA PIRT is described in LTR Section 2. In Section 2.1, the Applicant provides a historical background for the PIRT process and outlines a nine step approach for developing a PIRT. The initial steps in the PIRT development process, including the definition of the issue addressed by the PIRT, the PIRT objectives, identification of the plant and scenario of interest, and determination of the Figures-of-Merit (FoMs) used for ranking are described in LTR Section 2.2.

2.2.2 Westinghouse SBLOCA PIRT

LTR Section 2.2.1 documents the issue being addressed by the PIRT. The Applicant frames this issue in the context of ensuring a sufficient experimental and analytical database of information to support the licensing process required to obtain approval of any Evaluation Model (EM). The Applicant plans to use the results of the SBLOCA PIRT to undertake experiments in support of the EM assessment to address design phenomena questions in a hierarchical sequence such that the plant responses that are postulated to be of the highest safety significance are explored first. Section 2.2.2 reiterates the objectives of the SBLOCA PIRT from LTR Section 1.4 (reviewed in Section 3.1 of this SER).

The process requires that the entire reactor plant system being considered for the PIRT must be broken down into individual components to facilitate the phenomena identification and subsequent ranking. The component breakdown for the W-SMR provided in LTR Table 1-1 is used by the Applicant for the PIRT development.

In LTR Section 2.2.4, the representative SBLOCA scenarios that are considered for the PIRT are identified. All the candidate break locations corresponding to the major penetrations in the RPV are listed. [

]a,c The accident scenario is partitioned into logical time phases in which the phenomenological behaviors are reasonably similar. [

]a,c

The Applicant provides a detailed description of each phase along with the system behavior and events occurring during that phase in Table 2-1 of the LTR (Ref.1).

The FoMs that are used to determine and rank the relative importance of each phenomenon in the PIRT are provided in Section 2.2.5 of the LTR (Ref.1). The following FoMs are applicable across all the accident phases:
[

]a,c

The ranking scheme for the relative safety importance of the phenomena that was used by the PIRT panel assembled by the Applicant is provided in Section 2.2.7 of the LTR (Ref.1). Four rankings, 'High (H)', 'Moderate (M)', 'Low (L)' and 'Insignificant (I)' were used, accompanied by an explanation of what each of these rankings signifies (See Table 2-2 of the LTR).

The Applicant's PIRT panel also followed an operational practice described in LTR Section 2.2.7 for ranking the relative safety importance of components before assigning ranks to various phenomena. The same FoMs as those applied to the phenomena ranking were used for this purpose. The Applicant used this approach because they take the position that the approach was found to be useful because a phenomenon was not expected to have a higher rank than the component in which it occurred, thereby allowing the Applicant's panel to readily rank the relevant phenomena. In addition, the adopted operational approach also helped to determine

the ranking sequence since phenomena associated with highly ranked components were ranked first, followed by phenomena associated with moderately ranked components and lastly, the phenomena associated with low importance components.

The ranking scale for the current state of knowledge for each phenomenon in the PIRT that was used by the PIRT panel assembled by the Applicant is provided in Section 2.2.8 of the LTR (Ref.1). Four ranking scales, 'High (H)', 'Moderate (M)', 'Low (L)' and 'Not Applicable (I)', were used. The explanation of the meaning of each of the knowledge level scales is provided in LTR Table 2-3. The LTR states that the scope of the Applicant's PIRT panel with regards to the determination of the state of knowledge was limited to a qualitative, experience-based assessment.

The review of the PIRT methodology and the scenario description is provided in Section 3.2 of this report.

2.3 SBLOCA PIRT Results

Section 3 of the LTR (Ref.1) contains the bulk of the material that forms the SBLOCA PIRT for the W-SMR design.

Table 3-1 in Section 3.1 in the LTR lists the plausible phenomena for each component considered by the Applicant's PIRT panel. Table 3-1 also includes an indicator for the description of the corresponding phenomenon. Table 3-2 in the LTR provides the explanation for each phenomenon description indicator.

An expected scenario progression for the [ ]^{a,c} is provided in Section 3.2 of the LTR that is used for the phenomena ranking. Figures 3-1 through 3-5 in the LTR provide a schematic representation of the scenario progression described in LTR Section 3.2.

Table 3-3 in the LTR represents the final SBLOCA PIRT for the W-SMR design including the relative safety and knowledge level rankings for each of the component specific plausible phenomena listed in Table 3-1 in the LTR. The safety rankings are provided for each of the [ ]^{a,c} phases of the accident along with a corresponding indicator for the ranking rationale. A single state of knowledge ranking for each phenomenon is also provided with a corresponding indicator for the ranking rationale. Tables 3-4 and 3-5 in the LTR explain, respectively, the rationale for each safety and knowledge ranking rationale indicator. The indicators for the rationale in Table 3-3 in the LTR can be cross-referenced with Tables 3-4 or 3-5 to determine the thought process of the Applicant's PIRT panel behind assigning the safety or knowledge rankings.

The review of the Applicant's SBLOCA PIRT rankings is provided in Section 3.3 of this report.

2.4 Summary and Conclusions of the PIRT Process

Section 4 of the LTR (Ref.) summarizes the conclusions reached based on the documented PIRT results in Table 3-3. The conclusions directly impact the selection and development of the evaluation model and the corresponding test program.

Based on the PIRT results, [ ]^{a,c} are listed in Section 4.2 of the LTR (Ref.1) in their expected decreasing order of significance, in order to guide confirmatory experimental

testing, and continued analytical model development efforts. These components and the corresponding reasons for their significance are:
[

]^{a,c}

Section 4.3 of the LTR describes the recommendations for treating phenomena that received a high safety ranking in at least one phase of a SBLOCA scenario and a low or moderate knowledge ranking.

Section 4.3.1 of the LTR includes Table 4-1 which lists all the phenomena from the PIRT with a high safety ranking and a low knowledge ranking and the corresponding method for addressing this disparity. The general approach for such phenomena is to increase the state of knowledge using planned experiments. In the majority of the cases the required information is obtainable [

]^{a,c}

Section 4.3.2 of the LTR includes Table 4-2 which lists all the phenomena from the PIRT with high safety ranking and a moderate knowledge ranking and the corresponding method for addressing this disparity. According to the Applicant, most of the required information can be obtained from [

]^{a,c}

The review of this section of the LTR is documented in Section 3.3 of this SER. It is noted, however, that the review of the test plan, including the test facility scaling and test matrix, which is required to determine the acceptability of the proposed testing rationales as they relate to the EMDAP is not within the scope of the current LTR review.

Appendix A of the LTR entitled, "Westinghouse SMR SBLOCA PIRT Panel Organization and Members" include PIRT independent panel experts' curriculum vitae, PIRT Westinghouse experts' panel curriculum vitae, and Westinghouse SMR experts' curriculum vitae. Appendix B of the LTR describes the AP600 plant program test summaries. These Appendices are included for information only.

3. TECHNICAL EVALUATION

The review was performed by Office of New Reactors with the technical assistance of the Office of Nuclear Regulatory Research and their contractor, Energy Research, Inc.(ERI).

3.1 Westinghouse Description of the W-SMR Design

Section 1.1 of the LTR (Ref.1) provides an overview of the W-SMR plant design, its components, functions, and the intended operation of the ECCS. Several RAIs were formulated that requested specific details of the W-SMR design. Even though the LTR provides a description of the design, nonetheless, there are details and nuances that the reviewers considered important to developing a good understanding of the design before proceeding to evaluate the Applicant's PIRT. Furthermore, it is apparent from interactions with the Applicant that there are several areas where the design's attributes are still evolving. The information the Applicant provided in response to the staff's RAIs helped improve the reviewers' understanding of the W-SMR design. As mentioned earlier, NRC/RES also formed and convened an independent PIRT panel consisting of NRC RES staff and NRC consultants. The NRC panel developed an independent SBLOCA PIRT for the W-SMR based on their own deliberations. The RAI responses also helped the NRC panel to better understand the details of the W-SMR design. It should be noted that the RAIs seeking design information were formulated with the intent of understanding the system design to facilitate the LTR PIRT review and the NRC/RES PIRT development process. Therefore, the responses were evaluated solely on the basis of whether the requested information facilitated such endeavors. The staff's acceptance of the Applicant's RAI responses does not indicate an endorsement or approval of the design and operational features that form the subject of each RAI.

RAI-TR-SBLOCA-PIRT-1 (Ref.5) requested updated information supporting the LTR. In response, the Applicant provided a table that changed and supplemented important dimensions, locations, elevations, volumes, material specifications, operating conditions, system capacities, and applicable technical details. The staff found this information helpful in understanding the current state of the design and therefore, the response is acceptable.

RAI-TR-SBLOCA-PIRT-2 (Ref.5) requested the ICP operating pressure and the existence of any non-condensable gases (NCG). The Applicant's response describes the complement of ICPs and SITs and states that the operating pressure is [ ]^{a,c} It goes on to explain that non-condensable gases can be vented from the high point of the SITs as well as from each ICP, and [

]^{a,c} The response is acceptable because it provided the requested information.

RAI-TR-SBLOCA-PIRT-3 (Ref.5) requested the pressure difference used for the rupture disk at the top of the SITs. The Applicant's response states that the rupture disks serve as a protection against both over-pressurization and under-pressurization of the SITs and the ICP Tanks and that they are designed to rupture at [ ]^{a,c} As a follow-up, RAI-TR- SBLOCA-PIRT-40

(Ref.7) notes that in the response to RAI-TR-SBLOCA-PIRT-3(Ref.5) the opening pressure of the rupture disk is [ ][a,c] which would be more appropriate.

Since the SITs are initially at 14.7 psia, the initial pressure differential between the SITs and the containment can be considered as gauge pressure. However, the SIT pressure can change during an accident. The Applicant was asked to clarify whether the value in the response can be interpreted to be the differential pressure for the opening of the rupture disk throughout the accident. The Applicant's response states that indeed the pressure is differential as stated in the RAI and the value should be stated as [ ][a,c] The response is acceptable because it provided the required clarification.

RAI-TR-SBLOCA-PIRT-7 (Ref.5) requested a description and a diagram pertaining to the connections at the top of the SITs, clarification as to whether SITs are "water-solid" during operation, and if not, the volume of the gas space at the top. The Applicant's response provides a detailed schematic diagram showing the requested connections. The text of the response describes the operating philosophy of the SITs and ICPs. [

][a,c] The response provided the desired information and is acceptable.

RAI-TR-SBLOCA-PIRT-8 (Ref.5) requested clarification regarding the operation of the SITs/ICPs during injection, including the type and arrangement of the valves, the venting capability, and the cooling requirements. The Applicant's response describes the operation of [

][a,c] The response provided the desired information and is therefore acceptable.

This response also states that the SITs/ICPs are not expected to [

][a,c] The response to RAI-TR-SBLOCA-PIRT-8 (Ref.5) provided the requested clarifications on the operation of the SIT/ICP system and therefore it is acceptable.

RAI-TR-SBLOCA-PIRT-9 (Ref.5) requests clarification regarding the modeling of the AOV in the ICP injection line. In response, the Applicant elaborates that [

]^{a,c}

The response provided the required information and therefore it is acceptable.

RAI-TR-SBLOCA-PIRT-10 (Refs.5 and 6) and the follow-up RAI-TR-SBLOCA-PIRT-53 (Ref.7) requested clarification on the potential for [ ]^{a,c} Details on the components being designed to achieve this and remove any [ ]^{a,c} were requested in RAI-TR-SBLOCA-PIRT-53 (Ref.7). In response, the Applicant states that a [ ]^{a,c} In addition, technical specifications will set a maximum containment pressure and consequently [ ]^{a,c} Containment pressure above the technical specification limit will require the operators to take corrective action. The response is acceptable because it provided the required information necessary to understand the W-SMR design. Note that the acceptability does not imply an endorsement of the use or efficacy of the components, operational features or operator actions.

RAI-TR-SBLOCA-PIRT-11 (Ref.5) noted local high points in the CMT balance line and asked for clarification regarding how the accumulation of NCG in the high point of the piping is managed. The Applicant's response explains that the CMT balance line is [ ]^{a,c} The response is acceptable because it provided the requested information necessary to understand the W-SMR design.

RAI-TR-SBLOCA-PIRT-12 (Ref.5) requested clarification as to the maximum and nominal flow rate in the spray line from the RCP discharge to the pressurizer. The Applicant's response provided the minimum, nominal, and maximum flow rates as [ ]^{a,c} respectively. The response is acceptable because it provided the requested information.

RAI-TR-SBLOCA-PIRT-14 (Ref.5) noted that the Sump Coupling Valves (SCVs) seem to be located at an elevation below the sump injection valves and requested confirmation and greater details. The Applicant's response provided a schematic of the Passive Core Cooling System (PXS) which includes the noted components. It also provided the elevations using standard nomenclature. The response provided the requested information and is acceptable.

RAI-TR-SBLOCA-PIRT-19 (Ref.5) requested information regarding the plenum spring length and spring force in the W-SMR fuel rods. The Applicant responded that this attribute of the design is still under review but stated that it will have design margins comparable to that of the AP1000 plant design. The response provided qualitative information that is sufficient for understanding the design and it is acceptable.

RAI-TR-SBLOCA-PIRT-20 (Ref.5) requested information regarding the design pressure of the containment. The Applicant's response is that the containment design pressure is 250 psig. The response provided the required information and is acceptable.

RAI-TR-SBLOCA-PIRT-21 (Ref.5) asked whether the SBLOCA analysis assumes coincident Loss of Offsite Power (LOOP) and if the reactor is designed to trip on LOOP. In response, the Applicant stated that the reactor is assumed to be at 100% power at the beginning of the accident. Furthermore, the response indicated that safety analysis calculations [

]a,c The response provided the clarification sought and is acceptable.

RAI-TR-SBLOCA-PIRT-22 (Ref.5) noted from some of the available Westinghouse LOCA analysis results that the ADS-2 steam quality is higher than one might expect and requested clarification. The Applicant's response states that since [

]a,c The response provided the clarification requested and is acceptable. The acceptability does not imply an endorsement of the design or the operational characteristics of the ADS-2.

RAI-TR-SBLOCA-PIRT-23 (Ref.5) and RAI-TR-SBLOCA-PIRT-42 (Ref.7) requested information regarding automatic trip functions and their setpoints. The Applicant's response provided a detailed list of trip functions and states further that at this time in the design process, the setpoints are still being established. The response is acceptable because it provided the requested information.

RAI-TR-SBLOCA-PIRT-61 (Ref.8) requested information on the method employed in the W-SMR to deal with hydrogen and oxygen generated as a result of radiolysis during potential accidents. The Applicant stated that [

]a,c The response is acceptable because it provided the requested information necessary to understand the W-SMR design. Note that acceptability of the RAI response does not indicate an endorsement of the use or efficacy of the components mentioned in the response.

RAI-TR-SBLOCA-PIRT-69 (Ref.9), RAI-TR-SBLOCA-PIRT-70 (Ref.9), and RAI-TR-SBLOCA-PIRT-73 (Ref.9) requested clarification of certain information presented in the LTR which appears to be inconsistent with the latest available information. Specifically, RAI-TR-SBLOCA-PIRT-69 requested clarification for the location of the squib valves applicable to in-vessel retention. The location of the valves as shown in the LTR is inconsistent with recent design presentations by the Applicant. Similarly, RAI-TR-SBLOCA-PIRT-70 raised the inconsistency in the nomenclature for the tanks connected to the ICPs. These tanks are called "top ICPs" or "ICP tanks" in the LTR whereas the most recent nomenclature is "Sump Injection Tanks" or "SITs." Tables 1-2 and 1-3 and Figure 1-2 in the LTR appear to reflect older design information and RAI-TR-SBLOCA-PIRT-73 requested updates to these based on the latest design information. The latest design information and terminology was used in the preparation of the NRC/RES SBLOCA PIRT. The differences between the NRC/RES and the Applicant's PIRTs due to the evolution of the design and analysis can cause confusion during comparison and review. In response to the above-mentioned RAIs, the Applicant confirmed the presence of cited inconsistencies and agreed to rectify the cited inconsistencies based on the current design and nomenclature in an approved version of the LTR, which will be submitted to the NRC after receipt of this final safety evaluation. The changes proposed by the Applicant in response to RAI-TR-SBLOCA-PIRT-69, RAI-TR-SBLOCA-PIRT-70, and RAI-TRSBLOCA-PIRT-73 are acceptable.

A datum for various elevations provided in Table 1-2 of the LTR is not indicated and was requested as part of RAI-TR-SBLOCA-PIRT-72 (Ref.9). In response to this RAI, the Applicant specified that the datum is the inside bottom of the containment vessel. The response is

satisfactory. In addition, based on RAI-TR-SBLOCA-PIRT-73, the Applicant has also agreed to update LTR Table 1-2 using the latest design information and the resulting changes proposed by the Applicant are acceptable.

Section 1.2 of the LTR asserts that W-SMR safety components do not require AC power or operator action. RAI-TR-SBLOCA-PIRT-71 (Ref.9) requested information on the valve type and performance during loss of AC power for the CMT return (DVI) line and the ADS-1 to support this assertion. The Applicant responded by clarifying that the valves on the CMT return (DVI) line and the ADS-1 valves are [

]^{a,c} This RAI response is acceptable because it provided the required information, which supports the assertion that no AC power is required for the operation of various safety systems.

The additional information provided in response by Westinghouse to various NRC RAIs has significantly improved the understanding of the W-SMR design and the Westinghouse PIRT as documented in the LTR (Ref.1).

3.2 Approaches to the SBLOCA PIRT Development

The scenario description and progression specified in Section 3.2 of the LTR appears to be inconsistent in several details as compared to the information presented by the Applicant in RAIs related to the design and from the results of their simulation of the [ ]^{a,c} scenario.

The independent PIRT panel asked for detailed information on [ ]^{a,c} scenario because that scenario is used for the PIRT documented in the LTR. RAI-TR- SBLOCA-PIRT-4, RAI-TR-SBLOCA-PIRT-5, and RAI-TR-SBLOCA-PIRT-6 (all Ref.5) requested details regarding the model used by the Applicant to analyze the [ ]^{a,c} scenario, the description of the scenario, and analysis results. RAI-TR-SBLOCA-PIRT-4 (Ref 5) requested detailed inputs (including assumptions, initial conditions, ECCS setpoints, the credited Engineered Safety Features (ESFs), and operator actions, among others) and analysis results (e.g., event sequences) for the SBLOCA simulations performed by the Applicant. The response by the Applicant is detailed and provides a large amount of pertinent information. The Applicant describes the model used for the SBLOCA simulations. The model is developed for the WCOBRA/TRAC-TF2 code and represents [

]^{a,c} The response also provides a discussion of the event progression for the [ ]^{a,c} which is the representative SBLOCA simulated by the Applicant. The discussion is complemented by several figures showing the variation of key system parameters during the accident. An event sequence table is also provided. The Applicant also provides a list of the ECCS setpoints as requested in the RAI.

The information in the response to RAI-TR-SBLOCA-PIRT-4 (which includes the information requested in RAI-TR-SBLOCA-PIRT-5, and RAI-TR-SBLOCA-PIRT-6) is acceptable because it provided the requested information, which was useful to the NRC/RES PIRT panel in their deliberations. The NRC/RES PIRT panel used the results presented in response to RAI-TR-SBLOCA-PIRT-4 to supplement their knowledge of the scenario during the PIRT development and LTR review with the understanding that currently unapproved (i.e., by the

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NRC) methods are used to generate the results. RAI- TR-SBLOCA-PIRT-41 (Ref.7) is a follow-up to RAI-TR-SBLOCA-PIRT-4 and requested clarification for several details related to the [ ]^{a,c} scenario described in response to RAI-TR-SBLOCA-PIRT-4. The Applicant's response to RAI-TR-SBLOCA-PIRT-41 (Ref.7) provides the required clarifications and is acceptable. Note that the review and use of the material presented in response to RAI-TR-SBLOCA-PIRT-4 and RAI-TR-SBLOCA-PIRT- 41 for the purpose of supplementing the knowledge of the NRC/RES PIRT panel does not constitute a review and approval of the results (including the evaluation model) contained in the responses.

Several inconsistencies between the information presented in Table 2-1 of the LTR [1] and the event sequence for the [ ]^{a,c} provided in response to RAI-TR-SBLOCA- PIRT-4 were raised in RAI-TR-SBLOCA-PIRT-74 (Ref.9). The scenario description during the blowdown phase (first phase) as given in Table 2-1 states that [ ]^{a,c} which appeared to be contradicted by the event sequence in response to RAI-TR-SBLOCA-PIRT-4 wherein the [ ]^{a,c} In addition, the description in Table 2-1 states that [ ]^{a,c} Based on the information provided by the Applicant in response to RAI-TR-SBLOCA-PIRT-2, it appears that the tanks communicate with the containment [ ]^{a,c} This RAI also seeks clarification of Section 3.2 of the LTR, which contains the same inconsistencies. In response to RAI-TR-SBLOCA-PIRT-74 (Ref.9), the Applicant agreed to address the inconsistencies noted in the RAI in the approved LTR, which will be submitted to the NRC after receipt of this final safety evaluation. The corresponding changes proposed by the Applicant are acceptable.

The response to RAI-TR-SBLOCA-PIRT-30 (Ref.5) indicates that the inadvertent ADS-1 or ADS-2 actuation event may be considered as a LOCA by the Applicant. In RAI-TR- SBLOCA-PIRT-50 (Ref.7) the reviewers questioned why these events are considered accidents as opposed to AOOs. In the response, the Applicant described the inadvertent ADS operation as an accident based on the design and [ ]^{a,c} The response is acceptable as it provided the rationale for considering the inadvertent ADS operation as an accident. Note that a detailed review of the technical basis for the Applicant's classification of the scenario including [ ]^{a,c} used was not considered to be part of the scope of either the PIRT LTR review or the NRC/RES SBLOCA PIRT development process. Therefore, the acceptability of the response to RAI-TR-SBLOCA- PIRT-50 is not intended to indicate the acceptability of the technical basis for the Applicant's scenario classification. Based on the Westinghouse response, the NRC/RES PIRT panel considered the spurious activation of either an ADS-1 or ADS-2 valve in determining the representative SBLOCA scenario. The Applicant has also included this accident in the selection of the SBLOCA scenario for the LTR PIRT. The Applicant considered [ ]^{a,c} to be more limiting than the spurious activation of either an ADS-1 or ADS-2 valve [ ]^{a,c} The NRC/RES PIRT panel also reached a similar conclusion using NRC/RES independent PIRT process.

Figure 2-3 of the LTR shows the variation of the FoMs chosen by the Applicant during various phases of the representative SBLOCA.

The phase definitions and the variation of the FoMs during each phase as shown in Figure 2-3 is inconsistent with the analysis results presented in the response to RAI-TR-SBLOCA-PIRT-4. Similarly, the event descriptions in Figures 3-2 through 3-5 of the LTR also appear to be

inconsistent with the event timings provided in response to RAI-TR-SBLOCA-PIRT-4. The Applicant was requested to address these inconsistencies in RAI-TR-SBLOCA-PIRT-75 (Ref.9). Since the NRC/RES SBLOCA PIRT panel referenced the system response documented in RAI-TR-SBLOCA-PIRT-4 during their deliberations, it is important to resolve any inconsistencies with the information in the LTR. In response to the RAI, the Applicant agreed to update the LTR to address the inconsistencies noted in the RAI. However, the update to Figures 3-2 and 3-3 of LTR proposed by the Applicant do not appear to reflect the sequence of events accurately.

According to the response to RAI-TR-SBLOCA- PIRT-74 (Ref.9), the Applicant agrees that the [ ]a,c Similarly, the response to RAI-TR-SBLOCA-PIRT-74 also states that there is [ ]a,c The updated version of Figure 3-2 proposed by the Applicant does not appear to capture these changes and continues to state that the [ ]a,c Therefore, follow-up RAI-W SMR Test Plan and Scaling-80 was formulated to request that the Applicant make appropriate changes to Figures 3-2 and 3-3 of the LTR. The Applicant proposed to modify Figures 3-2 and 3-3 of the LTR in response to the follow-on RAI. Specifically, the Applicant stated that the last entry of the updated Figure 3-2 will indicate, [ ]a,c Figure 3-3 of the LTR is proposed to be modified so as to identify that the [ ]a,c The Applicant's changes and their implementation, as shown in the revised response to RAI-TR-SBLOCA-PIRT-103, are acceptable because it resolves the issue in the follow-up RAI, as stated above.

3.3 SBLOCA PIRT Results

The PIRT documented in Section 3.3 of the LTR has been reviewed. The review covered the importance and knowledge rankings and the corresponding rationales. The NRC/RES SBLOCA PIRT, which was developed independent of the LTR PIRT, was also compared against the results in Section 3.3 of the LTR during the review process. Several RAIs were formulated seeking explanation of the ranking rationale by Westinghouse, especially in cases where marked differences were observed as compared to the NRC/RES SBLOCA PIRT.

RAI-TR-SBLOCA-PIRT-65 (Ref.8) requested clarification on inconsistencies noted between the ECCS activation setpoint (with delay) and the sequence of events documented in the event sequence table provided as part of the response to RAI-TR-SBLOCA-PIRT-4. These inconsistencies were pointed out for the activation of the Steam Generator Depressurization Valves (SGDVs) and the closure of the Steam Drum Isolation Valves (SDIVs). In response, the Applicant acknowledged the identified inconsistency and provided updated versions of the ECCS activation and event sequence tables. Therefore, the response is acceptable.

Section 3.2 of the LTR mentions that the [ ]a,c This description is inconsistent with the information provided in response to RAI-TR-SBLOCA-PIRT-4 where [ ]a,c In addition, the above-mentioned statement on the opening of the valves in Section 3.2 of the LTR was also

found to be inconsistent with a statement in the same section which mentions that [ ]^{a,c} RAI-TR-SBLOCA- PIRT-76 (Ref.9) requested that the Applicant address these inconsistencies. In response, the Applicant agreed to address the inconsistencies in the approved LTR, which will be submitted to the NRC after receipt of this final safety evaluation. The corresponding changes proposed by the Applicant are acceptable.

RAI-TR-SBLOCA-PIRT-9 noted that the AOV in the ICP injection line does not appear to be considered as part of the analysis provided by Westinghouse. The Applicant's response states [ ]^{a,c} The response is acceptable as it provided information about the approach used by the Applicant, which was sufficient for the purpose of LTR PIRT review.

RAI-TR-SBLOCA-PIRT-51 (Ref.7) and RAI-TR-SBLOCA-PIRT-55 (Ref. 8) questioned the Applicant's characterization of the DVI break as a double-ended guillotine break because of the presence of an [ ]^{a,c} valve on the broken DVI line. This valve is normally closed and opens on the receipt of an activation signal. Therefore, the accident would be a single-ended break until the activation signal is received after which it would become double-ended. The analysis provided as part of RAI-TR-SBLOCA-PIRT-4 [ ]^{a,c} As a result, neither is the review of the LTR adversely impacted nor does the NRC/RES PIRT need to be revised. RAI-TR-SBLOCA-PIRT-66 (Ref.8) requested a simulation of a realistic DVI break SBLOCA scenario. The Applicant provides results of the requested calculation in response to RAI-TR-SBLOCA-PIRT-66. These results confirm that even though event timings are altered as compared to the results presented in RAI-TR-SBLOCA-PIRT-4, nonetheless, the differences are not significant and the overall behavior of the system does not change appreciably. The Applicant further stated that [ ]^{a,c} The response to RAI-TR-SBLOCA-PIRT-66 is acceptable as it provided the necessary information thereby also closing RAI-TR-SBLOCA-PIRT-51 and RAI-TR-SBLOCA-PIRT-55.

RAI-TR-SBLOCA-PIRT-56 (Ref.8) requested timing information on ADS-1 and ADS-2 flow transition from sonic to sub-sonic, draining of the pressurizer, and collapsed water level progression. The Applicant provided the specific times for the transition of the break and ADS-1 flow from sonic to sub-sonic. The Applicant also clarified that the ADS-2 flow [ ]^{a,c} The response included a figure showing the draining of the pressurizer and the time at which it is calculated to be empty. In addition, the Applicant stated that even though the [ ]^{a,c} The response provided the requested information and is acceptable.

RAI-TR-SBLOCA-PIRT-59 (Ref.8) requested information on the possible flooding of the break. In response, the Applicant states that their simulations show that the [

]^{a,c} The response is acceptable because it provided the requested information. Both the LTR PIRT and the NRC/RES SBLOCA PIRT rank the importance and knowledge of the phenomena of reverse flow from the containment to the RPV via the break, and the resulting transport of solids and chemicals into the RPV. Although the response to RAI-TR-SBLOCA-PIRT-59 implies that the [
]^{a,c} inclusion of related phenomena in the PIRTs addresses any uncertainties in predictions and expands the applicability of the PIRTs. The response provided the requested information and is acceptable.

The [
]^{a,c} RAI-TR-SBLOCA-PIRT-60 requested the Applicant to elaborate on the importance of this phenomenon, and to explain the approach that is planned to be used to determine [
]^{a,c} In response, the Applicant has provided information on the [

]^{a,c} The response is acceptable on the basis that it provided the requested description of the Applicant's approach. The Applicant intends to perform testing for [ ]^{a,c} The staff requested that the Applicant submit the test data related to [
]^{a,c} The Applicant must ensure that the [ ]^{a,c} is treated realistically and appropriately in future analysis and testing submittals.

RAI-TR-SBLOCA-PIRT-8 (Ref.5) requested clarification of the type and operation of the valves on top of the SITs and on the sump injection lines connecting the ICPs to the RPV. The response states that [ ]^{a,c} on each sump injection line. These valves isolate each group of SIT and ICP tanks from the RPV. [

]^{a,c}

[
]^{a,c} The response provided the necessary information and clarification; therefore, it is acceptable.

RAI-TR-SBLOCA-PIRT-13 (Ref.5) requested clarification on the path available for liquid from the containment sump to enter the RPV. The response provided details of the path along with an accompanying figure. [

]a,c The response provided the necessary information; therefore, it is acceptable.

RAI-TR-SBLOCA-PIRT-15 (Ref.5) requested information on any sensitivity calculations performed by the Applicant to ascertain the importance of phenomena for the purpose of PIRT rankings. The Applicant's response provided details of sensitivity studies performed during the W-SMR design development. [
]a,c However, as described in the response, insights from these studies contribute to the Applicant's PIRT development. The response provides additional insight into the relative importance of phenomena and was beneficial to the NRC/RES panel deliberations on the SBLOCA PIRT and the LTR review. [

]a,c The response provided the requested information and is acceptable.

RAI-TR-SBLOCA-PIRT-16 (Ref.5) requested details of the debris profile expected in the W- SMR during an SBLOCA such as the [ ]a,c scenario. The Applicant states that it expects the debris during an SBLOCA to consist of:
[

]a,c

The Applicant contends that [

]a,c

The information contained in the response to RAI-TR-SBLOCA-PIRT-16 is acceptable as it provides the required information. However, the Applicant's assertion [
]a,c needs to be confirmed as part of the PIRT confirmation process.

In response to RAI-TR-SBLOCA-PIRT-17 (Ref.5), the Applicant states that [

]a,c

According to the event description in the LTR and the response to RAI-TR-SBLOCA-PIRT-4,

[

][a,c] RAI-TR-SBLOCA-PIRT-54 (Ref.7) requested clarification of the trigger for initiation of Phase 4 and, in particular, [

][a,c] In addition, it also requested the timings for the completion of each phase based on the analysis results provided in response to RAI-TR-SBLOCA-PIRT-4. The response is acceptable.

In response to RAI-TR-SBLOCA-PIRT-54, the Applicant provides a figure that shows [

][a,c] The Applicant also provides the timing for the completion of the phases based upon the analysis results in response to RAI-TR-SBLOCA-PIRT-4. The response is acceptable and the phase completion times provided by the Applicant have been used for the NRC/RES PIRT development.

RAI-TR-SBLOCA-PIRT-18 (Ref.5) requested the Applicant to describe the process that will be followed by the Applicant to change the importance rankings in the W-SMR SBLOCA PIRT based on the results of the planned integral and separate effects tests. The response states that [

][a,c] The response is acceptable because it provided the requested details.

Justification was sought for the importance ranking for the phenomenon of "[

][a,c] As a result, this phenomenon was ranked as being of 'Medium' importance in phases 2 through 4 in the NRC/RES SBLOCA PIRT. In response to the RAI, the Applicant clarified that the phenomena is [

][a,c] The importance ranking for this phenomenon on the outside shell of the containment vessel in the NRC/RES SBLOCA PIRT is 'Medium' for Phase 3 while being 'Low' for all other phases. The 'Medium' importance rank in Phase 3 in the NRC/RES SBLOCA PIRT was due to the activation of the ADS resulting in a large discharge of steam to the containment. In addition, the steam discharge may introduce non-uniform effects due to the staggered opening of the ADS-1 and ADS-2 valves. The Applicant provided sufficient technical justification for their ranking.

In response to RAI-TR-SBLOCA-PIRT-77 the Applicant further states that the phenomenon of [

][a,c] For consistency, the Applicant agreed to update the LTR to include phenomenon V.1.b in the section A.1 without any change to the importance

ranking for the subject phenomenon. Based on the clarification, importance ranking for [
]^{a,c} is higher in the Applicant's PIRT as compared to the NRC/RES SBLOCA PIRT. The response to the RAI and the corresponding changes proposed by the Applicant are acceptable.

The phenomena of [
]^{a,c} The knowledge ranking is questioned in RAI-TR-SBLOCA-PIRT-78 (Ref.9) because this issue is highly design specific. [
]^{a,c} It is for these reasons that the NRC/RES SBLOCA PIRT assigned a 'Low' knowledge rank to these phenomena. Results from any CFD calculations performed by the Applicant to assign the knowledge ranking are also sought in RAI-TR-SBLOCA-PIRT-78.

The response to RAI-TR-SBLOCA-PIRT-78 cites [
]^{a,c}
Therefore, follow-up RAI-W SMR Test Plan and Scaling-81 was formulated that requested the Applicant to provide justification for the [
]^{a,c} Specifically, the Applicant was asked to explain the rationale for [
]^{a,c}

In response to RAI-W SMR Test Plan and Scaling-81 (Ref.12), which is a follow-up to RAI-TR-SBLOCA-PIRT-78, the Applicant qualifies the original response and provides additional details of the planned approach to resolving the gaps in knowledge created by the unique W-SMR containment design. [
]^{a,c}

According to the Applicant, [ ]^{a,c} is deemed sufficient to qualify the safety analysis models for the W-SMR. The Applicant's contention [

]^{a,c} However, requesting and reviewing [ ]^{a,c} is beyond the scope of this report. Use of data from the planned W-SMR specific IETs is considered appropriate for the validation and verification of the analysis tools.

However, it is necessary to carefully review the scaling basis for the [

]^{a,c} A review of the scaling basis for the Applicant's planned IET facility is outside the scope of the current work. In addition to the above, the Applicant also stated in the response to RAI-W SMR Test Plan and Scaling-81 that [

]^{a,c} However, the responses to RAI-TR-SBLOCA-PIRT-01 and RAI-TR-SBLOCA-PIRT-53 (Ref.7) indicate that a [ ]^{a,c} is allowed for operation and safety analysis. The higher end of this range was considered in the NRC/RES PIRT resulting in a 'Medium' importance ranking for the phenomena [ ]^{a,c}

The [ ]^{a,c} that is present in the W-SMR design should be accounted for in the experiments as well as the planned model validation studies. In summary, the response to RAI-W SMR Test Plan and Scaling-81 is acceptable because the Applicant has provided a clarification of the planned course of action and it has addressed the concerns outlined in the RAI. However, as discussed above, the Applicant's approach needs to be reviewed to establish the applicability to the [ ]^{a,c}

Therefore, it is requested that any past data used by the applicant to qualify the analysis tools for application to the [ ]^{a,c} are reviewed by Westinghouse to ensure that the expected range of [ ]^{a,c} conditions are encompassed by such data. These conditions should include the [ ]^{a,c} In addition, it is also recommended to review the scaling for the Applicant's planned IET facility to ensure that the [ ]^{a,c} are adequately captured in the IETs. Moreover, the boundary conditions of the test should also reflect [ ]^{a,c} The Westinghouse PIRT includes and ranks the phenomenon of [ ]^{a,c} Design information is [ ]^{a,c} The model documented in response to RAI-TR-SBLOCA-PIRT-4 [ ]^{a,c} as confirmed by the response to RAI-TR-SBLOCA-PIRT-16 (Ref.5). Based on the design description and the results of RAI-TR-SBLOCA-PIRT-4 available to the NRC/RES PIRT panel, [ ]^{a,c} were not considered in the NRC/RES SBLOCA PIRT.

RAI-TR-SBLOCA-PIRT-79 (Ref.9) requested the rationale for including the aforementioned phenomenon/component in the Westinghouse PIRT. In the response, the Applicant clarified that the current W-SMR design [ ]^{a,c} which is the subject of the RAI (A.1.L) from Table 3-3 in the LTR. The corresponding change proposed by the Applicant is acceptable.

The analysis results made available by Westinghouse in response to RAI-TR-SBLOCA- PIRT-4 indicate that [ ]^{a,c} The response to RAI-TR-SBLOCA-PIRT-21 (Ref.5) also indicates this. [

]^{a,c}
Clarification on these issues was sought in RAI-TR-SBLOCA-PIRT-80 (Ref.9). [

]^{a,c} The response and the corresponding change proposed by the Applicant are acceptable. Due to the change, [ ]^{a,c} is consistent between the NRC/RES and the LTR PIRTs. The Applicant has retained a [ ]^{a,c} in contrast to the NRC/RES SBLOCA PIRT. However, the difference in rankings is in the conservative direction and is acceptable. In addition, the highest importance ranking accorded to [ ]^{a,c} is the same between the NRC/RES and Applicant's PIRT.

Both [

]^{a,c} in the Westinghouse PIRT. The rationale for the rankings (P14 in LTR Table 3-4) states that these phenomena are [

]^{a,c}
Additional details on the rationale for these rankings in the Westinghouse PIRT were requested in RAI-TR-SBLOCA-PIRT-81. (Ref.9) In the response the Applicant agreed with the rationale presented in the RAI. The Applicant agreed to update the LTR by assigning a [ ]^{a,c} to both phenomena B.3.a and B.3.b in Table 3-3 of the LTR.

The knowledge ranking for these phenomena will be retained as being [ ]^{a,c} by the Applicant. The Applicant will revise the rationale for the importance rankings to indicate that the phenomenon is important to the FoM. The response and the proposed changes are acceptable. The changes make the updated importance ranking for [ ]^{a,c} in the LTR PIRT higher than that in the NRC/RES SBLOCA PIRT. However, the difference in rankings is in the conservative direction and acceptable.

The phenomenon of [ ]^{a,c} component in the PIRT in the LTR. The rationale for the importance ranking (P23 in LTR Table 3-4) is attributed to the [ ]^{a,c} This is considered highly unlikely during the representative SBLOCA by the NRC/RES PIRT panel. Therefore, this phenomenon was not considered in the NRC/RES PIRT. As a result, additional details on the bases for the inclusion of the phenomenon and its ranking rationale such as [

]^{a,c} were sought in RAI-TR-SBLOCA-PIRT-82 (Ref.9). In response, the Applicant agreed to remove [ ]^{a,c} from the PIRT in the approved LTR, which will be submitted to the NRC after receipt of this final safety evaluation. Therefore, the response and the corresponding changes proposed by the Applicant are acceptable.

The importance ranking for [ ]^{a,c} component

(B.7.b in LTR Table 3-3) is questioned in RAI-TR-SBLOCA-PIRT-83 (Ref.9). The importance ranking for that phenomenon is [ ]a,c of the accident in the LTR. However, the [

]a,c The NRC/RES SBLOCA PIRT ranks the [ ]a,c as 'Medium' importance.

[

]a,c The response and the corresponding changes to the LTR are acceptable.

[

]a,c On the basis of the analysis results presented in response to RAI-TR-SBLOCA-PIRT-4, [ ]a,c Therefore, [ ]a,c was considered unlikely in Phase 1 and assigned a 'Low' importance rank in the NRC/RES SBLOCA PIRT.

Explanation on the potential for [ ]a,c of the accident was sought in RAI-TR-SBLOCA-PIRT-84 (Ref.9). In response, the Applicant agreed that [ ]a,c Therefore, the importance ranking for this phenomenon is proposed to be changed to [ ]a,c The corresponding rationale is also proposed to be revised accordingly. The response and the proposed changes to the LTR are acceptable. The NRC/RES SBLOCA PIRT assigns a 'Low' importance ranking to [ ]a,c in all phases of the accident.

The NRC/RES panel considered it unlikely that [ ]a,c is prevalent due to the relatively large hydraulic diameter of the upper plenum. The [ ]a,c in the Westinghouse PIRT is conservative as compared to the NRC/RES SBLOCA PIRT and is acceptable.

The phenomenon of [

]a,c in the PIRT in the LTR. The corresponding rationale [

]a,c This inconsistency was raised in RAI-TR- SBLOCA-PIRT-85 (Ref.9). In addition, the rationale does not account for the potential that [ ]a,c An explanation for not including this possibility was also sought in RAI-TR- SBLOCA-PIRT-85. In the response, the Applicant clarified that the [

]a,c The Applicant agreed to revise the rationale for phenomenon C.1.b in the LTR to reflect this as well as the [ ]a,c The response and the changes resulting from this RAI as proposed by the Applicant are acceptable. It is noted that the NRC/RES SBLOCA PIRT assigned a 'Low' importance to the phenomenon of

[ ]a,c The NRC/RES panel considered [ ]a,c as unimportant in Phases 1 and 2 since [ ]a,c are not likely. During Phase 3 although the [ ]a,c the NRC/RES PIRT panel did not expect an appreciable impact on the FoMs which are driven by overall flow rate through the upper plenum. The importance rankings for [ ]a,c for the Westinghouse PIRT for Phases 1 and 3 are in a conservative approach and are acceptable.

The importance ranking for [ ]a,c Therefore, clarification on the rationale for the importance ranking for phenomenon C.4.d in LTR Table 3-3 in Phase 4 was sought in RAI-TR-SBLOCA- PIRT-86 (Ref.9). It is noted that the NRC/RES SBLOCA PIRT assigned a 'Low' importance to this phenomenon for all the accident phases due to the reasons described above. The RAI was issued although the difference in the importance rankings between the NRC/RES and the Applicant's PIRT in Phase 4 is in the conservative direction to understand if details of the system behavior were overlooked by the NRC/RES panel. In response the Applicant provides justification for the [ ]a,c importance ranking. The Applicant states that there is a [ ]a,c The justification provided by the Applicant is acceptable. As indicated above, the difference in the importance rankings between the NRC/RES and the LTR PIRTs in Phase 4 is in a conservative approach.

Additional justification related to the rationale for ranking [ ]a,c (D.2 in LTR Table 3-3) was sought in RAI-TR-SBLOCA-PIRT-87 (Ref.9). The LTR discusses the impact of the phenomenon due to [ ]a,c NRC/RES considers the potential for [ ]a,c to be minimal in Phase 2 of the accident.

Therefore, the NRC/RES PIRT panel assigned a 'Low' importance ranking to this phenomenon for all phases. The RAI was issued, considering that the difference in the importance rankings between the NRC/RES and the LTR PIRT in Phase 4 is in the conservative direction, in order to understand if details of the system behavior were overlooked by the NRC/RES panel.

In response, the Applicant agreed that [ ]a,c The Applicant further agreed to change the ranking for phenomenon D.2 Table 3-3 of the LTR during Phase 2 to 'Low.' The response and the proposed change are acceptable. The ranking for the [ ]a,c phenomenon across the accident phases will be consistent between the NRC/RES and the Westinghouse PIRT following the proposed changes.

The knowledge ranking for the phenomenon of [ ]a,c

make testing or, at least, detailed calculations necessary to understand the performance of the separation plates. Even though the behavior of the [ ]^{a,c} the lack of test data makes this claim unsubstantiated. Due to these reasons, justification for the rationale for the knowledge ranking for the above-mentioned phenomenon was sought in RAI-TR-SBLOCA-PIRT-88 (Ref.9). The NRC/RES SBLOCA PIRT ranked the knowledge level for [ ]^{a,c} due to the unique design and the need for testing. The Applicant agreed that the knowledge ranking for the phenomenon identified in the RAI should be [ ]^{a,c} The Applicant further agreed to change the ranking and the corresponding rationale. The changes to the knowledge ranking are acceptable. However, the Applicant also stated that the importance ranking for the phenomenon is [ ]^{a,c}

The changes resulting from this RAI as proposed by the Applicant also show that the importance ranking for phenomenon E.1 in LTR Table 3-3 will be changed [ ]^{a,c} No justification for the change in the importance ranking has been provided. The importance ranking was never questioned in the original RAI. Detailed justification for decreasing the importance ranking was sought from the Applicant in follow-up RAI-W-SMR Test Plan and Scaling-84 (Ref.12). In response to the follow-up RAI the Applicant agreed to revise the importance ranking for phenomenon E.1 in LTR Table 3-3 to [ ]^{a,c} The response to the follow-up RAI is acceptable because it addresses the concern that was outlined in the RAI. However, the updated LTR Table 3-3 in the revised response to RAI-TR- SBLOCA-PIRT-103 did not initially show the changes proposed by the Applicant but the changes were provided later. Necessary information was provided in response to RAI-TR-SBLOCA-PIRT-103 (Ref.9 and Ref.14).

The importance ranking in the PIRT in the LTR for all the phenomena under [ ]^{a,c} in the "SG – Primary/Tube Side" (G.2.a-c in LTR Table 3-3) was questioned in RAI-TR-SBLOCA-PIRT-89. The importance ranking is [ ]^{a,c} The corresponding rationale (P47 in LTR Table 3-4) states that a [ ]^{a,c} Due to the influence on loop-wide natural circulation, the [ ]^{a,c} has been ranked as 'Medium' importance in phases 1 and 2 in the NRC/RES SBLOCA PIRT. In response to the RAI, the Applicant provided justification for the importance ranking. According to the Applicant, [ ]^{a,c}

This explanation is acceptable in explaining the difference between the rankings for Phase 2 in the NRC/RES and the Westinghouse PIRTs. However, the rationale for the importance ranking of phenomenon G.2.a-c in LTR Table 3-3 states that a [ ]^{a,c} This rationale was questioned and the Applicant was requested to clarify the basis for the importance ranking of phenomenon G.2.a-c in LTR Table 3-3 in follow-up RAI-W SMR Test Plan and Scaling-82. In response to the follow-up RAI, the Applicant agreed to modify the rationale for phenomena G.2.a-c in the LTR to reference the identifier P89. In conjunction with that change, the Applicant proposed to update the text for

rationale P89 in Table 3-4 of the LTR to provide the basis for the importance ranking as explained in response to the original RAI (i.e. RAI-TR-SBLOCA-PIRT-89). The resulting changes shown in the revised response to RAI-TR-SBLOCA-PIRT-103 are acceptable because they resolve the issue that was raised in the follow-on RAI. It should be noted that the identifier P89 was previously changed to "Not used" in response RAI-TR-SBLOCA-PIRT-100. The response to RAI-W SMR Test Plan and Scaling-82 will supersede the previous change.

The importance ranking of phenomena [ ]^{a,c} in the "SG – Secondary/Shell Side" component (H.1 in LTR Table 3-3) was questioned in RAI-TR- SBLOCA-PIRT-90 (Ref.9). Part (a) of the RAI questioned the importance rank for the [ ]^{a,c} phenomenon (H.1.a in LTR Table 3-3) which is assigned as [

]^{a,c} Therefore, the NRC/RES SBLOCA PIRT assigns a 'Low' importance ranking for all phases to the phenomenon of [ ]^{a,c} on the SG secondary side. In addition, the rankings for [ ]^{a,c} (H.1.a in LTR Table 3-3) and [ ]^{a,c} (H.1.d in LTR Table 3-3) are identical which also appears to be contradictory. In response to part (a) of the RAI, the Applicant agreed that [ ]^{a,c} and agreed to remove that phenomena (H.1.a in LTR Table 3-3). The response and the proposed change are acceptable. In part (b) of RAI-TR-SBLOCA-PIRT-90 the importance ranking for [ ]^{a,c} (H.1.b in LTR Table 3-3) and [ ]^{a,c} (H.1.c in LTR Table 3-3) was questioned. These phenomena carry an importance ranking of [ ]^{a,c} The corresponding rationale (P48 in LTR Table 3-3) does not provide any details.

It is unclear how the contribution of these phenomena is significant because the amount of energy transmitted via the hot leg wall to the secondary side and from the RPV wall due to stored energy release is expected to be small as compared to the fission and decay power. Due to the relative unimportance of [ ]^{a,c} as compared to decay heat, they are assigned a 'Low' importance rank for all accident phases in the NRC/RES SBLOCA PIRT.

In response to part (b) of RAI-TR-SBLOCA-PIRT-90, the Applicant stated that even though the [ ]^{a,c} are retained as these rankings are in the conservative direction. This approach and the response are acceptable.

The importance ranking for [ ]^{a,c} (H.3.e in Table 3-3) and [ ]^{a,c} (H.4 in Table 3-3) is [ ]^{a,c} On the basis of the analysis results presented in response to RAI-TR-SBLOCA-PIRT-4 and the phase definitions, the [ ]^{a,c} of the accident. The Applicant was asked to address this inconsistency in RAI-TR-SBLOCA-PIRT-91 (Ref.9) because it makes the sequence of events used to assign importance rankings in the NRC/RES and the Westinghouse PIRTs inconsistent.

In response to the RAI, the Applicant agreed to change the importance ranking and the rationale to reflect the fact that the [ ]^{a,c} and therefore, the phenomenon is inactive in that phase. The response is acceptable. However, the resulting changes as discussed in response to RAI-TR-SBLOCA-PIRT-103 simply alter the importance ranking for [

]^{a,c} In response to the follow-up RAI the Applicant agreed to change the importance ranking for the phenomena [ ]^{a,c} The response to the follow-up RAI is acceptable because it resolves the issue that was raised. However, the updated LTR Table 3-3 in the revised response to RAI-TR-SBLOCA-PIRT-103 does not show the changes proposed by the Applicant. Necessary information was provided in response to RAI-TR-SBLOCA-PIRT-103 (Ref.9).

Additional description for the rationale for the ranking for [ ]^{a,c} in the "SG – Secondary/Shell Side" component (H.3.a in LTR Table 3-3) was requested in RAI-TR-SBLOCA-PIRT-92. The rationale under P132 in LTR Table 3-4 does not provide information about how [ ]^{a,c} impacts the FoMs for the PIRT. The Applicant provides an explanation for the cited phenomenon and its ranking. The Applicant asserts that the [ ]^{a,c} The Applicant's response and the proposed changes are acceptable. Note that the phenomenon of [ ]^{a,c} is not explicitly present for the "SG Secondary (Shell Side)" component in the NRC/RES SBLOCA PIRT. The NRC/RES staff noted that the influence of this phenomenon is included in the ranking for "Two-phase pressure drop" and "Choked flow through SGDVs."

The [ ]^{a,c} in conjunction with the SBLOCA is expected to have an appreciable impact on the FoMs. However, the [ ]^{a,c}

[ ]^{a,c} The Applicant was asked to explain the reason for the exclusion of the [ ]^{a,c} in RAI-TR-SBLOCA-PIRT-93 (Ref.9). In response, the Applicant clarified that the [ ]^{a,c} In addition, based on the updated event sequence the Applicant agreed to change the importance ranking for this phenomenon to [ ]^{a,c} The response and the proposed change are acceptable. Note that the phenomenon of [ ]^{a,c} is considered explicitly in the NRC/RES SBLOCA PIRT. The phenomenon also carries a 'Medium' importance rank for Phase 2 of the accident.

There appear to be inconsistencies in the importance rankings for [ ]^{a,c} in the "CMT" component (L.1.c in LTR Table 3-3) and [ ]^{a,c} in the "PRHR HX – Tube Side (RCS)" component (M.1.c in LTR Table 3-3). The rationale for L.1.c (P63 in LTR Table 3-4) refers to [ ]^{a,c} If L.1.c is indeed ranked based on [ ]^{a,c} it is expected that the rankings for M.1.c should be the same as those for L.1.c.

However, this is not the case for [ ]^{a,c} The Applicant was asked to clarify the phenomena that are being considered in L.1.c and M.1.c in RAI-TR-SBLOCA- PIRT-94 (Ref.9).

In response, the Applicant [

]a,c agrees to change the LTR accordingly. The response and the proposed changes are acceptable.

According to the event description for the DVI DEGB, the [
]a,c The calculated ADS-1 and ADS-2 flow rates (provided as part of the response to RAI-TR-SBLOCA-PIRT-4) appear to [

]a,c The Applicant was asked to confirm this behavior in RAI-TR-SBLOCA-PIRT-95 (Ref.9). The Applicant clarified that [

]a,c Therefore, the inclusion of the phenomena related to [
]a,c in the PIRT is justified. The response is acceptable since it provided the requested information.

The NRC/RES SBLOCA PIRT ranks phenomena during the [ ]a,c based on independent panel's understanding of the scenario progression prior to the receipt of the response to RAI-TR-SBLOCA-PIRT-95 (Ref.9).

The Westinghouse PIRT does not distinguish between the [
]a,c The NRC/RES SBLOCA PIRT considered the [ ]a,c separately. The flow (choked or otherwise) from the [ ]a,c is expected to have an impact on the FoMs for the PIRT. However, this phenomenon does not appear in the LTR PIRT. The lack of consideration of the flow from the [ ]a,c in the Westinghouse PIRT was questioned in RAI-TR-SBLOCA-PIRT-96. In response the Applicant clarifies that the [ ]a,c is captured in the [ ]a,c component (Component K in LTR Table 3-3).

The phenomena in the [ ]a,c component in the LTR are consistent with those that were considered in the NRC/RES SBLOCA PIRT from the [ ]a,c In addition, the importance rankings for several of these phenomena in the LTR are higher than the rankings of similar phenomena in the NRC/RES SBLOCA PIRT. As a result, the response to the RAI is acceptable.

The PIRT in the LTR does not distinguish between the [
]a,c The NRC/RES SBLOCA PIRT considered the [ ]a,c separately. Confirmation was sought from the Applicant in RAI-TR-SBLOCA- PIRT-97 (Ref.9) that the rankings for the phenomena in the [ ]a,c component (S in LTR Table 3-3) are equally applicable to the [ ]a,c The response appears to confirm that the [

]a,c The phenomena in the [ ]a,c component (S in LTR Table 3-3) are consistent with those that were considered in the NRC/RES SBLOCA PIRT for the [ ]a,c According to the Applicant, the phenomenon of [ ]a,c considered for [ ]a,c is ranked collectively in the [ ]a,c (Component K in LTR Table 3-3). In addition, the importance rankings for these phenomena in the LTR are higher than or same as the rankings of similar phenomena in the NRC/RES SBLOCA PIRT. As a result, the response to the RAI is acceptable.

RAI-TR-SBLOCA-PIRT-98 (Ref.9) questioned the importance rankings for some of the phenomena under [ ]^{a,c} in the "CMT Balance Line" component (S.1 in LTR Table 3-3). Based on the phenomena definitions and the rationale provided for [ ]^{a,c} (S.1.b in LTR Table 3-3) and [ ]^{a,c} (S.1.g in LTR Table 3-2), it appears that S.1.b accounts for S.1.g. The [ ]^{a,c} The Applicant was asked to explain the influence of the [ ]^{a,c} that is being ranked in phenomena S.1.g and is not captured in S.1.b in part (a) of RAI-TR-SBLOCA-PIRT-98. In response to part (a) of the RAI the Applicant agreed that [ ]^{a,c} The Applicant further agreed [ ]^{a,c} The rationale in the LTR (P121 in LTR Table 3-4) for the importance rankings for [ ]^{a,c} (S.1.c in LTR Table 3-3) mentions the phases during the accident when [ ]^{a,c} is present in the CMT. However, the reason for the rankings is missing. As a result, it is difficult to determine what exactly is being ranked and how phenomenon S.1.c differs from phenomena S.1.b and S.1.g in LTR Table 3-3. The NRC/RES SBLOCA PIRT does not consider the phenomenon of [ ]^{a,c} separately as the phenomenon of [ ]^{a,c} is expected to capture the resulting influence. The Applicant was asked to expand the rationale for the importance ranking for S.1.c in LTR Table 3-3 in part (b) of RAI-TR-SBLOCA-PIRT-98. In addition, there appears to be an inconsistency in the importance rankings for [ ]^{a,c} (S.1.b in LTR Table 3-3) and [ ]^{a,c} (S.1.c in LTR Table 3-3) in Phase 4. It is unclear how [ ]^{a,c} The Applicant was asked to address this inconsistency in part (c) of the RAI-TR-SBLOCA-PIRT-98. In response to part (b) of the RAI the Applicant agreed to expand the rationale (P121 in LTR Table 3-4).

In addition, the Applicant agreed to change the ranking for phenomenon S.1.c in LTR Table 3-3 to [ ]^{a,c} which addresses part (c) of the RAI. The change in the ranking of [ ]^{a,c} (S.1.c in LTR Table 3-3) to [ ]^{a,c} makes the rankings of that phenomenon the same as those for [ ]^{a,c} (S.1.b in LTR Table 3-3) for all phases. Therefore, the approach in the NRC/RES SBLOCA PIRT of ranking only the [ ]^{a,c} is valid. The response to RAI-TR-SBLOCA-PIRT-98 and the proposed changes to the LTR are acceptable.

The rationale for the importance ranking for the phenomenon [ ]^{a,c} in the "ICP" component (T.1.e in LTR Table 3-3) raises the possibility of [ ]^{a,c} (P83 in Table 3-4).

The importance rank of [ ]^{a,c} for the phenomenon as well as the corresponding [ ]^{a,c} knowledge rank was questioned in RAI-TR-SBLOCA-PIRT-99. The questions were based on the presumption that the phenomenon refers to the piping connecting adjacent ICPs. This presumption was also used in the ranking for the same phenomenon in the NRC/RES SBLOCA PIRT resulting in a 'Low' importance and knowledge ranking. In response, the Applicant clarifies that that the phenomenon ranked in item T.1.e of LTR Table 3-3 is related to the [

]^{a,c} The clarification and justification provided by the Applicant are acceptable. The clarification explains the difference in the rankings between the NRC/RES and the Westinghouse PIRTs for the [ ]^{a,c} phenomenon. The discrepancy in the rankings arises due to different interpretation of the phenomenon. It should be noted that the importance ranking in the Westinghouse PIRT is higher than that in the NRC/RES PIRT and is therefore, conservative. However, the definition for the [ ]^{a,c} phenomenon (D37 in LTR Table 3-2) is unclear and does not contain the clarification provided in response to the RAI. A follow-up RAI, RAI-W SMR Test Plan and Scaling-83, recommended that the definition in the LTR be clarified. Such clarification would also help in identifying the difference between the NRC/RES and Westinghouse PIRT rankings for [ ]^{a,c} In response to the follow-up RAI, the Applicant agreed to change the identifier for the phenomenon of [ ]^{a,c} in LTR Table 3-2 to D58. In conjunction with this change, the Applicant also proposed to update the description for D58 to clarify the phenomenon as explained in the response to the original RAI (i.e. RAI-TR-SBLOCA-PIRT-99 (Ref.9). The resulting changes shown in the revised response to RAI-TR-SBLOCA-PIRT-103 are acceptable because they resolve the issue that was raised in the follow-on RAI. It should be noted that the identifier D58 was previously changed to "Not used" in response RAI-TR-SBLOCA-PIRT-79. The response to RAI-W SMR Test Plan and Scaling-83 will supersede the previous change.

The importance ranking rationale described in P89 in LTR Table 3-4 is not used anywhere in LTR Table 3-3. RAI-TR-SBLOCA-PIRT-100 (Ref.9) requested the Applicant to confirm and if necessary, delete the rationale from the LTR. In response the Applicant agreed to remove rationale in P89 from LTR Table 3-4 because it is not used anywhere in LTR Table 3-3.

The resulting change as shown in response to RAI-TR-SBLOCA- PIRT-103 indicates that P89 is not actually deleted from LTR Table 3-4 but is marked as "Not Used". This approach is also acceptable, even though it is inconsistent with the response to RAI-TR-SBLOCA-PIRT-100. A follow-up RAI was not formulated since the issue raised in the RAI has been resolved. However, in response to RAI-W SMR Test Plan and Scaling-82 (Ref.12) that was issued subsequent to RAI-TR-SBLOCA-PIRT-100, the Applicant will use P89, with modification to its text, to provide the rationale for phenomena G.2.a-c in Table 3-3 of the LTR. That change supersedes the response to RAI-TR-SBLOCA-PIRT-100.

RAI-TR-SBLOCA-PIRT-101 requested details of the logic that would be employed by the Applicant in selecting the bounding values for sensitivities that seek to characterize the effect of [ ]^{a,c} The obvious bounding value for [ ]^{a,c} It was unclear, based on the review of the LTR, how any other value could be justified. In response to RAI-TR-SBLOCA-PIRT-101 (Ref.9) the Applicant has qualitatively explained that the [ ]^{a,c}

The intent of the explanation appears to be to discuss the approach that can be used to justify the selected limiting values. According to the Applicant, the [

]^{a,c} Even though the explanation by the Applicant appears to be plausible, it cannot be verified due to the qualitative nature of the response, and lack of any supporting analyses. It is not clear that the [

]^{a,c} can be convincingly quantified "using engineering principles" as stated by the Applicant. However, requesting and reviewing the calculations that follow the Applicant's approach is beyond the scope of this report. As a result, the response is acceptable since the Applicant has explained how it intends to justify bounding assumptions. The Applicant is requested to submit the results of all code calculations and any available test results showing [

]^{a,c} Similarly, the Applicant is also requested to submit the rationale and calculations performed in support of bounding assumptions used in computer simulations to demonstrate the [ ]^{a,c}

Tables 4-1 and 4-2 in Section 4, "Summary and Conclusions," of the LTR include specific recommendations for testing that make references to a [

]^{a,c}

The Applicant has provided WCAP-17712, "Westinghouse SMR Test Plan" (Ref.10), which also contains functional requirements for both the IETs and SETs. It is noted that the review of the test plan including the test facility scaling and test matrix is not within the scope of this review. RAI-TR-SBLOCA-PIRT-102 requested clarification of the Applicant's intent of providing the information in the testing rationale columns in Tables 4-1 and 4-2 in the LTR and is therefore, out of scope of the present LTR review.

RAI-TR-SBLOCA-PIRT-103 requested the Applicant to provide a table summarizing the changes to the WCAP-17573-P due to the responses to RAI-TR-SBLOCA-PIRT-69 through -102. In response the Applicant provided Table 103-1 which summarizes the changes to WCAP-17573-P that were discussed in response to RAI-TR-SBLOCA-PIRT-69 through -102. In addition, related pages of the LTR are included in Table 103-1 with the corresponding updates. It is noted that the content of Table 103-1 is reviewed in conjunction with each individual RAI from RAI-TR-SBLOCA-PIRT-69 through -102.

The Applicant updated the response to RAI-TR-SBLOCA-PIRT-103 to capture the changes due to the response to RAI-W SMR Test Plan and Scaling-79 through -84. The changes are found to be acceptable. Table-1 of this SER lists the changes to the LTR that the Applicant has committed to undertake. Necessary information was provided in response to RAI-TR-SBLOCA-PIRT-103 (Ref.9).

4 SUMMARY AND CONCLUSIONS

A review of the SBLOCA PIRT for the W-SMR and relevant information as documented in the LTR (Ref.1) submitted by the Applicant has been performed. This included a review and evaluation of responses to a large number of RAIs that were submitted by the Applicant to the NRC as part of the review process. This review was performed subsequent to the development of an independent SBLOCA PIRT for the W-SMR by a panel under the auspices of NRC/RES. The NRC/RES SBLOCA PIRT also formed the basis for several RAIs questioning specific aspects of the importance and knowledge rankings associated with the SBLOCA PIRT as reviewed in this SER.

4.1 Conditions and Limitations

Based on the evaluation of the LTR that is documented in this SER, the following conditions and/or limitations have been identified by the NRC:

1. The SBLOCA PIRT and the resulting conclusions documented in the LTR are to be restricted to the W-SMR design as currently described in Sections 1.1 and 1.2 of the LTR (including the changes to the LTR that have been committed to by the Applicant). The Applicant is to submit, for review and further evaluation by the NRC, any changes to the W-SMR design as compared to that documented in Sections 1.1 and 1.2 of the LTR, including the impact of any changes in the design on the SBLOCA PIRT and the corresponding LTR conclusions.

2. The SBLOCA PIRT submitted with the LTR (Ref.1) is to be confirmed by the applicant through a combination of code sensitivity/uncertainty studies and analysis of experimental data gathered during the planned test program. These confirmation studies will highlight the most important processes/phenomena. Based on past experience, these studies can change the number of highly ranked phenomena in the PIRTs.

   Furthermore, it is desirable to perform these confirmatory studies once the relevant test data is available and the evaluation model has been approved by the NRC for use in W-SMR licensing applications.

   The Applicant is to submit for review any changes to the SBLOCA PIRT and the LTR as a consequence of PIRT confirmation studies performed using a combination of code sensitivity and/or uncertainty analyses, results of planned SETs and IETs, and any other experimental data that will be utilized for the purpose of any future safety assessment studies and design certification submittals to the NRC.

3. The Applicant is to make available for audit the test data related to ADS-2 liquid entrainment, the incorporation of the entrainment data and corresponding correlation in the SBLOCA evaluation model (WCOBRA-TRAC TF2) and the code SKBOR (used for boron concentration calculations) for review by the NRC during the design certification submittals. (RAI-TR-SBLOCA-PIRT-RAI-60).

4. The Applicant is to make available for audit the code calculations and any available test results showing sensitivity of the system behavior to form losses in the "trash rack" and

sump screen. Similarly, the Applicant is to make available for audit the rationale and the calculations performed in support of any bounding assumptions used in computer simulations to demonstrate the effect of debris blockage in a line on the key FoMs. (RAI-TR-SBLOCA-PIRT-RAI-17 and 101).

5. The LTR (Ref.1) is to be revised to include all commitments by the Applicant in its response to several NRC RAIs. The list of changes that the Applicant has committed to is provided in the response to RAI-TR-SBLOCA-PIRT-103 and is also included in Table 1 of this report.

6. The use of the SBLOCA PIRT and the resulting conclusions documented in the LTR (Ref.1) are restricted to the following objectives listed by the Applicant in the LTR (Ref.1):

   (a) To determine the requirements for an adequate evaluation model to perform the safety analyses (SBLOCA) for the W-SMR, and

   (b) To develop a test matrix of SETs and IETs intended to provide an adequate evaluation model assessment database for application to the W-SMR.

7. The review of the test plan including the test facility scaling and test matrix is not within the scope of this review. RAI-TR-SBLOCA-PIRT-102 requested clarification of the Applicant's intent of providing the information in the testing rationale columns in Tables 4-1 and 4-2 in the LTR and is therefore, out of scope of the present LTR review.

8. The review of the LTR focused solely on the SBLOCA PIRT. Therefore, the conclusions on the LTR listed above do not extend to the testing recommendations contained in Section 4. The review of the test plan, including the test facility scaling and test matrix, which is required to determine the acceptability of the proposed testing rationale as they relate to the EMDAP is not within the scope of the current review.

4.2 Conclusions

Based on the present review of the LTR, the following general conclusions are in order:

- The Westinghouse PIRT development process has followed the EMDAP guidance as outlined in Regulatory Guide 1.203.

- The LTR documents a PIRT for SBLOCAs which is supported by sufficient rationale and justification for the assigned importance and knowledge rankings.

- This review finds that once the LTR is modified by the Applicant in the response to various RAIs, the PIRT would be acceptable subject to conditions and limitations given above for use to support EMDAP for the planned application by Westinghouse to the W-SMR design as part of the design certification process.

- When Westinghouse submits the DCA for the W SMR, the W-SMR PIRT evaluation will support the evaluation of the W-SMR test programs and safety analysis methodologies in accordance with Standard Review Plan (SRP) 15.0.2, "Review of Transient and Accident Analysis Method."

The staff finds the LTR (Ref.1) acceptable subject to conditions and limitations given above for referencing in licensing actions.

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George Thomas, NRO

5. REFERENCES

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6. TABLE 1, INDEX OF CHANGES TO LTR RESULTING FROM RAI RESPONSES.

(Note: This table lists the changes to the LTR that the Applicant committed to make as part of the responses to the listed RAIs.)

TABLE 1 - INDEX OF CHANGES TO LTR RESULTING FROM RAI RESPONSES

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LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADS	Automatic Depressurization System
ADS-1	ADS Stage One
ADS-2	ADS Stage Two
CCFL	Counter Current Flow Limitation
CHF	Critical Heat Flux
CMT	Core Makeup Tank
CRDM	Control Rod Drive Mechanism
CSAU	Code Scaling, Applicability, and Uncertainty
CV	Containment Vessel
DVI	Direct Vessel Injection
FoM	Figure of Merit
ICP	In-containment Pool
IET	Integral Effects Test
iPWR	Integral PWR
IRWST	In-containment Refueling Water Storage Tank
IVR	In-vessel Retention
LBLOCA	Large Break LOCA
LOCA	Loss-of-Coolant Accident
LTCC	Long-term Core Cooling
MFIV	Main Feed Isolation Valve
MSIV	Main Steam Isolation Valve
OCP	Outside Containment Pool
PCCWST	Passive Containment Cooling Water Storage Tank
PIRT	Phenomena Identification and Ranking Table
PLS	Plant Control System
PMS	Protection Monitoring System
PORV	Power Operated Relief Valve
PRHR	Passive Residual Heat Removal
RCCA	Rod Cluster Control Assembly
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RFA	Robust Fuel Assembly
RV	Reactor Vessel
SBLOCA	Small Break LOCA
SCV	Sump Coupling Valve
SDIV	Steam Drum Isolation Valve
SET	Separate Effects Test
SG	Steam Generator
SGDV	Steam Generator Depressurization Valve
SIT	Sump Injection Tank
SMR	Small Modular Reactor
SoK	State of Knowledge
UHS	Ultimate Heat Sink

EXECUTIVE SUMMARY

The Westinghouse SMR is a modular pressurized water reactor with an integral configuration (all primary system components—reactor core, internals, steam generators, pressurizer, and control rod drive mechanisms—are inside the reactor vessel). The Westinghouse SMR plant conceptual design was completed in 2011 and the preliminary design is currently underway. The first line of defense in the Westinghouse SMR is to eliminate event initiators that could potentially lead to core damage. If it is not possible to eliminate certain accidents altogether, then the design inherently reduces their consequences and/or decreases their probability of occurring. One of the most obvious advantages of the Westinghouse SMR approach is the elimination of intermediate and large break LOCAs since no large primary penetrations of the reactor vessel or large loop piping exist. Handling of small break LOCAs is equally important, where the Westinghouse SMR approach is to limit and eventually stop the loss of coolant from the vessel and then rely on proven passive technology to remove the reactor decay heat to the environment and to provide makeup water to the core.

The Westinghouse SMR approach is a logical step in the effort to produce advanced reactors. With the elimination of intermediate and large break LOCAs, an important next consideration is to show that the Westinghouse SMR design fulfills the promise of adequate safety for SBLOCAs. The Westinghouse SMR Program issue being addressed is the planning for continued development of the experimental data and analytical tools needed for safety analysis, particularly in the licensing arena, in a sufficient and cost effective manner. Thus, the primary objective of the Westinghouse SMR SBLOCA PIRT project was to identify the relative importance of phenomena in the Westinghouse SMR response to SBLOCAs. This relative importance, coupled with the current relative state of knowledge for the phenomena, then provides a framework for the planning of the continued experimental and analytical efforts.

To satisfy the SBLOCA PIRT objectives, Westinghouse organized an expert panel whose members were carefully selected to insure the PIRT results reflect internationally recognized experience in reactor safety analysis and was not biased by program preconceptions internal to the Westinghouse SMR Program. The panel employed the well proven PIRT Process to determine the range/conditions of SBLOCA scenarios that needed to be analyzed and then applied that methodology. A cold-side line break in one of the two 2-inch sump injection lines or in one of the four 3-inch direct vessel injection (DVI) lines was determined to be representative of a SBLOCA scenario and would satisfy the SBLOCA PIRT objectives. These scenarios were subsequently analyzed and the results are documented in this report. The results most significant to formulating conclusions related to guiding further experimental data and analytical tool development are given in Figure ES-1 and Tables ES-1, ES-2, ES-3, and ES-4. The conclusions follow below.

The SBLOCA PIRT panel concluded confirmatory experimental testing and continued analytical tool development in the following areas, in decreasing level of significance, are perceived as important with respect to satisfying the safety analysis and licensing objectives of the Westinghouse SMR Program:

1. Integral operation of the passive safety injection system

2. Integral operation of the passive residual heat removal system

3. Liquid carryover and two-phase pressure drop from the upper plenum through the ADS-2 lines/valves

4. Interaction between steam venting through the ADS-1 and ADS-2 valves and parallel flow in the hot leg balance line with condensation in the CMT

5. Close thermal-hydraulic coupling between the reactor coolant system and the compact, high-pressure containment

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Figure ES-1 Scenario Selection Process

Table ES-1 Westinghouse SMR SBLOCA Figures of Merit

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Table ES-2 Westinghouse SMR SBLOCA Scenario Phases

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Table ES-3 SBLOCA Ranking Scales
Safety Ranking Scale
H = The phenomenon is considered to have high importance to safety. Accurate modeling of the phenomenon during the particular phase is considered to be important to the correct prediction of the transient.
M = The phenomenon is considered to have moderate importance to safety. The phenomenon must be modeled with sufficient detail to obtain accuracy in the simulation; however, the phenomenon is expected to have less impact on the overall results than those ranked high.
L = The phenomenon is not considered to be very important to safety during the transient. The phenomenon needs to be modeled in the code (or accounted for in the methodology), but inaccuracies in modeling this phenomenon are not considered likely to have a significant impact on the overall transient results.
I = The phenomenon is considered insignificant or does not occur at all. This phenomenon need not be modeled or taken into consideration as it has an insignificant impact on results.
State of Knowledge Ranking Scale
H = Relevant test data and a mature calculation method exist. There is sufficient understanding of this phenomenon such that it could be treated in a conservative or bounding manner in a model. No new testing or model development is needed to predict this phenomenon.
M = Relevant test data and/or calculation methods exist, but they may not be directly applicable to the scenario or geometry under consideration. There is sufficient understanding of the phenomenon such that it may be treated in a conservative or bounding manner. However, additional tests or model development may be necessary to properly address this phenomenon if it is ranked high.
L = Little or no relevant test data exists and calculation methods that may exist have not been validated to the scenario or geometry under consideration. There is insufficient understanding of the phenomenon such that it cannot be treated in a conservative or bounding manner in a model. Tests and/or model development will be necessary to properly address this phenomenon if it is ranked high.
I = Not applicable.

Table ES-4 Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

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Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

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Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

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Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

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Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

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1 INTRODUCTION

1.1 WESTINGHOUSE SMR PLANT DESCRIPTION

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1.2 COMPARISON OF THE WESTINGHOUSE SMR AND AP1000 PLANT PASSIVE SAFETY SYSTEMS

The safety systems of the Westinghouse SMR draw heavily on the passive systems developed for the **AP1000**®[1] plant. All of the system components are passive and require no AC power or operator action to function. Table 1-4 shows the specific safety functions, and which system and component perform each of the functions for both the Westinghouse SMR and the **AP1000** plant. More detailed descriptions of the passive safety systems are shown in the following section.

1.2.1 Short-term Reactivity Control

Westinghouse SMR

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AP1000 Plant

The **AP1000** plant utilizes 83 RCCAs which are similar in design and function but are fourteen feet long.

1.2.2 Long-term Reactivity Control

Westinghouse SMR

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1. **AP1000**® is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their owners.

AP1000 Plant

The **AP1000** plant also utilizes CMTs for boron injection. The primary differences are that the CMT balance lines for the **AP1000** plant are connected to the RCS cold legs, and the decay heat removal function is provided by a separate component, the passive residual heat removal (PRHR) heat exchanger. The CMTs operate in natural circulation mode until the cold, borated water is completely replaced by hot water from the RCS. In a LOCA event, the RCS inventory loss out of the break will eventually result in steam entering the CMT balance lines and the CMTs begin to drain. When the CMTs are 50 percent drained, the automatic depressurization system (ADS) is actuated to provide controlled depressurization of the RCS in order to enable gravity injection from the in-containment refueling water storage tank (IRWST).

1.2.3 Decay Heat Removal

Westinghouse SMR

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AP1000 Plant

For the **AP1000** plant, there are two main heat removal paths for a LOCA. First, RCS inventory is expelled to the containment, first through the break, and later through the ADS valves. Steam is condensed on the inside of the containment. Then, heat is then conducted through the wall and is removed by the passive containment cooling system (PCS).

The second means of removing heat is through the passive residual heat removal (PRHR) heat exchanger which is connected to the RCS, and is situated in the IRWST at an elevation above the reactor core. The PRHR heat exchanger is maintained at RCS pressure, and isolation valves at the outlet prevent flow during normal operation. In the event of an S-Signal, the isolation valves are opened, hot reactor coolant enters the PRHR heat exchanger from the RCS hot leg, and transfers heat to the IRWST. Cold water is returned to the RCS cold leg. The water in the IRWST is heated, reaches saturation, and generates steam. The steam is condensed on the containment. Then, heat is conducted through the wall and is removed by the PCS.

The **AP1000** plant uses nitrogen-charged accumulators to provide post-LOCA makeup water to the reactor. After the accumulators empty, the nitrogen expands into the RCS and accumulates in the high points including the reactor vessel head, steam generator tubes, and the PRHR tubes. After becoming filled with nitrogen, the PRHR heat exchanger becomes less effective and nearly all decay heat removal is through the ADS valves into containment. Accumulators are the primary defense for large break LOCAs. (There are no large break LOCAs in the Westinghouse SMR.)

1.2.4 Long-Term Core Makeup Water Supply

Westinghouse SMR

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AP1000 Plant

For the **AP1000** plant, the CMTs also provide makeup flow at all RCS pressures. After the ADS valves are actuated, the RCS pressure falls and the nitrogen-charged accumulators begin to inject. As the RCS pressure is equalized with the containment, gravity injection of the IRWST water starts when the pressure difference is less than the hydrostatic head in the IRWST.

Condensed steam from the containment fills the containment sump. As the sump level increases, valves are opened between the sump and the IRWST creating one source of water. The CMTs, accumulators, IRWST and sump all inject into the reactor vessel downcomer through two direct vessel injection (DVI) lines.

The IRWST injection in the **AP1000** plant is functionally similar to the SIT gravity injection in the Westinghouse SMR. The sump injections for the two designs are also functionally similar.

1.2.5 Automatic Depressurization

Westinghouse SMR

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AP1000 Plant

The **AP1000** plant has four stages of ADS valves. The three high pressure stages vent from the top of the pressurizer and are piped to the IRWST where the steam is condensed. The ADS is actuated on 50 percent CMT level which is an indication of the degree of inventory loss in the RCS. After the high pressure stages are opened, the RCS pressure is decreased and the CMTs continue to drain. At 20 percent CMT level, the low pressure stage of ADS is actuated which vents the RCS directly off the hot legs. The location of these valves assures that a steam/water mixture is vented which mitigates the concentration of boric acid in the reactor vessel.

The ADS-1 valves on the Westinghouse SMR are functionally similar to the ADS-1, -2, and -3 valves on the **AP1000** plant. The ADS-2 valves on the Westinghouse SMR are functionally similar to the ADS-4 valves on the **AP1000** plant.

1.2.6 Ultimate Heat Sink

Westinghouse SMR

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AP1000 Plant

The **AP1000** plant utilizes the containment vessel as a heat exchanger to remove heat to the environment. A large tank of water, the passive containment cooling water storage tank (PCCWST), is located on the top of the shield building to provide a water film to the outer surface of the containment. Heat is removed by evaporation of the water film and natural convection air cooling to maintain the containment pressure below the design limit. The PCCSWT is sized for three days of operation without the need for AC power or operator action. After three days, the tank can be replenished and the process can continue indefinitely.

1.3 WESTINGHOUSE SMR APPROACH TO SBLOCA MITIGATION

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Further discussion of the Westinghouse SMR SBLOCA phase descriptions and mitigation strategy are provided in Table 2-1 and Section 3.2, respectively.

1.4 SBLOCA PIRT

The Westinghouse SMR approach is a logical step in the effort to produce advanced reactors. With the elimination of intermediate and large break LOCAs, an important next consideration is to show that the Westinghouse SMR design fulfills the promise of adequate safety for the SBLOCA. To this end, a PIRT was prepared to evaluate the SBLOCA. There are two primary objectives of the PIRT:

1. To obtain the functional requirement for an adequate evaluation model for the purpose of performing the safety analyses (LOCA) for the SMR

2. To develop a suitable test design and test matrix intended to provide an adequate evaluation model assessment database

To satisfy these objectives, a PIRT panel was organized consisting of:

- Three members totally independent of Westinghouse, and having extensive experience in reactor safety analysis,

- Eight Westinghouse members independent of the Westinghouse SMR project, and having significant experience in other Westinghouse plant designs (**AP600™**[2] plant, **AP1000** plant, etc.).

2. **AP600™** is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. Other names may be trademarks of their owners.

Additional information regarding the PIRT panel and the qualifications of the panel members are provided in Appendix A.

Although not considered panel members, the project was supported by Westinghouse SMR experts. These individuals were Westinghouse engineers responsible for various areas of the Westinghouse SMR design. To insure transparency in the process, the role of the Westinghouse SMR experts was to address requests for information from the PIRT panel.

1.5 REPORT STRUCTURE

The PIRT methodology used for this SBLOCA application is described in Section 2. Section 2.1 focuses on the generalized PIRT process. Section 2.2 then expands the generalized process to those features common to the SBLOCA scenario addressed. Section 3 presents the results of the PIRT in several tables. The significant conclusions drawn from the results are given in Section 4.

Table 1-1 Westinghouse SMR Component Descriptions

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Table 1-1 (cont.) Westinghouse SMR Component Descriptions

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Table 1-1 (cont.) Westinghouse SMR Component Descriptions

Table 1-1 (cont.) Westinghouse SMR Component Descriptions

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Table 1-2 Westinghouse SMR Important Dimensions

Table 1-3 Westinghouse SMR Normal Operating Conditions

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Table 1-4 Comparison of Systems and Components to Perform Safety Functions between AP1000 Plant and the Westinghouse SMR

Safety Function	AP1000 Plant	Westinghouse SMR
Short-term reactivity control	Control rods	
Long-term reactivity control	Boration by CMTs (2)	
Decay heat removal	PRHR HX (1) which removes heat from the reactor coolant system (RCS) to the in-containment refueling water storage tank (IRWST).	
Long-term makeup water supply	IRWST (1) with transition to sump recirculation	
Automatic depressurization	Four stages of automatic depressurization system (ADS) valves are used to provide a means to depressurize the RCS and permit gravity injection from the IRWST and sump.	
Ultimate heat sink	Passive containment cooling system (PCS) consisting of a PCCWST (1) located at the top of the shield building. Heat removal capability is provided by the PCS for 72 hours following a design basis accident.	

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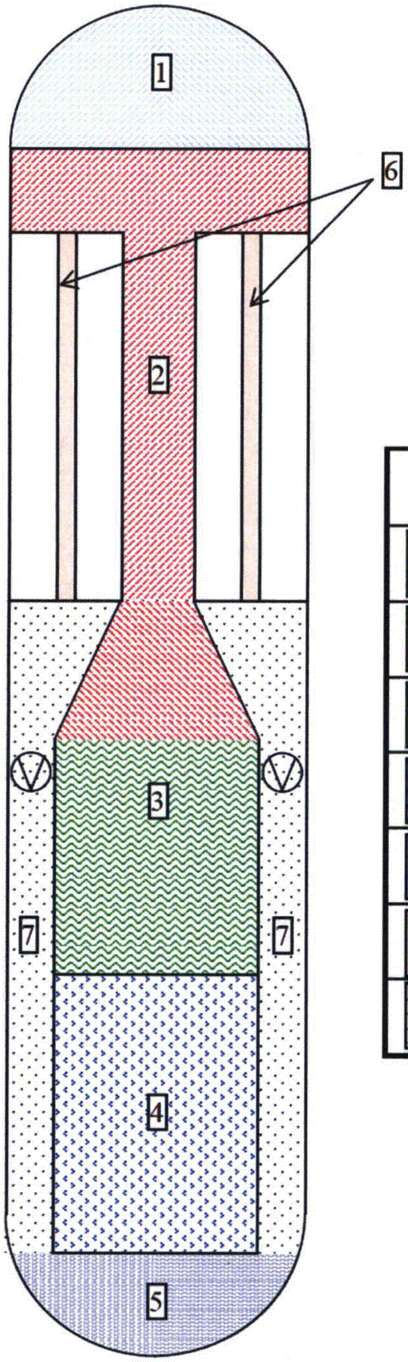
Figure 1-1 Schematic of Safety Systems Design



Parameter	Value
1 Pressurizer Volume	
2 Hot Leg & Cone Volume	
3 Upper Plenum Volume	
4 Core Volume	
5 Lower Plenum Volume	
6 Steam Generator Primary Volume	
7 Downcomer Volume	

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Figure 1-2 Reactor Vessel Regions

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Figure 1-3 Illustrations of Westinghouse SMR ICP

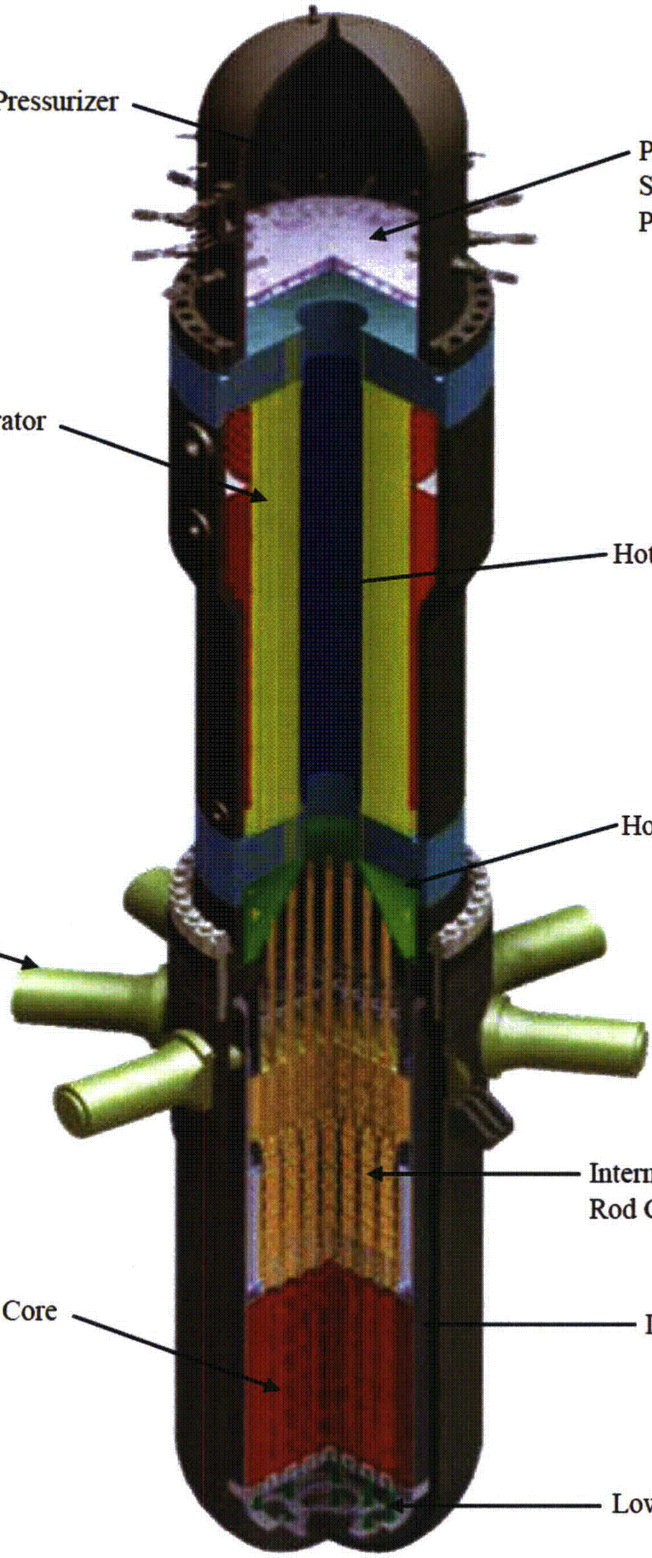

Figure 1-4 Illustration of Westinghouse SMR RV with Quarter Cutaway

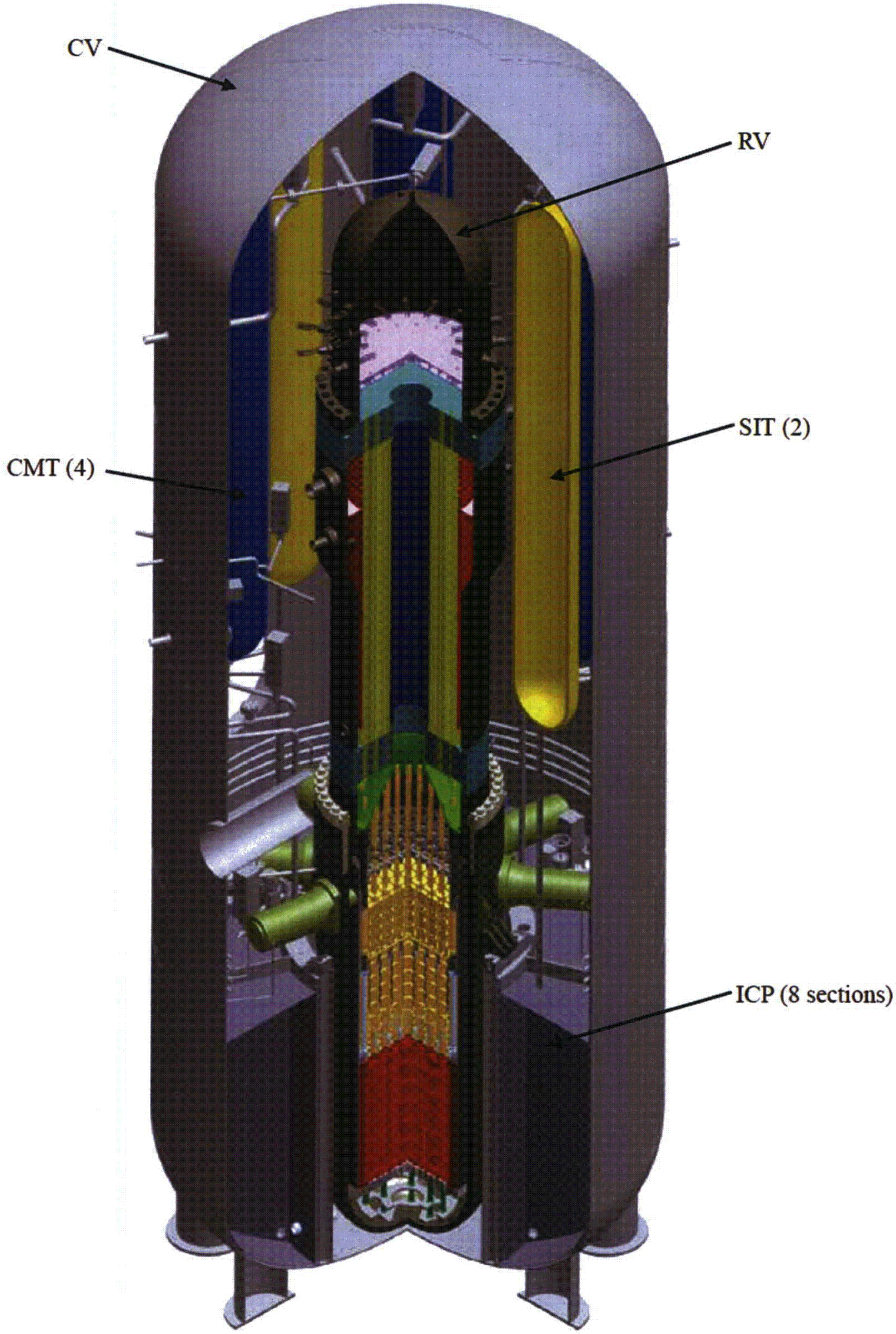

Figure 1-5 Illustration of Westinghouse SMR CV with Quarter Cutaway

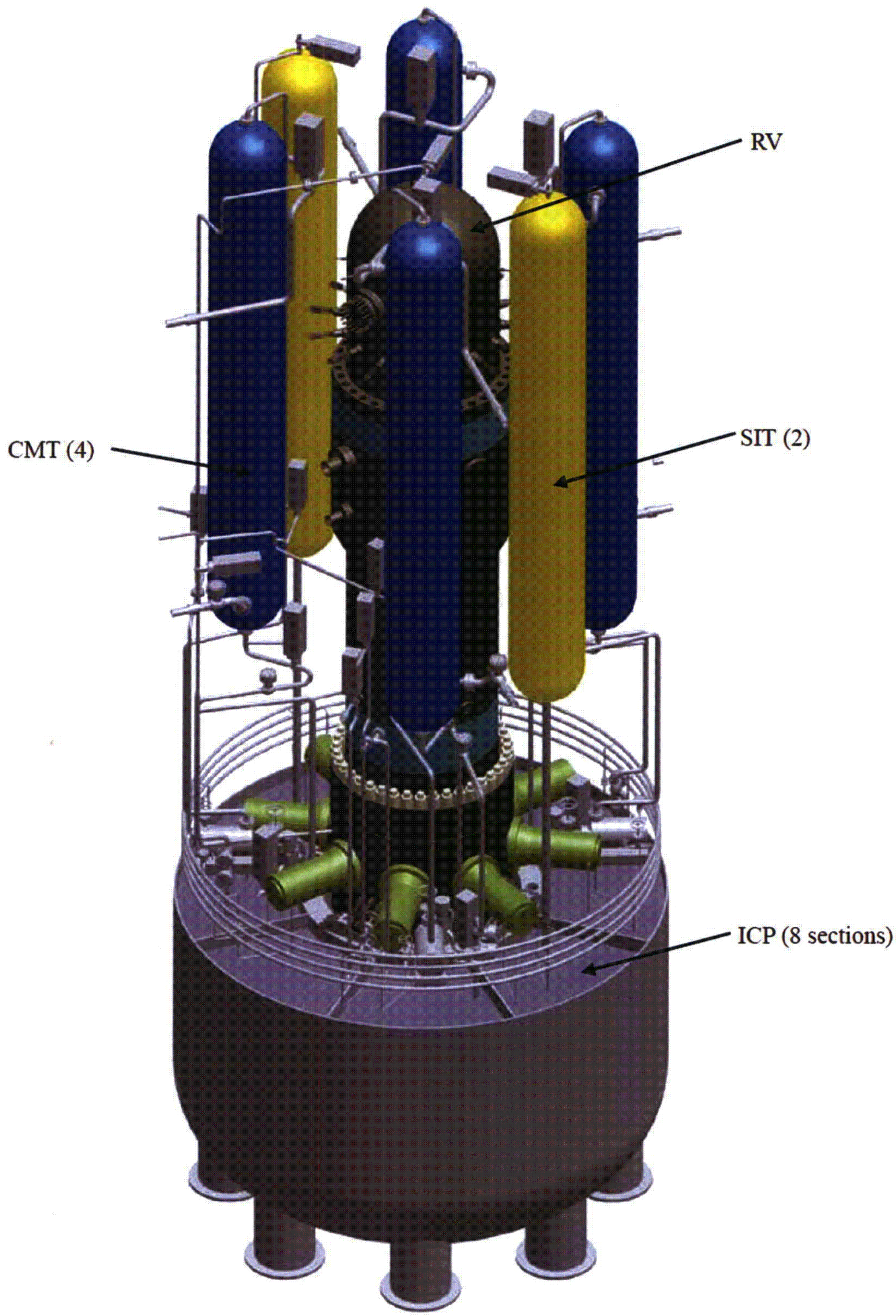

Figure 1-6 Illustration of Westinghouse SMR CV with Full Cutaway

2 METHODOLOGY AND APPROACH

2.1 PIRT METHODOLOGY

The US NRC and its contractors developed the PIRT (Phenomena Identification and Ranking Tables) process in 1989 as part of the CSAU (Code Scaling, Applicability and Uncertainty) effort (Reference 2.1). As originally conceived and applied to a PWR LBLOCA the process proved highly successful. However, the original process application was somewhat complex and labor intensive. As a first-of-a-kind product the process did not necessarily recognize future applications in which more limited objectives would be sufficient. In the intervening twenty years the process has been applied and refined in more than fifteen projects, for example:

- Light water reactor accident scenarios:
  - Large break LOCA
  - Small break LOCA
  - Main steam-line break
- Steam generator tube rupture
- Debris transport in wet and dry containments
- Containment coatings
- High burnup fuel under accident conditions
- Burnup credit
- TRISO fuel (manufacturing, operation, and accident life-cycle phases)

As now evolved, the PIRT process provides for the identification and ranking of safety-significant phenomena and associated research needs through the sequential consideration of the elements shown in Figure 2-1.

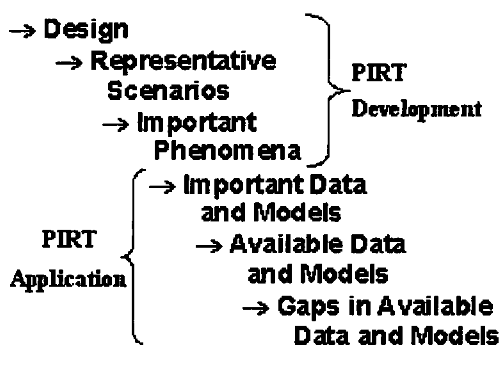

Figure 2-1 Elements Considered in the PIRT Process and Application

With respect to the elements illustrated in Figure 2-1, the PIRT process accommodates several key issues:

- Identification of all relevant phenomena;
- Recognition of phenomenon's relative importance including the associated rationales. That is, some phenomena are more important than others in complex and coupled physical systems. Conversely, some phenomena are not as important;
- Once important phenomena are identified, attention and resources can be focused more efficiently;
- Recognition of the relative state of knowledge for the phenomena including the associated rationales;
- Documentation for users.

The evolved nine step PIRT process is illustrated in Figure 2-2:

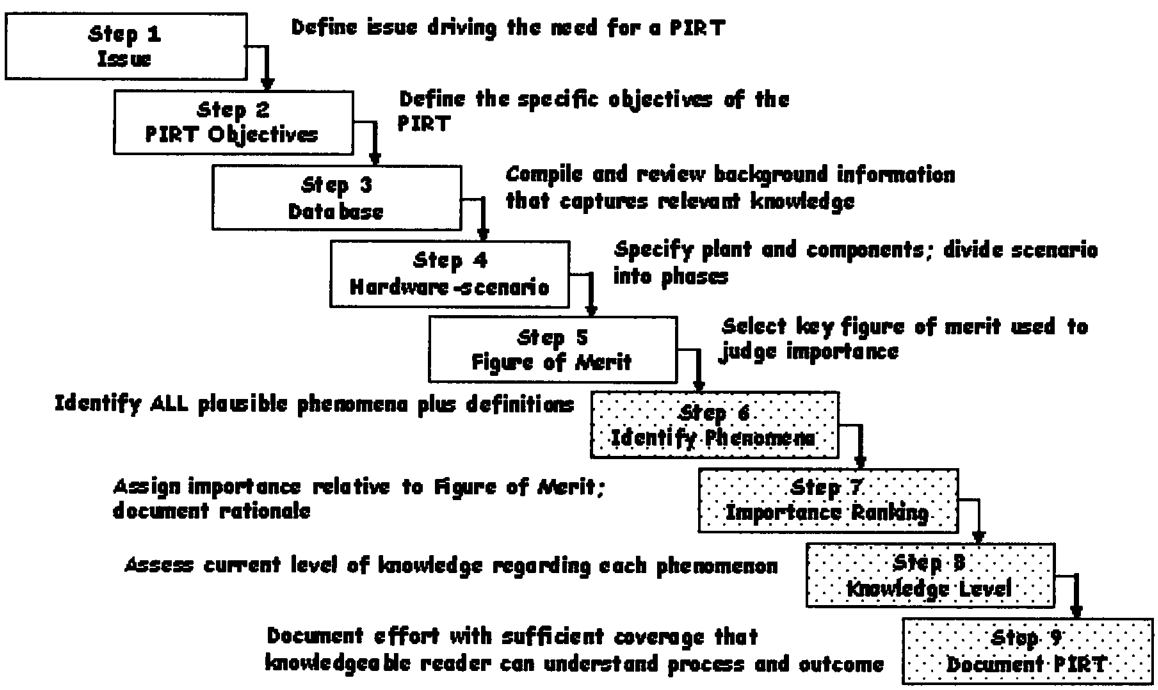

Figure 2-2 Nine-Step PIRT Process (Reference 2.2)

2.2 WESTINGHOUSE SMR SBLOCA PIRT

The PIRT panel followed the process illustrated in Figure 2-2. The general process features are described in the remainder of this section.

2.2.1 Issue Definition

From the perspective of the Westinghouse SMR Program, the primary issue is to insure that a sufficient experimental and analytical database exists to support the licensing process. This must be done in a cost effective manner. That is, the experimental and analytical database development should be planned to address design phenomena questions in a hierarchical sequence in which the plant responses that are postulated to be of the highest safety significance are explored first. In this context, "safety significance" denotes the combination of how influential a phenomenon may be on the successful mitigation of an accident scenario and how well that behavior can be predicted by experimental data and/or analytical modeling (the current state of knowledge level). From this perspective, it follows that behaviors of highest significance to the PIRT are those that have a high influence on the plant response and are the least well predicted with the current state of knowledge. The full range of decreasing safety significance determinations then progresses through the highly important phenomena with a moderate state of knowledge, moderately important phenomena with a low state of knowledge, moderately important phenomena with a moderate state of knowledge, etc. Table 3 in the executive summary lists significant phenomena in this order.

2.2.2 SBLOCA PIRT Objectives

The traditional PWR intermediate and large break LOCAs scenarios are eliminated by design in the Westinghouse SMR, therefore Westinghouse SMR LOCAs are limited to scenarios corresponding to SBLOCAs in PWRs making this event the next most important challenge to plant safety. Based on the Westinghouse SMR Program issue just discussed, the SBLOCA PIRT project had two primary objectives:

1. To obtain the functional requirement for an adequate evaluation model for the purpose of performing the safety analyses (LOCA) for the SMR

2. To develop a suitable test matrix intended to provide an adequate evaluation model assessment database

2.2.3 Westinghouse SMR SBLOCA Data Base Review

The Westinghouse SMR design development borrows heavily from the **AP600** and **AP1000** passive plant development efforts. Therefore, a large database exists related to the design, including several analytical and experimental studies to explore the potential design response to postulated accidents. Examples include Appendix B.

2.2.4 System, Component and Scenario Specifications

A hierarchical system break down in subsystems and components was performed in order to complete the PIRT. For example, a reactor design can be partitioned into systems and components within those systems. As noted in the previous section, a sufficiently mature design database existed to partition the plant into systems and components that provided a logical framework for the subsequent plausible phenomena identification (see subsection 2.2.6). The systems and components are described in Table 1-1.

For reasons already given, this PIRT effort was directed to SBLOCAs. Postulated breaks that were considered by the PIRT panel include:

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Table 2-1 Westinghouse SMR SBLOCA Scenario Description

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Table 2-1 (cont.) Westinghouse SMR SBLOCA Scenario Description

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2.2.5 Figures of Merit

Figures of Merit are those criteria against which the relative importance of each "phenomenon" is judged. Successful figures of merit have distinct characteristics, and in particular they are (1) directly related to the issue(s) being addressed by a PIRT, (2) directly related to the phenomena being assessed for relative importance, (3) easily comprehended, (4) explicit, and (5) measurable. In this context, the design goals of the Westinghouse SMR design provide the basis for selection of suitable Figures of Merit. The design goals are to:

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Accordingly, the Figures of Merit appropriate to the SBLOCA PIRT are consistent throughout all four phases of the scenarios and are: the core coolant inventory as associated with successful removal of the initial stored energy and core decay heat, the containment pressure and successful heat removal to the environment, and the demonstration of long-term core coolability accounting for debris and chemical precipitation as indicated by a core exit quality less than one. Figure 2-3 shows the SBLOCA Figures of Merit from above as predicted from models as a function of time.

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Figure 2-3 SBLOCA Figures of Merit

2.2.6 Phenomena Identification

In the PIRT process, phenomena are broadly defined. Plausible phenomena are those physical behaviors and/or processes that may have some influence in reactor plant's response. It is important to clearly characterize the plausible phenomena before a PIRT panel considers what safety importance (ranking) a phenomenon may have in influencing the plant response. That is, the panel first considers all possible physical behaviors and/or processes that may occur before evaluating if each phenomenon has real

consequences in the plant response. Twenty years of PIRT experience has shown this is the most successful approach to insure all significantly influential phenomena are addressed.

By careful, systematic evaluation of all four phases of the SBLOCA scenario, the PIRT panel was successful in developing a set of plausible phenomena. Those results are provided in Section 3. As might be expected the plausible phenomena are cast in terms of the system and component partitioning, and scenario time phases already described. Descriptions of the phenomena are also provided in Section 3.

2.2.7 Ranking of Phenomena Relative Safety Importance

The ranking of the relative safety importance of a phenomenon is based on its impact to the Figures of Merit as described in subsection 2.2.5. The phenomena safety ranking scale used in this PIRT is based on the principles described in Table 2-2.

Table 2-2 Westinghouse SMR SBLOCA Phenomena Safety Ranking Scale

Rank	Meaning
High (H)	The phenomenon is considered to have high importance. Accurate modeling of the phenomenon during the particular phase is considered to be important to the correct prediction of the transient.
Moderate (M)	The phenomenon is considered to have moderate importance. The phenomenon must be modeled with sufficient detail to obtain accuracy in the simulation; however, the phenomenon is expected to have less impact on the overall results than those ranked high.
Low (L)	The phenomenon is not considered to be very important during the transient. The phenomenon needs to be modeled in the code (or accounted for in the methodology), but inaccuracies in modeling this phenomenon are not considered likely to have a significant impact on the overall transient results.
Insignificant (I)	The phenomenon is considered insignificant or does not occur at all. This phenomenon need not be modeled or taken into consideration as it has an insignificant impact on results.

An operational practice that has proven its value in the application part of a PIRT effort is for a panel to rank the relative safety importance of components before ranking the phenomena. The same Figures of Merit are used as those applied to the phenomena ranking. Noting that a phenomenon cannot have a higher rank than the component in which it occurs, a panel can more quickly determine the order in which phenomena should be ranked. That is, the ranking sequence should progress through: phenomena located in highly ranked components first, followed by phenomena located in moderately ranked components second, followed by phenomena located in low importance components third. It may be noted that phenomena occurring in a low importance component can only be of low importance, therefore, are automatically ranked low once the component is ranked. Phenomena located in components ranked as insignificant can be eliminated from further consideration. The phenomena associated with low and insignificant ranked components are usually a reasonably large number of phenomena in the normally complex reactor designs being addressed by the PIRT process. Accordingly, ranking of components, first, produces a significantly more efficient PIRT application. This practice was adopted by the Westinghouse SMR SBLOCA PIRT panel and proved to be effective. It may be noted that while a specific result is achieved in the component ranking, these results are eventually subsumed in the phenomena ranking

tables. Therefore, it is not necessary to report the component ranking results separately from the phenomena ranking results. In the case of this PIRT effort, the safety ranking results are reported in Section 3.

2.2.8 Determination of the Phenomena Current State of Knowledge

The combination of a phenomenon's relative safety importance and its current state of knowledge provides the basis for determining how further efforts to conduct experimental programs and develop analytical tools can be accomplished in a sufficient and cost effective manner. That is, the experimental and analytical effort to achieve a certain level of knowledge is appropriate to the relative importance of a phenomenon.

Similar to phenomena safety ranking, a PIRT panel must adopt a state of knowledge ranking scale that is sufficient, efficient, and explicit. The Westinghouse SMR SBLOCA PIRT panel employed a scale that has been effective in other PIRT efforts, as described in Table 2-3.

Table 2-3 Westinghouse SMR SBLOCA State of Knowledge Ranking Scale

Rank	Meaning
High (H)	Relevant test data and a mature calculation method exist. There is sufficient understanding of this phenomenon such that it could be treated in a conservative or bounding manner in a model. No new testing or model development is needed to predict this phenomenon.
Moderate (M)	Relevant test data and/or calculation methods exist, but they may not be directly applicable to the scenario or geometry under consideration. There is sufficient understanding of the phenomenon such that it may be treated in a conservative or bounding manner. However, additional tests or model development may be necessary to properly address this phenomenon if it is ranked high.
Low (L)	Little or no relevant test data exists and calculation methods that may exist have not been validated to the scenario or geometry under consideration. There is insufficient understanding of the phenomenon such that it cannot be treated in a conservative or bounding manner in a model. Tests and/or model development will be necessary to properly address this phenomenon if it is ranked high.
Not Applicable (I)	Phenomenon is not applicable.

The state of knowledge ranking results are reported in Section 3 corresponding to the phenomena safety ranking results. Note that the scope of the PIRT panel with regards to the determination of the state of knowledge was limited to a qualitative, experience-based assessment.

2.2.9 Document the PIRT

Detailed and complete documentation is critical to successfully completing a PIRT assessment. This document incorporates the elements that have proven worthwhile in other PIRT efforts. This report is expected to serve the needs of the Westinghouse SMR Program in planning continued experimental program and analytical tool development.

3 SBLOCA SCENARIO PIRT RESULTS

3.1 INTRODUCTION

The general scenario including system and component descriptions and phase details were described in Sections 1 and 2, respectively. A list of plausible phenomena is provided in Table 3-1. As might be expected, the plausible phenomena are cast in terms of the component partitioning already described. Descriptions of the phenomena are also provided in Table 3-2. Additional information relative to the expected scenario progression is given in the following section.

Table 3-1 Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-2 Plausible Phenomena Descriptions

a,c,e

Table 3-2 (cont.) Plausible Phenomena Descriptions

a,c,e

Table 3-2 (cont.) Plausible Phenomena Descriptions

a,c,e

Table 3-2 (cont.) Plausible Phenomena Descriptions

a,c,e

3.2 EXPECTED SCENARIO PROGRESSION

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]a,c,e

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]a,c,e

3.3 RANKING RESULTS

The complete body of ranking results for the DVI break is provided in Tables 3-3, 3-4, and 3-5. Table 3-3 shows the phenomena safety rank for each phase and the state of knowledge rank. Also, listed in this table are rationale codes for each safety rank (denoted as PX) and state of knowledge rank (denoted as SX). These codes correspond to the descriptions given for every safety rank rationale and state of knowledge rank rationale in Tables 3-4 and 3-5, respectively.

a,c,e

Figure 3-1 Westinghouse SMR During Normal Operation

a,c,e

Figure 3-2 Westinghouse SMR During a SBLOCA Blowdown Phase (Phase 1)

a,c,e

Figure 3-3 Westinghouse SMR during a SBLOCA CMT Natural Circulation and Draining Phase (Phase 2)

a,c,e

Figure 3-4 Westinghouse SMR during a SBLOCA ADS Phase (Phase 3)

a,c,e

Figure 3-5 Westinghouse SMR During a SBLOCA Long-term Core Cooling Phase (Phase 4)

Table 3-3 Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) **Phenomena Importance**

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Safety Ranking Scale

H = The phenomenon is considered to have high importance. Accurate modeling of the phenomenon during the particular phase is considered to be important to the correct prediction of the transient.

M = The phenomenon is considered to have moderate importance. The phenomenon must be modeled with sufficient detail to obtain accuracy in the simulation; however, the phenomenon is expected to have less impact on the overall results than those ranked high.

L = The phenomenon is not considered to be very important during the transient. The phenomenon needs to be modeled in the code (or accounted for in the methodology), but inaccuracies in modeling this phenomenon are not considered likely to have a significant impact on the overall transient results.

I = The phenomenon is considered insignificant or does not occur at all. This phenomenon need not be modeled or taken into consideration as it has an insignificant impact on results.

Table 3-3 (cont.) Phenomena Importance

a,c,e

State of Knowledge Ranking Scale

H = Relevant test data and a mature calculation method exist. There is sufficient understanding of this phenomenon such that it could be treated in a conservative or bounding manner in a model. No new testing or model development is needed to predict this phenomenon.

M = Relevant test data and/or calculation methods exist, but they may not be directly applicable to the scenario or geometry under consideration. There is sufficient understanding of the phenomenon such that it may be treated in a conservative or bounding manner. However, additional tests or model development may be necessary to properly address this phenomenon if it is ranked high.

L = Little or no relevant test data exists and calculation methods that may exist have not been validated to the scenario or geometry under consideration. There is insufficient understanding of the phenomenon such that it cannot be treated in a conservative or bounding manner in a model. Tests and/or model development will be necessary to properly address this phenomenon if it is ranked high.

I = Not applicable.

Table 3-4 Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

a,c,e

Table 3-4 (cont.)	**Safety Ranking Rationales**

Table 3-5 State of Knowledge Ranking Rationales

a,c,e

Table 3-5 (cont.) State of Knowledge Ranking Rationales

a,c,e

Table 3-5 (cont.) State of Knowledge Ranking Rationales

a,c,e

4 SUMMARY AND CONCLUSIONS

4.1 SUMMARY

The Westinghouse SMR is a pressurized water reactor with an integral configuration (all primary system components – core, steam generators, pressurizer, and control rod drive mechanisms – are inside the reactor vessel). The Westinghouse SMR plant conceptual design was completed in 2011 and the preliminary design is currently underway. The first line of defense in the Westinghouse SMR is to eliminate event initiators that could potentially lead to core damage. In the Westinghouse SMR, accident sequences are eliminated from occurring to the extent possible rather than coping with their consequences. If it is not possible to eliminate certain accidents altogether, then the design inherently reduces their consequences and/or decreases their probability of occurring. One of the most obvious advantages of the Westinghouse SMR is the elimination of intermediate and large break LOCAs, since no large primary penetrations of the reactor vessel or large loop piping exist. An equally important example is given by the handling of SBLOCAs, which historically have been most plaguing to PWRs. The Westinghouse SMR approach is to utilize passive safety systems to keep the core covered, limit the containment pressure to acceptable levels, and maintain core coolability for up to seven days following the accident initiation without the need for AC power.

While the Westinghouse SMR design is a logical step in the effort to produce advanced reactors, the desired advances in safety must still be demonstrated in the licensing arena. With the elimination of intermediate and large break LOCAs, an important next consideration is to show that the Westinghouse SMR design fulfills the promise of increased safety for the SBLOCA. Accordingly, Westinghouse established the SBLOCA PIRT process. The purpose of the PIRT process is the planning for continued development of the experimental data and analytical tools needed for safety analysis, particularly in the licensing arena, in a sufficient and cost effective manner. Thus, the primary objective of the Westinghouse SMR SBLOCA PIRT project is to identify the relative importance of phenomena in the Westinghouse SMR response to SBLOCAs. This importance, coupled with the current relative state of knowledge for the phenomena, provides a framework for the planning of the continued experimental and analytical efforts.

To satisfy the prime objective of the Westinghouse SMR SBLOCA PIRT project, Westinghouse organized an expert panel. The members of this panel were selected to insure that the PIRT results reflect internationally recognized experience in reactor safety analysis and were not biased by program preconceptions internal to the Westinghouse SMR Program. The panel included external consultants totally independent of Westinghouse and the Westinghouse SMR Program and Westinghouse safety analysis experts with experience in passive plant analysis through the **AP1000** plant program, but independent of the Westinghouse SMR Program, and was augmented by Westinghouse SMR design and safety engineers to provide expertise on details of the Westinghouse SMR design. This panel employed the PIRT process to determine the range/conditions of SBLOCA scenarios that needed to be analyzed and then apply that methodology. A cold-side line break in one of the two 2-inch sump injection lines or in one of the four 3-inch direct vessel injection (DVI) lines was determined to be representative of a SBLOCA scenario and would satisfy the SBLOCA PIRT objectives. This accident scenario was subsequently analyzed with the detailed results documented in this report.

4.2 CONCLUSIONS

The following conclusions are based on the PIRT results summarized in Section 3 and are listed in their expected decreasing order of significance to guide confirmatory experimental testing and continued analytical tool development efforts.

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4.3 PHENOMENA WITH HIGH SAFETY RANKING

In the previous sections, components were identified that are highly important for the safe operation of the Westinghouse passive safety systems during a small break LOCA event. The following sections describe the recommendations that should be considered to increase the state of knowledge (SoK) of phenomena that received a high safety ranking in at least one phase of a SBLOCA scenario and also a low or moderate SoK rank. In some cases, testing may be selected to close these gaps, while in other cases, bounding assumptions may be used during the simulation of the accident scenario.

In the case of high safety and high SoK ranking phenomena, no new testing or model development is needed to predict these phenomena since there is already sufficient understanding. For these high safety and high SoK ranking phenomena, the justification is given in Table 3-5.

4.3.1 Recommendations to Support Phenomena with High Safety and Low State of Knowledge Ranking

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Table 4-1 High Safety and Low State of Knowledge Ranking Phenomena Recommendations

a,c,e

Table 4-1 (cont.) High Safety and Low State of Knowledge Ranking Phenomena Recommendations

a,c,e

Table 4-1 (cont.) High Safety and Low State of Knowledge Ranking Phenomena Recommendations

a,c,e

4.3.2 Recommendations to Support Phenomena with High Safety and Moderate State of Knowledge Ranking

Table 4-2 lists all phenomena that received a high safety ranking in at least one phase of a SBLOCA scenario and also a moderate SoK rank. The table describes the recommendations that may be considered to increase the SoK. In some cases, the information can be developed using tests while in other cases, a bounding approach in the computer simulation can be used.

Table 4-2 High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations

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Table 4-2 (cont.) High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations

a,c,e

Table 4-2 High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations (cont.)

a,c,e

Table 4-2 (cont.) High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations

a,c,e

Table 4-2 (cont.) High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations

a,c,e

Table 4-2 High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations (cont.)

a,c,e

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APPENDIX A
WESTINGHOUSE SMR SBLOCA PIRT PANEL ORGANIZATION AND MEMBERS

To help support the pre-application licensing effort, Westinghouse organized the Westinghouse SMR SBLOCA PIRT project. The objective of this project is two-fold:

1. To obtain the functional requirement for an adequate evaluation model for the purpose of performing the safety analyses (LOCA) for the SMR

2. To develop a suitable test design and test matrix intended to provide an adequate evaluation model assessment database

To insure no "conflict of interest", the Westinghouse SMR management and staff organized a PIRT panel consisting of three members completely independent of Westinghouse and eight Westinghouse members who were independent of the Westinghouse SMR Program. Although not considered panel members, the project was also supported by Westinghouse SMR experts. These individuals were Westinghouse engineers responsible for various areas of the Westinghouse SMR design. To insure transparency in the process, the role of the Westinghouse SMR experts was to address requests for information from the PIRT panel. The Curriculum Vitae for the PIRT panel members and the Westinghouse SMR experts follow.

A.1 PIRT PANEL INDEPENDENT EXPERTS CURRICULUM VITAE

Jacopo Buongiorno – (Nuclear Engineering Ph.D., MIT, 2000; Nuclear Engineering B.S., Polytechnic of Milan, 1996) is an Associate Professor of Nuclear Science and Engineering at the Massachusetts Institute of Technology (MIT) in Cambridge, MA, since 2004. Between 2000 and 2004 he worked at the Idaho National Laboratory (INL) as technical director of the U.S. Generation-IV research program for the development of the Super Critical Water cooled Reactor (SCWR). His areas of technical expertise and research interest are nanofluid technology, fluid dynamics, heat transfer and two-phase flow in nuclear systems. He has authored over 40 journal articles on these topics. For his research work and his teaching at MIT Prof. Buongiorno won several awards, including, recently, the Landis Young Member Engineering Achievement Award (American Nuclear Society, 2011), and the Ruth and Joel Spira for Distinguished Teaching Award (MIT, 2011). Of particular relevance to this PIRT evaluation effort are his recent activities on the development of a Quantitative PIRT (QPIRT) in the context of the R7 code project at INL, as well as his activities on advanced simulation of two-phase flow and heat transfer phenomena. Prof Buongiorno's group uses interface tracking methods to study liquid entrainment in annular flow in BWRs and bubble dynamics in subcooled flow boiling in PWRs. Synchronized high-speed infrared thermometry, Particle Image Velocimetry (PIV), Laser Induced Fluorescence (LIF) and high-speed video capabilities have been developed to resolve boiling and multiphase flow phenomena, and generate data for validation of the predictive methods and simulations. Prof. Buongiorno is a consultant to the nuclear industry and a member of the American Nuclear Society (ANS) and American Society of Mechanical Engineers (ASME).

Masahiro Kawaji – is a Professor of Mechanical Engineering at City College of New York, and a core member of the CUNY Energy Institute. He was recruited from the University of Toronto in 2009 to develop a nuclear engineering program and conduct reactor thermal-hydraulics and safety research. At the University of Toronto, he was Professor and Acting Chair of the Department of Chemical Engineering and Applied Chemistry, the Chair of Nuclear and Thermal Power option in the Engineering Science program, and a member of the Radiation Protection Authority.

He received M.S. and Ph.D. degrees in nuclear engineering from UC Berkeley and has over 30 years of experience in conducting nuclear reactor thermal-hydraulics and safety research. Starting with a doctoral thesis on rewetting of nuclear fuel rods under LOCA conditions, he conducted large-scale, high pressure/high temperature two-phase flow experiments at Japan Atomic Energy Research Institute in 1983-86. As a member of the ROSA team, he contributed to the development of the Large Scale Test Facility (LSTF) and conducted small-break LOCA experiments and data analysis for PWRs. After moving to the University of Toronto in 1986, he worked on a wide range of thermal-hydraulics projects ranging from fundamental research on interfacial transport phenomena to LWR and CANDU reactor safety. He has authored or co-authored over 350 archival publications including 13 books and book chapters, 130 refereed journal papers, 95 refereed conference papers, and 135 non-refereed conference papers and technical reports in nuclear, chemical and mechanical engineering fields. His research interests include nuclear reactor thermal-hydraulics and safety involving two-phase flow and phase change heat transfer, microfluidics, micro-heat pipes, microgravity fluid physics and transport phenomena, advanced instrumentation, numerical simulation of free surface problems, compact heat exchangers, and thermal energy storage systems with ice slurry and phase change materials.

He is a Fellow of the Canadian Academy of Engineering, ASME and Chemical Institute of Canada. In 2002, he received a Jules Stachiewicz Medal from the Canadian Society for Chemical Engineering for contributions to heat transfer research, and in 2006 an Ontario Professional Engineers Award – Engineering Medal for Research and Development. He is a member of ANS and a Senior Member of AIChE. He served as Director (2005-present) and Chair (2009) of AIChE's Transport and Energy Processes Division, a member of AIChE/ASME Max Jakob Memorial Award Selection Committee in 2005-07, and chaired the Donald Q. Kern Award Selection Committee in 2009. In academic journals, he has served on the Editorial Advisory Board of the International Journal of Multiphase Flow (1997-2011) and Editorial Board of the Process Mechanical Engineering (1999-2005). He is presently a Regional Editor of the International Journal of Transport Phenomena and serving on the Editorial Board of Experimental Thermal and Fluid Science (2004-present). He has supervised 32 Post Doctoral Fellows and Visiting Scholars, 26 Ph.D. students, and 35 Master's students. In the past three years at City College of New York, he has received over 1.5 million dollars in grants from the US Nuclear Regulatory Commission, and research grants of over 1.4 million dollars from DOE's NEUP program.

He has also served on the organizing and scientific committees of numerous international conferences, for example, International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH), International Conference on Multiphase Flow (ICMF), International Conference on Heat Transfer and Fluid Flow in Microscale, International Topical Team Workshop on Two-Phase Systems for Ground and Space Applications, International Conference on Nanochannels, Microchannels & Minichannels (ICNMM), International Symposium on Transport Phenomena (ISTP), IIR Conference on Phase Change Materials and Slurries for Refrigeration and Air Conditioning, and International Symposium on Gas Transfer at Water Surfaces, among others.

Annalisa Manera – is an Associate Professor at the University of Michigan since June 2011 (Ph.D. Nuclear Engineering, Delft University of Technology, The Netherlands; M.Sc. Nuclear Engineering with honors, University of Pisa, Italy; Qualified Expert of Radiation Protection Level III, The Netherlands). Prior to her employment at the University of Michigan, she was the head of the group "Nuclear Systems Behaviour" in the Reactor Physics Laboratory at the Paul Scherrer Institute (Switzerland), senior nuclear engineer at Colenco Power Engineering (Switzerland), and research scientist at the Research Center Rossendorf-Dresden (Germany).

She has more than 10 years of experience in nuclear reactor safety and thermal-hydraulics, ranging from thermal-hydraulic experiments to analytical and computational analyses of nuclear power plants. Her analytical activities include safety analyses of nuclear power plants with 1D best-estimate thermal-hydraulic (TH) codes combined with sensitivity and uncertainty analysis, coupling of 1D TH codes with 3D neutronics codes and investigation of NPP transients such as BWR ATWS, coupling between 1D TH codes and CFD (computational fluid dynamics), BWR stability analyses in time and frequency domain. While at the Paul Scherrer Institute, she provided technical support to the Swiss Nuclear authority and to the Swiss utilities for the simulation of NPP transients and the analysis of computational methodologies for specific NPPs issues such as PTS (pressurized thermal shock).

Since 1999 she has been working on passive systems of Gen-III+ LWRs, starting with the GE ESBWR and most recently focusing on the KERENA reactor design developed by AREVA. Since 2008 she has been supporting the AREVA experimental team with the definition of optimal experimental procedures for their large-scale test facility INKA, and with the investigation of passive systems performance.

Her experimental activities have been focused on the use of advanced instrumentation (e.g., wire-mesh sensors, laser-Doppler anemometry, needle-probes, gamma tomography and gamma densitometry) for the generation of high spatial and time resolved measurements for single-phase and two-phase flows, and on experiments aimed at investigating the behavior of natural circulation BWRs and passive systems of Gen-III+ LWRs.

Until May 2011, she was the Vice-President of the Swiss Nuclear Society, and the Swiss U.S.NRC CAMP representative, with her group contributing to the validation and further development of the NRC best-estimate code TRACE. She has over 30 refereed journal publications and about 60 publications in referred international conference proceedings.

A.2 PIRT PANEL WESTINGHOUSE EXPERTS CURRICULUM VITAE

William L. Brown (Mechanical Engineering M.S., University of Pittsburgh; BAE, Pennsylvania State University) – Mr. Brown is a Fellow Engineer for Westinghouse Electric Company in the Passive Plant Technology group. He has over thirty years experience in the design, analysis, scaling, and testing of thermal-hydraulic systems and equipment.

The first ten years of Mr. Brown's experience supported nuclear submarine design, analysis, and testing for the U.S. Navy, including the Seawolf Class and Los Angeles Class submarines. Mr. Brown's testing experience in graduate school mainly focused on boundary layer turbulence while his testing experience for nuclear submarines focused upon turbulent mixing and transport of airborne contaminants and explosive gases. The last twenty years of Mr. Brown's career have been largely devoted to the design,

analysis, testing, and licensing of advanced passive nuclear reactor plant designs with emphasis on the **AP600** and **AP1000** plants. Mr. Brown's testing experience with commercial nuclear power plants includes the following:

- **AP600** plants passive safety systems and equipment testing
- **AP1000** plants passive safety systems and equipment testing
- Steam generator moisture separator testing
- Bluff body turbulence testing
- Reactor vessel core inlet flow distribution testing
- Ultrasonic cross-correlation flow meter testing
- Velocity and turbulence profile testing for piping disturbances
- Two-Phase Countercurrent flow and liquid entrainment testing in complex reactor geometries
- Boiling heat transfer testing in the presence of debris and chemical contaminants
- Enhanced passive containment heat transfer testing

Mr. Brown has lead several thermal-hydraulic PIRT, scaling, and testing programs performed for advanced passive plant technology and successfully defended results from these programs to the Nuclear Regulatory Commission. Mr. Brown has received recognition for these technical achievements including the George Westinghouse Signature Award of Excellence in 1996, 1997, 2001, 2004, and 2010. Mr. Brown is a member of ASME and has served as a technical reviewer for Nuclear Technology Journal and ASME Journal of Fluids Engineering. He has been an invited lecturer on the subjects of passive plant testing and scaling of thermal hydraulic phenomena at universities and nuclear power utilities in the United States and Japan.

Edward L. Carlin – (Electrical Engineering B.S., University of Pittsburgh, 1982) Mr. Carlin has more than 30 years of experience in methods, computer codes and analyses of deterministic non-LOCA safety analyses. He is currently the technical lead for **AP1000** plant non-LOCA design basis safety analyses. This also includes support of Anticipated Transients Without SCRAM (ATWS). His previous significant effort was on the **AP600** plant project. In addition to performing non-LOCA analyses, this work included developing computer models used for non-LOCA analyses and support of the reactor protection system functional design. The **AP600** plant work included preparation of licensing documentation and resolution of NRC/ACRS questions. His past work included non-LOCA and LOCA safety analyses for the Advanced PWR (APWR) program. Cognizant engineer for the original FSAR non-LOCA safety analyses and resolution of NRC questions for the Catawba, South Texas and Wolf Creek plants. Experience also includes some work for VVER PWR (Temelin) safety analyses and BWR safety analyses. Mr. Carlin is currently a Principal Engineer with Westinghouse working in transient analysis with 38 years of nuclear experience. His current areas of responsibility include **AP1000** Plant Non-LOCA Technical Lead, ATWS, detailed steam generator secondary side models for transient analyses, and support of operating plant reloads, power up-rates and steam generator replacements.

Larry E. Conway – (Chemical Engineering B.S., University of Pittsburgh, 1969) Mr. Conway is a Fellow Engineer at the Westinghouse Electric Company. He has over 40 years of experience in the nuclear industry and has worked primarily as a fluid systems designer, and in component and system testing. Mr. Conway is the co-inventor of the **AP600/AP1000** plant type passive safety system design which was successfully developed, tested, and licensed; as well as the co-inventor of the **AP600/AP1000** plant passive containment cooling system.

He was the lead technical design engineer for the **AP600** plant test program having provided the engineering design for many of the **AP600** plant tests, established test specifications and matrices, and personally directed several tests including the SPES-2 Integral Systems Test and the Automatic Depressurization System Test, which were performed in Italy by SIET and ENEA, respectively. Mr. Conway was also the technical lead for IRIS reactor development program, developing an even more simplified passive safety system approach for a small integral PWR. Mr. Conway has performed many roles in the current **AP1000** plant commercialization effort from finalization of the technical portion of the China contract, issuance of the PSARs for the China projects, co-coordinating plant interfaces between diverse parties in the China project, to technical leader on implementation of the **AP1000** plant 50HZ design for European application. Mr. Conway is also participating in the development of the SMR, providing consultation based on his experiences in developing the IRIS, and in developing the SMR test program.

Jason M. Douglass – Mr. Jason Douglass holds a Master's Degree in Nuclear Engineering from the University of South Carolina and Bachelor's Degrees in Mechanical Engineering and Aerospace Engineering from West Virginia University. He has spent the last five years working in the Containment and Radiological Analysis group at Westinghouse, where he is a technical lead in the area of BWR containment and works in many other areas performing GOTHIC analyses. Prior to working at Westinghouse he worked at Bechtel Bettis Atomic Power Laboratory, where he attended Naval Officer Nuclear Power School and worked in the Space Engineering organization.

Cesare Frepoli – (Nuclear Engineering Ph.D., Pennsylvania State University, 2001; Nuclear Engineering M.E., Politecnico di Milano, 1990) Dr. Frepoli has 20+ years experience in the nuclear industry. He is a recognized expert in the area of thermal-hydraulic, fluid-dynamics, numerical methods, physical models for computer simulation and uncertainty methodologies for nuclear power plant safety analysis and design. Dr. Frepoli leads various development program and teams within the industry and authored several publications in the area. He is cognizant of the various licensing and regulatory aspects of safety analyses methodologies, operation and maintenance of PWRs, as well as design certification of new generation nuclear power plants (**AP600/AP1000** plants, IRIS, APWR, and APR1400). Dr. Frepoli specialized in the execution of activities following the Evaluation Model Development and Assessment Process (EMDAP, Regulatory Guide 1.203). He is also cognizant in state-of-the-art statistical methodology for the convolution of uncertainties in the frame of Best-Estimate Plus Uncertainties Methods.

Dr. Frepoli's most recent contribution is the development of the new Westinghouse Realistic LOCA Evaluation Model called Full Spectrum LOCA Methodology (U.S. Patent Appln. Serial No. 13/303,188). The methodology is a "first-of-its-kind" in the industry as it represents the first realistic (best-estimate plus uncertainty) license-grade PWR LOCA evaluation model which covers large, small and intermediate break sizes scenario by the industry. Such methods are expected to generate significant additional PWRs operational margin.

Dr. Frepoli is an expert in various T/H system codes such as WCOBRA/TRAC, TRACE and RELAP5 both as developer and user. Over the years, he has participated to various research activities to improve evaluation models and supported code development and validations. Dr. Frepoli has experience in setting up test programs, and pre-test and post-test analyses. It is worth mentioning that he completed the design and scaling of the Penn State "Rod Bundle Heat Transfer (RBHT)" test facility. This was a five year

research program sponsored by the U.S. Nuclear Regulatory Commission to improve core accuracy in modeling core T/H during postulated Large Break LOCA. In the 90's, Dr. Frepoli participated to various activities in the frame of **AP600** plant and then **AP1000** plant development. Activities included the post-test analysis of the experiments performed in the SPES-2 and OSU (APEX) integral test facilities. These tests were conducted to study the **AP600** plant behavior under SB-LOCA and Long Term Cooling transient scenario. Within these activities, he participated to various PIRT panels.

Rick P. Ofstun – Mr. Richard Ofstun graduated from the University of Wisconsin in May of 1980 with a Master's of Science (M.S.) degree in Nuclear Engineering. He began his career with Westinghouse in the Operational Safeguards Analysis group within the Nuclear Safety Department in June of 1980. While in this position, he helped develop a desktop simulator code (TREAT) and several associated plant models. He also helped write and verify the generic Westinghouse emergency response guidelines that were used as the basis for the plant specific emergency operating procedures. Later, his experience in performing transient thermal hydraulic analyses was used to develop the integrated plant evaluation success criteria for probabilistic risk assessments. Mr. Ofstun joined the containment analysis group in 1996. He helped develop the **AP600** plant containment evaluation model, was responsible for the PCS water coverage modeling methodology, and became the code responsible engineer for the WGOTHIC and GOTHIC computer codes within Westinghouse. Mr. Ofstun led the **AP1000** plant containment model development and analysis effort. More recently, he has led the development of a new Westinghouse LOCA mass and energy release analysis methodology and the development of various BWR containment models. Mr. Ofstun is currently a Fellow Engineer with Westinghouse and is a registered Professional Engineer.

James H. Scobel – (Mechanical Engineering B.S., Pennsylvania State University, 1983) Mr. Scobel has had over 28 years experience with Westinghouse in nuclear safety analysis and probabilistic risk assessment (PRA) of conventional and advanced passive nuclear power plants. He specializes in thermal-hydraulic analyses supporting PRA and the analysis of beyond design basis accidents and the severe accident phenomena associated with them. Mr. Scobel is proficient in modeling severe accident phenomena. He is the technical leader and author of the Westinghouse guidebook for the application of the GOTHIC thermal-hydraulic computer code to long-term containment integrity analyses. Mr. Scobel has experience in the use of WGOTHIC modeling for design basis containment analyses of the **AP1000** plant passive containment. He is the technical leader for the probabilistic risk assessment (PRA) containment and consequence analyses and severe accident thermal-hydraulic phenomenological analyses for the **AP1000** plant advanced passive nuclear power plant, including the analyses of in-vessel and ex-vessel steam explosion, cladding water reactions and hydrogen generation, hydrogen combustion and detonation, in-vessel retention of molten core debris, melt attack on containment structures, high pressure melt ejection and direct containment heating, core-concrete interactions, containment pressurization from decay heat and non-condensable gas generation, and equipment survivability. Mr. Scobel was directly involved with the research and implementation of the accident management strategy of in-vessel retention (IVR) of molten core debris by external reactor vessel cooling to the **AP1000** and **AP600** advanced passive nuclear plants performed using the Risk Oriented Accident Analysis Methodology (ROAAM). He was the Westinghouse industry advisor to the Advanced Reactor Severe Accident Program (ARSAP) Source Term Expert Group.

Frank T. Vereb – Mr. Frank Vereb entered the U.S. Navy Nuclear Power Program in 1991 as an Electrician's Mate and went on to serve aboard the fast attack submarine, USS Minneapolis St. Paul (SSN 708), where he qualified the most senior in-rate position of Engineering Watch Supervisor. During this time, he was responsible for at sea operation of a Navy nuclear propulsion plant including management of the 9 plant operators. After separating from the Navy, Mr. Vereb later went on to join the Performance Engineering Department at Beaver Valley Power Station and developed the plant's vibration analysis program. After spending 9 years as an engineering consultant in the field of predictive maintenance, he joined the Westinghouse Electric Company **AP1000** Plant Layout group in 2009 where Mr. Vereb executed the basic design of the **AP1000** plant domestic Turbine Building, including the development of mitigation measures for sub-compartment pressurization effects during postulated high energy line breaks. Later, he joined the Passive Plant Technology group where he authored a series of white papers describing the **AP1000** plant response to a postulated station blackout as well as other communications materials which describe the operation of the passive safety systems. Mr. Vereb is currently a Senior Engineer with Westinghouse and has a Bachelor of Science (B.S.) degree in Nuclear Engineering Technology from Thomas Edison State College.

A.3 WESTINGHOUSE SMR EXPERTS CURRICULUM VITAE

Ramsey P. Arnold – Mr. Arnold graduated from the Massachusetts Institute of Technology in 2011 with a Master's of Science in Nuclear Science & Engineering and Carnegie Mellon University in 2009 with a Bachelor's of Science in Chemical Engineering. Upon graduation from Carnegie Mellon, Mr. Arnold joined the Defense Nuclear Facilities Safety Board and worked on the safety analysis review of several radioactive waste treatment facilities throughout the DOE's nuclear weapons complex. He is currently on a year-long assignment from the DNFSB working at Westinghouse. Mr. Arnold is supporting the Westinghouse SMR licensing program and also the plant design and safety analysis.

William E. Cummins – Mr. Cummins has spent his 35-year Westinghouse career in a variety of assignments in project management, engineering management and new plant design. Prior to joining Westinghouse in 1976, Ed served seven years in the U.S. Navy with assignments in engineering and operations on two nuclear powered submarines. Mr. Cummins' first assignments in Westinghouse were in the Power Systems Projects Division as a project engineer and then engineering manager for the turnkey project implementation of the Krsko Project in Yugoslavia. In 1982, he joined the Preheat Steam Generator Task Force as project manager for the counterflow preheat steam generator effort.

In late 1983, Mr. Cummins returned to turnkey project business as Project Deputy Director for the Philippine nuclear project. Following completion of the Philippine plant construction, he served as program manager to develop a standard 1000MW plant design and cost estimate to be used for international turnkey opportunities in the mid 1980s. In 1985, Ed joined the Plant Engineering Division as a Department Manager responsible for nuclear mechanical equipment, materials and fossil plant engineering. In 1988 and 1989, he was responsible for the project management, project development, financing, and contracts structure for a Westinghouse-owned gas turbine combined cycle project in Mojave, California. In 1990, Mr. Cummins joined the **AP600** plant project development team as manager of Balance of Plant Design. He served in various program and design management positions on the **AP600** plant, including Project Manager for the First of a Kind Engineering Program. In 1997, Mr. Cummins became General Manager of the New Plant Projects Division, assuming responsibility for the marketing and project implementation for new nuclear plant projects.

In March of 2000, Westinghouse initiated development of the **AP1000** plant designed to be competitive with natural gas fired combined cycle plants. Since that time Ed has served as Vice President of Engineering, Vice President of Regulatory Affairs and Vice President & Chief Technologist for New Plant Technologies in support of **AP1000** plant commercialization. He is currently Vice President & Chief Technologist of New Plant Technologies, responsible for passive plant technology. He is also coordinating the design activities for the Westinghouse Small Modular Reactor. Mr. Cummins holds a Bachelor of Science Degree from the U.S. Naval Academy, a Master of Science Degree in Engineering Applied Science from the University of California, Davis, Livermore and a Master of Business Administration from Duquesne University.

Matthew C. Smith – Mr. Smith graduated from the Pennsylvania State University in May of 2002 with a Bachelor's of Science (B.S.) degree in Mechanical Engineering. He began his career with Westinghouse in the Transient Analysis group of Nuclear Services in May of 2002. While in this position, he helped develop a model to take credit for reactor coolant system metal mass in non-LOCA safety analyses using the RETRAN-02W computer code. He also developed models to determine the potential for loop flow stagnation to occur during a reactor coolant system cooldown with faulted or inactive steam generators. Other areas of responsibility have included development of detailed steam generator secondary side models for transient analyses, and support of operating plant reloads, power up-rates and steam generator replacements. More recently, he has been a member of the Westinghouse SMR conceptual design team where he serves as the Safety Analysis Lead among other engineering roles. Mr. Smith is currently a Principal Engineer with Westinghouse.

Richard F. Wright – (NucEng PhD, University of Florida 1994; MechEng MS, University of California, Berkeley 1983, EngSci BS, Penn State University 1980) is a Consulting Engineer with Westinghouse Electric Company with over 30 years experience with advanced reactor safety analysis, design, testing and licensing. He has worked for 20 years on passive light water reactor designs including the **AP600** plant, **AP1000** plant and the Westinghouse SMR where he was responsible for testing and safety analysis. He has recently worked as licensing lead for the **AP1000** plant in the United Kingdom, and is currently licensing lead for the Westinghouse SMR. He has authored over 70 journal articles and conference papers on advanced plant safety system design, analysis and testing. Dr. Wright is a member of the American Nuclear Society (ANS).

APPENDIX B
AP600 PLANT PROGRAM TEST SUMMARIES

The following provides a summary of each **AP600** plant test including their purpose, a description of the facility, and a discussion of the test matrix/results.

B.1 PASSIVE CORE COOLING SYSTEM (PXS) TEST SUMMARIES

The following tests were performed for the PXS:

- Departure from Nucleate Boiling (DNB) test (subsection B.1.1)
- Passive Residual Heat Removal Heat Exchanger (PRHR HX) test (subsection B.1.2)
- Automatic Depressurization System (ADS) test , phase A (subsection B.1.3)
- ADS test, phase B (subsection B.1.4)
- Core Makeup Test (CMT) test (subsection B.1.5)
- Low-pressure, integral systems test, OSU (subsection B.1.6)
- Low-pressure, integral systems test, OSU-NRC (subsection B1.7)
- High-pressure, integral systems test, SPES-2 (subsection B.1.8)
- High-pressure, integral systems test, ROSA-**AP600** (subsection B.1.9)

B.1.1 DNB Tests

General Purpose/Description

While low-flow DNB tests have been performed successfully on other fuel assembly geometries, data accumulated over several years of testing on the current Westinghouse fuel designs have concentrated on the higher flow range associated with operating conditions of conventional, higher-power density cores. The purpose of these tests was to determine the critical heat flux (CHF) performance of the **AP600** plant fuel assembly design, particularly at low-flow conditions. In addition, the effect on CHF of the intermediate flow mixer (IFM) grids at low-flow conditions was measured.

The test objective was to gather CHF data on typical and thimble cell **AP600** plant bundle geometry covering the range of fluid conditions anticipated during **AP600** plant DNB-related ANS Condition I and II transients. The conditions cover the following ranges:

Pressure:	1500 to 2400 psia
Mass velocity:	0.5 to 3.5 x 10^6 lbm/hr-ft^2
Inlet temperature:	380° to 620°F

Also, a typical cell test where the **AP600** plant bundle has the IFM grids replaced by simple support grids (SSGs) was run to assess the effect of the IFMs at low-flow conditions.

To perform a series of low-flow tests, two test bundles were constructed. The test bundles consisted of a small 5 by 5 array of rods, which are electrically heated and well-instrumented with thermocouples. The components for the test bundles were shipped to the test site, Columbia University, and assembled just prior to testing.

Test Results/Matrix

Sufficient data were taken to provide a basis for reducing the lower limit on mass velocity by 60 to 70 percent from the current value of 0.9 by 106 lb/hr-ft2 (i.e., to the 3 to 4 fps range).

The results of the DNB tests were used to extend the existing Westinghouse DNB correlation to lower flow rates than previously tested. Other correlations, however, did extend to lower flow rates, and the DNB margin has been shown to exist using these correlations over the lower range of flow rates. Since the **AP600** plant has ample DNB margin, this test did not impact the core or fuel design.

B.1.2 PRHR HX Test

General Description/Purpose

An experimental program was performed to characterize the thermal performance of the PRHR HX and the mixing behavior of the in-containment refueling water storage tank (IRWST). The experiment used stainless steel tubing material, tube diameter, pitch and length. The tubes were located inside a scaled IRWST. Since the vertical length was preserved, the buoyant- induced flow patterns inside the tank simulated the **AP600** plant. The main scaling parameter for the experiment was the pool volume per FIX tube so that the heat load characteristics, resulting tank fluid conditions, and induced flow pattern would be similar to those in the **AP600** plant.

Test Matrix/Results

The PRHR HX test confirmed the heat transfer characteristics of the PRHR HX and mixing characteristics of the IRWST. These results validated the FIX size and configuration.

The test conditions covered a full range of expected flow rates, including forced-convection PRHR cooling [reactor coolant pumps (RCPs) running] and natural circulation flows by varying the pumped flow through the tubes. The tests also examined different initial primary fluid temperatures over a range from 250° to 650°F using hot pressurized water that flowed downward inside the tubes. The initial tank temperature was either ambient temperature (70°F) or near boiling (212°F). The test data were reduced to obtain the local wall heat flux on the PRHR tubes. Comparisons of the PRHR test data with existing correlations for free convection and boiling were made, and a design correlation for the PRHR HX was developed.

The following conclusions were drawn from the test results:

- A boiling heat flux correlation similar to recognized correlations was developed from the PRHR data. Using the PRHR boiling correlation, an overall heat transfer coefficient can be calculated to determine the required surface area and evaluate the PRHR performance during postulated accidents.

- Mixing of the water in the simulated IRWST was very good. Localized boiling did not occur until the entire IRWST water volume was significantly heated. The test demonstrated that the IRWST water will not steam into the **AP600** plant containment for about 2 hours.

B.1.3 ADS Test – Phase A

General Description/Purpose

The purpose of these tests was to simulate operation of the ADS, to confirm the capacity of the ADS, and to determine the dynamic effects on the IRWST structure.

The ADS phase A test was a full-sized simulation of one of the two **AP600** plant depressurization system flow paths from the pressurizer that duplicated or conservatively bounded the operating conditions of the **AP600** plant ADS valves, sparger, and IRWST. A full-sized sparger was tested. The loadings on the sparger and its support were measured, as were temperatures and pressures throughout the test arrangement.

A pressurized, heated water/steam source was used to simulate the water/steam flow from the **AP600** plant RCS during ADS operation. The flow was piped to a full-sized sparger submerged in a circular rigid quench tank simulating the IRWST. Instrumentation to measure water and steam flow rate, equipment dynamic loads, IRWST dynamic loads, and sparger/IRWST steam quenching was provided.

The ADS phase A test arrangement is shown schematically in Figure B.1-1. Phase A testing consisted of saturated steam blowdowns, at rates simulating ADS operation, through the submerged sparger. Sparger steam quenching was demonstrated from ambient to fully saturated IRWST water temperatures.

Test Matrix/Results

Phase A was conducted to provide both the maximum possible blowdown rate when all three stages of the **AP600** plant ADS were actuated, and to simulate the minimum blowdown rate (end of blowdown) when the pressurizer was essentially depressurized. For these tests, all three piping connections between the test drum and the discharge line were open. These tests were used to select the quench tank water level to be used in all subsequent ADS blowdowns.

Tests were performed to simulate the actuation of the first stage of ADS and blowdown to 500 psig. One test simulated the inadvertent opening of a second- or third-stage ADS valve when the reactor is at operating pressure. Additional tests provided the maximum blowdown rate that will occur in the **AP600** plant when the first- and second-stage ADS valves are open.

Results of the phase A tests were used to verify the design of the ADS sparger and obtain sufficient information to perform preliminary design of the IRWST. Tests performed with a fully saturated quench tank water showed that loads on the IRWST decrease as water temperature increases.

B.1.4 ADS Test – Phase B

General Description/Purpose

The ADS phase B test was a full-sized simulation of one of the two **AP600** plant depressurization system flow paths from the pressurizer that duplicated the operating conditions of the **AP600** plant ADS valves,

sparger, and IRWST. A full-sized ADS valve piping package was tested. The loadings on the sparger and its support were measured, as were temperatures and pressures throughout the test arrangement.

Phase B testing was performed at ENEA's VAPORE test facility in Casaccia, Italy. The test collected sufficient thermal-hydraulic performance data to support the development and verification of analytical models of the ADS used in safety analyses of events for which the ADS is actuated. In addition, it provided the design requirements of the ADS components and obtained sufficient information to establish component design specifications.

Phase B testing included the addition of piping to permit the blowdown of either saturated steam or saturated water from the pressurizer, and installation of piping and valves representative of the actual ADS. The ADS phase B test arrangement is shown schematically in Figure B.1-2. Figure B.1-3 shows the prototypic sparger being installed in the facility quench tank.

ADS phase B test data were used to assess the critical and subsonic flow models for the valves in the ADS system, as well as the sparger, when the flow is two-phase. ADS phase B tests supported proper specification of the functional requirements for the valves.

Test Matrix/Results

The test matrix is shown in Table B.1-1. Tests were run with various ADS valve flow areas. The final test report has been written. The key results and observations for ADS phase B are:

- The sparger operated properly over the full range of ADS flow rates, fluid qualities, and quench tank temperatures.
- ADS quench tank loads resulting from sparger-induced pressure pulses during phase A are conservative.
- Loads observed for steam and steam/water blowdowns are less than phase A.
- Data for water through the piping and valves were obtained.
- No low-flow slugging was exhibited by the sparger.
- Blowdowns into a hot (212°F) quench tank produced small loads.

B.1.5 CMT Test

General Description/Purpose

The purpose of this test was:

- To simulate CMT operation over a wide range of prototypic pressures and temperatures
- To simulate CMT operability

- To simulate the operability of the CMT level instrumentation
- To obtain data to support the development and verification of computer models to be used in safety analyses and licensing of the **AP600** plant design.

The CMT test facility consisted of a CMT tank, a steam/water reservoir, instrumentation, and associated steam supply inlet and water discharge piping and valves (Figure B.1-4). A layout comparison between the **AP600** plant CMT and RCS, and the CMT test tank and steam/water reservoir is provided in Figure B.1-5. The CMT used in the test was a carbon steel pressure vessel about 2 ft in diameter and 10 ft in overall length. The tank was mounted vertically and elevated so that the height between the bottom of the tank and the steam/water reservoir was equivalent to the initial head for gravity draining available in the plant. The CMT steam supply line from the steam water reservoir to the CMT simulated the cold leg to the CMT balance line. During testing, only one of the two steam lines was open. Steam line 1 had higher resistance than steam line 2 and connected to the top of the steam/water reservoir. Steam line 2 projected into the steam water reservoir and was heat-traced to better simulate the cold-leg balance line. The steam water reservoir was used to provide a source of steam to the CMT and to collect the water discharged from the CMT. Thus, it acted as a simulated RCS for the test facility.

The CMT test was designed to accommodate a device used to reduce steam jetting directly into the tank. A steam distributor (consisting of a short pipe with a series of holes in the cylindrical section of the pipe and a capped end, attached to a flange) was inserted into the inlet piping to test the effectiveness of the device during the hot pre-operational tests.

The performance of an instrument that may have the characteristics for the desired plant level instrumentation was obtained for this CMT test program. To test the operation and performance of the CMT level instrumentation which may be used in the actual plant, four pairs of resistance temperature detectors, each pair consisting of one heated resistance temperature detector and one unheated, were located at different elevations on their test tank. The output signals from the four resistance temperature detector pairs were recorded during each matrix test. The data was analyzed by the instrumentation engineers and the performance of the instrument characterized and evaluated at the conclusion of the test program to determine their overall performance and establish design criteria and specifications for the actual plant level instrumentation. The CMT test level measurement system data will be analyzed to assess the behavior of the CMT differential pressure cells and the response of the CMT level device to a wide range of thermodynamic conditions.

Technical justification that the data from the CMT test size and configuration in this and the SPES-2 and OSU tests can be extrapolated to the plant CMT conditions via analysis, particularly with regards to two- and three-dimensional effects, is provided in the CMT scaling report. These tests capture the thermal-hydraulic phenomena that a full-sized CMT would display.

Test Matrix/Results

Shakedown testing was used to establish system volumes, line resistances, valve positions required to establish specific steam injection, and CMT draindown rates. The matrix tests are provided in Table B.1-2.

The objectives of the CMT matrix tests were:

- To simulate CMT conditions and measure the rate of steam condensation on the CMT walls and water surface versus steam pressure and water-drain rate
- To obtain detailed measurements of CMT through-wall temperature profiles, CMT liquid inventory temperature profiles, and condensate drain rates versus steam pressure
- To simulate stable behavior of the CMT water level as the cold water drains and is replaced by steam over a wide range of drain rates and piping resistances bounding the prototypic design
- To evaluate the operation of CMT level instrumentation used to actuate the ADS at typical CMT conditions

During CMT hot pre-operational testing, the model CMT diffuser was plastically deformed. Through examination and analysis of this CMT diffuser, Westinghouse determined the root cause. During preoperational testing of high-pressure steam injecting into an empty tank, the diffusers were subjected to a high differential pressure in conjection with high temperatures, beyond the system design basis. The diffuser suffered fatigue failure, which is not expected within an **AP600** plant operating life. Other diffusers used during more prototypic tests performed without incident.

The key results and observations are:

- The test tank operated over the full range of pressures, temperatures, and flow rates.
- Sufficient data were obtained for model development and code validation for recirculation and draindown.
- The steam diffuser reduced condensation and limited mixing to about 12 inches below the diffuser, without waterhammer.
- Hydraulics of the test were well predicted by using simple mass and energy equations.
- Narrow range differential pressure level sensors were selected for use in the **AP600** plant based on their ability to accurately measure water levels in the tests.

B.1.6 Low-Pressure Integral Systems Test (OSU)

General Description/Purpose

The low-pressure, 1/4-height integral systems test was conducted at the Corvallis campus of OSU. Scaling studies indicated that a scaled low-pressure test facility could capture the thermal-hydraulic phenomena of interest for the lower pressure behavior of the **AP600** plant.

The OSU test facility is a facility constructed specifically to investigate the **AP600** plant passive system behavior. The test design accurately modeled the detail of the **AP600** plant geometry including the primary system, pipe routings, and layout for the passive safety systems. The primary system consisted of one hot leg and two cold legs with two active pumps and an active steam generator (SG) for each loop, shown in Figure B.1-6. There were two CMTs connected to one primary loop; the pressurizer was connected to the other primary loop, as in the **AP600** plant design. Gas-driven accumulators were connected to the direct vessel injection (DVI) lines. The discharge lines from the CMT and one-of-two IRWST and reactor sump lines were connected to each DVI line. The two independent tiers of ADS-1/2/3 valves were lumped together as a single ADS stage. The two-phase flow from the ADS stages one, two, and three were separated in a swirl-vane separator. The liquid and vapor flows were measured to obtain the total ADS flow rate. The separated flow streams were then recombined and discharged into the IRWST through a sparger. Thus, the mass flow and energy flow from the ADS into the IRWST were preserved.

The time period for the simulation included not only IRWST injection, but long-term containment recirculation operation of the **AP600** plant. The duration of this simulation was from several hours to a half day. The time scale for the OSU test facility was about one-half, i.e., phenomena occur at twice the rate of OSU as in the **AP600** plant.

To model the long-term cooling aspects of the transient, two-phase flow from the break was separated in a swirl-vane separator, and the liquid and vapor portions of the total flow were measured. The liquid fraction of the flow was discharged to the reactor sump, as in the **AP600** plant; the vapor was discharged to the atmosphere; and the equivalent liquid flow was added to the IRWST and reactor sump to simulate condensate return from passive containment. A similar approach was used for the fourth-stage ADS valve on the hot leg. Two-phase flow was separated in a swirl-vane separator; the two streams were measured; the liquid phase was discharged into the reactor sump, the vapor flow was discharged to the atmosphere, and the liquid equivalent was added to the IRWST and LCS. The IRWST and LCS can be pressurized to simulate containment pressurization following a postulated LOCA.

A multi-tube PRHR HX is located in the IRWST. The HX uses the same C-tube design as the **AP600** plant and has two instrumented tubes to obtain wall heat fluxes during tests. There are primary fluid thermocouples, wall thermocouples, and differential pressure drop measurements to determine when the HX begins to drain. The IRWST is also instrumented with strings of fluid thermocouples to determine the degree of mixing in the tank and assess the temperature of the coolant delivered to the test vessel.

The reactor vessel for the OSU tests included a 3-ft heated core simulator consisting of 48 1-inch diameter heater rods. The heater rods had a top-skewed power shape. There were wall thermocouples swaged inside the heater rods to measure the heater rod wall temperature. There were also five thermocouple rods in the heater rod bundle, including fluid thermocouples, to measure the axial coolant temperature distribution. The scaled flow area in the core and flow area in the test vessel upper plenum were preserved. There were simulated reactor internals in the upper plenum to preserve the flow area and the correctly scaled fluid volume. The reactor vessel included an annular downcomer into which the four cold legs and the DVI lines were connected. The hot legs penetrated the reactor annulus and connected with the loops. The **AP600** reactor vessel neutron reflector was simulated using a ceramic liner to reduce the metal heat release to the coolant.

There was about 1.5 E09 J/hr (640 kW) of electrical power available at the OSU test site, which corresponds to a decay heat of 2 percent of full power in the **AP600** plant.

Test Matrix/Results

The OSU experiments examined the passive safety system response for the SBLOCA transition into long-term cooling. A range of small break loss-of-coolant accidents (SBLOCAs) was simulated at different locations on the primary system, such as the cold leg, hot leg, CMT cold-leg pressure balance line, and DVI line. The break orientation (top or bottom of the cold leg) was also studied. Different single failure cases were examined to confirm that the worst situation was used in the **AP600** Plant Standard Safety Analysis Report (SSAR) analysis. Selected tests continued into the long-term cooling, post-accident mode in which passive SI was from the reactor sump as well as the IRWST. A larger-break, post-accident, long-term cooling situation was also simulated. A summary of the test matrix is provided in Table B.1-3.

A specific test was performed at the OSU test facility to examine the effects of a higher backpressure on an SBLOCA transient. A sensitivity study was also performed on the effects of containment backpressure, verifying the test assumptions.

The OSU test data was analyzed to determine the long-term cooling behavior of the system. The calculated mass and energy balances from the OSU test facility will be used to determine these effects. If needed, a simple transport model, using the OSU mass balance data as a method of verification, will be written to track the boron distribution. The key results and observations for the OSU test are:

- The core remained covered for all design basis transients although there were oscillations during long-term recirculation operations.
- All passive systems functioned as expected, with no adverse consequences, including CMT recirculation and draindown, PRHR HX heat removal, ADS depressurization, accumulator injection, IRWST gravity draining, and stable long-term sump injection.
- The CMTs refilled due to condensation effects during long-term recirculation.
- Minor steam condensation events occurred in the upper downcomer region.
- Thermal stratification occurred in both the hot and cold legs.

B.1.7 Low Pressure, Integral Systems Test (OSU-NRC)

The NRC conducted additional testing at the OSU test facility. Some small changes were made to the facility with respect to the ADS-1/2/3 flow capacity to improve scaling at low pressure and some instrumentation was improved. The objective of the tests were to provide the NRC confirmatory data in support of licensing the **AP600** plant. Tests performed included multiple failure scenarios that would severely challenge the passive safety systems capabilities and demonstrated the robustness in the **AP600** plant design. Table B.14 provides the OSU-NRC test matrix. Westinghouse did not use this test data in its **AP600** plant design or licensing activities.

B.1.8 High-Pressure, Integral Systems Test (SPES-2)

General Description/Purpose

A full-pressure, full-height integral systems test was performed to provide a simulation of the passive core cooling system (PXS) system integrated performance. The existing SPES test facility was configured as a full-height, full-pressure integral test with **AP600** plant features, including two loops with one hot leg and two cold legs per loop, two CMTs, two accumulators, a PRHR HX, an IRWST, and an ADS. The facility included a scaled reactor vessel, SGs, pressurizer, and RCPs. Water was the working fluid, and core power was simulated with electric heater rods.

The test facility was designed to be capable of performing tests representative of a SBLOCA, steam generator tube rupture (SGTR), and steam line break (SLB) transients. The design certification analysis was compared to the test results.

The facility simulated the following:

- Primary circuit
- Secondary circuit up to the main steam line isolation valve
- All passive safety systems – CMT, IRWST, PRHR HX, ADS
- Nonsafety NSSS systems – chemical and volume control system (CVS), normal residual heat removal system (RNS), and startup feedwater system (SEWS)

A scaling, design, and verification analysis has been made to delineate the specific design features to be incorporated and modifications to be made to the SPES-1 facility to simulate the **AP600** plant design.

The following general criteria have been applied to the design of the SPES-2 test facility:

- Conservation of thermodynamic conditions (pressure and temperature)
- Power over volume ratio conservation in each component
- Power over mass flow rate conservation
- Fluid transit time preservation
- Heat flux conservation in heat transfer components (core and SG)
- Elevations maintained in lines and components
- Preservation of Froude number in the primary circuit loop piping (hot and cold legs) in order to preserve the slug to stratified flow pattern transition in horizontal piping

The SPES-2 facility consisted of a full simulation of the **AP600** plant primary and passive core cooling systems. The stainless steel test facility used a 97-rod heated rod bundle with a uniform axial power shape and skin heating of the heater rods. The tests were initiated from scaled, full power conditions. There were 59 heater rod thermocouples distributed over 10 elevations with most located at the top of the bundle to detect the possibility of bundle uncovery. The heater rods were single-ended, connected to a ground bus at the top of the bundle at the upper core plate elevation. All but two rods were designed to have the same power; two heater rods were "hot" rods that had 19 percent higher power.

The primary system, shown in Figure B.1-7, included two loops each with two cold legs, one hot leg, an SG, and a single RCP. The cold leg for each loop was divided downstream of the simulated RCP into two separate cold legs, each of which connected into an annular downcomer. The pumps delivered the scaled primary flow, and the heater rod bundle produced the scaled full-power level so that the **AP600** plant steady-state temperature distribution was simulated. The SGs had a secondary side cooling system that removed heat from the primary loop during simulated full-power operation. Startup feedwater and power-operated relief valve heat removal was provided following a simulated plant trip.

The upper portion of the simulated reactor vessel included an annular downcomer region, where the hot and cold legs as well as the SI lines were connected as shown in Figure B.1-8. The annular downcomer was connected to a pipe downcomer below the DVI lines; the pipe downcomer then connected to the vessel lower plenum. In this fashion, the four cold-leg/two hot-leg characteristics of **AP600** plant were preserved, along with the downcomer injection. There were turning devices to direct the safety injection (SI) flow down in the annular downcomer as in the **AP600** plant.

A full-height single PRHR HX, constructed in a C-tube design, was located in a simulated IRWST and maintained at atmospheric pressure. The line pressure drop and elevations were preserved, and the heat transfer area was scaled so that the natural circulation behavior of the **AP600** plant PRHR HX was simulated.

The design of the CMTs was developed so that the CMT metal mass was scaled to the **AP600** plant CMT. The CMT design used a thin-walled vessel inside a thicker pressure vessel, with the space between the two vessels pressurized to about 70 bar. In this manner, the amount of steam that condensed on the CMT walls during draindown was preserved. Since the CMTs were full- height and operated at full pressure, the metal mass-to-volume of a single pressure vessel would have been excessive, resulting in very large wall steam condensation effects.

The SPES-2 ADS combined the two sets of **AP600** plant ADS piping off the pressurizer into a single set with the first-, second-, and third-stage valves. An orifice in series with each ADS isolation valve was used to achieve the proper scaled flow area. The three ADS valves shared a common discharge line to a condenser and a collection tank that used load cells to measure the mass accumulation. A similar measuring arrangement was also used for the two ADS fourth-stage lines, which were located on the hot legs of the primary system. The SPES-2 tests simulated the **AP600** plant transients up to the time of IRWST injection at low pressure.

Small breaks were simulated using a spool piece that contained a break orifice and quick- opening valve. The break discharge was also condensed and measured by collecting the flow into a catch-tank.

The SPES-2 facility instrumentation was developed to provide transient mass balances on the test facility. There were about 500 channels of instrumentation that monitored the facility, component pressure, temperature, density, and mass inventory. Flows into the simulated reactor system, such as CMT discharge flow, accumulator flow, and IRWST flow, were measured using venturi flow meters. Flows out of the test facility, such as break flow and ADS flow, were measured with a turbine meter and condenser/collection tank. The use of condensers allowed accurate integrated mass versus time measurements of the two-phase ADS and break-flow streams. The use of collection tanks following the condensers provided redundancy for the critical measurements of the mass leaving the test system. Differential pressure measurements were arranged as level measurements on all vertical components to measure the rate of mass change in the component. There were also differential pressure measurements between components to measure the frictional pressure drop, both for single- and two-phase flow. The CMTs were instrumented with wall and fluid thermocouples to measure the CMT condensation and heat-up during their operation. The PRHR HX was also instrumented with wall and fluid thermocouples so that the tube wall heat flux could be calculated from the data. There were thermocouples in the simulated IRWST to measure the fluid temperature distribution and assess the amount of mixing that occurred. Rod bundle power was measured accurately to obtain rod heat flux and total power input to the test facility.

Test Matrix/Results

The overall objectives of the **AP600** plant SPES-2 integral system test were:

- To simulate the **AP600** plant thermal-hydraulic phenomena and behavior of the passive safety systems following specified SBLOCAs, steam generator tube rupture (SGTRs), and SLBs.
- To obtain detailed experimental results for verification of safety analysis computer codes.

The SPES-2 test matrix (Table Bd-5) examined the **AP600** plant passive safety system response for a range of SBLOCAs at different locations on the primary system, SGTRs with passive and active safety systems, and a main steam line break (MSLB) transient. The SPES-2 final test report was issued in April 1995.

Key results and observations for the SPES-2 test are:

- The core remained covered following all simulated events, included a DEG DVI line break with only passive safety systems operating.
- There was no CMT draindown; therefore, no ADS actuation occurred following the single SGTR with no operator action or nonsafety systems operating.
- Nonsafety system operation had no adverse interaction with passive system operation, and actually added margin to the plant safety response.
- All passive safety systems functioned as expected with no adverse occurrences including CMT recirculation and draindown, PRHR HX heat removal, ADS depressurization, and IRWST gravity draining.

- Timely RNS operation following a LOCA can limit CMT draindown and prevent ADS fourth-stage actuation.

B.1.9 High-Pressure, Integral Systems Test (ROSA-AP600)

A full-pressure, full-height integral systems test was performed to provide a simulation of the PXS system integrated performance. The existing ROSA test facility was modified to simulate an **AP600** plant, providing two loops including the reactor vessel, SGs, RCPs and pressurizer. The passive safety features connected to the RCS were simulated. Nonsafety systems providing makeup to the reactor and the SGs were also simulated. Water was the working fluid and the core was simulated with electrical heater rods. ROSA is a large scale facility, with about 1/30 of the **AP600** plant primary side volume.

The test facility was designed to be capable of performing tests representative of a SBLOCA, SGTR, and SLB transients. The design certification analysis was compared to the test results.

The facility simulated the following:

- Primary circuit with one hot leg, cold leg, SG, RCP per loop and a pressurizer

- Secondary circuit up to the main steam line isolation valve

- Passive safety systems connected to the RCS – CMTs, accumulators, IRWST, PRHR and ADS

- Nonsafety NSSS systems – chemical and volume control system (CVS), normal residual heat removal system (RNS), and startup feedwater system (SFWS)

The ROSA/**AP600** facility consisted of a full simulation of the **AP600** plant primary and passive core cooling systems. The stainless steel test facility used a heated rod bundle with an axial power shape similar to the **AP600** plant shape. The heater rod bundle was capable of producing about 163 percent of the scaled **AP600** plant power. The tests were initiated from scaled, full power conditions.

The primary system, shown in Figure B.1-9, included two loops each with one cold leg, one hot leg, an SG, and a single RCP. Figure B.1-10 (sheets 1 and 2) show the elevations of the ROSA/**AP600** facility. The RCPs have a shallow loop seal with a bypass to further reduce the influence of the loop seals. The cold legs and hot legs connect to the reactor vessel (RV) at the same elevation instead of the cold leg being slightly higher as in the **AP600** plant. Studies indicate that the facility adequately simulates the **AP600** plant.

A new pressurizer was added to ROSA/**AP600** and was scaled to represent the **AP600** plant pressurizer. The internal height of the pressurizer was preserved, and the internal flow area was scaled. Flow velocities within the pressurizer are therefore equivalent; hence, entrainment/de-entrainment phenomena are preserved. The pressurizer surge line was scaled to represent the **AP600** plant surge line resistance and to represent the flooding of the line as closely as possible. The geometry of the connection to the hot leg, however, is not similar to the **AP600** plant. In the **AP600**, the surge line connects to the top of an inclined pipe, while the ROSA/**AP600** plant surge line connects to the top of a horizontal pipe.

The **AP600** passive safety features connected to the RCS were simulated in ROSA/**AP600**. Typically, the components were designed to preserve the volume scaling ratio of 1:30, to preserve the **AP600** plant elevations, and to maintain similar hydraulic resistance in pipes.

A full-height single PRHR HX, constructed in a C-tube design, was located in a simulated IRWST and maintained at atmospheric pressure. The tube bundle was full-height; each tube was full diameter. The number of tubes was reduced to scale the heat transfer area. The line pressure drop and elevations were preserved so that the natural circulation behavior of the **AP600** plant PRHR HX was simulated.

The internal volume of the CMTs has been scaled 1:30, and the internal height was preserved. As a result the tank shapes were not preserved, with the **AP600** plant CMTs being nearly spherical, while the Large-Scale Test Facility (LSTF) CMTs are more cylindrical. The ROSA/**AP600** CMTs each have a sparger at the top of the tank, which disperses flow from the balance line, like the **AP600** plant CMTs. Insulation was added to the CMTs to reduce the scaling distortion caused by excessive heat loss.

Because ROSA/**AP600** only has one cold leg per loop, the CMTs balance lines are normally connected to the same cold leg. This arrangement is referred to as the "common mode." Asymmetrical CMT behavior is limited with this arrangement however, so another configuration is provided that allows the balance lines to be connected to separate cold legs. This arrangement is referred to as the "separate mode." In this mode, the balance lines for one CMT is connected to the cold leg in the other loop.

The ROSA/**AP600** plant ADS combined the two sets of **AP600** plant ADS piping off the pressurizer into a single set with the first-, second-, and third-stage valves. An orifice in series with each ADS isolation valve was used to achieve the proper scaled flow area. The three ADS valves shared a common discharge line to an IRWST as in the **AP600** plant. The **AP600** plant stage 4 of the ADS has 4 valves, two per hot leg. ROSA/**AP600** simulated this arrangement with one ADS-4 valve per hot leg. An orifice in series with these ADS-4 valves allowed simulation of one or two ADS-4 valves opening for each hot leg. The ADS-4 lines are routed to catch tanks that are vented to the atmosphere.

The IRWST volume is about 34 percent underscaled. This is the result of design changes to the **AP600** plant that occurred just after the IRWST had been installed. Consequently, because there is less liquid mass in the ROSA/**AP600** IRWST, the liquid temperature will increase faster than that of the **AP600** plant as the PRHR heat exchanger and the discharge from ADS-1/2/3 transfers energy to the liquid. The decrease in the static head that results from the discharge of a unit of liquid mass from the tank also became somewhat larger than the ideal. One test was conducted to evaluate the effect of the undersizing of the IRWST.

Small breaks were simulated using a spool piece that contained a break orifice and quick-opening valve. The break discharge was also condensed and measured by collecting the flow into a break flow storage tank. It is possible to condense break flow from two break locations, consequently double ended breaks can be simulated.

Prior to the ROSA/**AP600** program, the facility already had in place the hardware needed to measure and control processes throughout the facility. Instrumentation was added to accommodate the passive safety features and other simulated systems of the **AP600** plant. Data from the instruments is recorded on magnetic disks in digital format. Process and instrumentation displays are located in the control room, as are alarms, actuators, controls, etc. Most of the facility functions that are required to conduct a test can be initiated from the control room.

Test Matrix/Results

The overall objective of the ROSA/**AP600** integral system test was to provide data to allow the NRC to confirm the performance of the **AP600** plant during small LOCAs, SGTRs, steam line breaks and station black outs.

The test matrix for the ROSA/**AP600** testing is contained in Table B.1-6.

Table B.1-1 ADS Phase B Test Specification ADS Performance Test Matrix

Facility Configuration	Test Run No.	ADS Simulation	Supply Tank Pressure
Saturated water blowdowns from bottom of supply tank, no orifices in spool pieces, cold quench tank water	310	Stages 1, 2, and 3 open	High
"	311	Stages 1, 2, and 3 open	Intermediate
"	312	Stages 1, 2, and 3 open	Low
"	330	Stages 1 and 2 open	High
"	331	Stages 1 and 2 open	Intermediate
"	340	Stage 2 open (inadvertent opening)	High
Saturated water blowdowns from bottom of supply tank, orifices installed in spool pieces	250	Stage 2 open (inadvertent opening)	Intermediate
"	210	Stage 1 open	High
"	211	Stage 1 open	High
"	212	Stage 1 open	High
"	220	Stages 1 and 2 open	Intermediate
"	221	Stages 1 and 2 open	High
"	230	Stages 1 and 3 open	Intermediate
"	231	Stages 1 and 3 open	High
"	240	Stages 1, 2, and 3 open	Intermediate

Table B.1-1 ADS Phase B Test Specification ADS Performance Test Matrix (cont.)

Facility Configuration	Test Run No.	ADS Simulation	Supply Tank Pressure
Saturated water blowdowns from bottom of supply tank, orifices installed in spool pieces	241	Stages 1, 2, and 3 open	Low
"	242	Stages 1, 2, and 3 open	Low
Saturated steam blowdowns from top of supply tank, orifices installed in spool pieces	110	Stage 1 open	High
"	120	Stages 1 and 2 open	High
"	130	Stages 1 and 3 open	Intermediate
"	140	Stages 1, 2, and 3 open	High
Saturated water blowdowns from bottom of supply tank, no orifices in spool pieces, quench tank water at 212°F (100°C)	320	Stages 1, 2, and 3 open	High
"	321	Stages 1, 2, and 3 open	Intermediate
"	322	Stages 1, 2, and 3 open	Low
"	350	Stages 1 and 2 open	High
"	351	Stages 1 and 2 open	Intermediate

Table B.1-2 Matrix Tests, CMT Test

Test	Test Type	CMT Drain Rate	Steam Supply Pressure(s)	Comments
101	CMT wall condensation with and without non-condensable gases	CMT drain rate based on steam condensation rate and drain capability	10	CMT initially contains no water and is evacuated
102			135	
103			685	
104			1085	
105			2235	
106			10	CMT pressure with air (or N_2) to .236, 1.13, and 2.13 psia, respectively
107				

Table B.1-2 Matrix Tests, CMT Test (cont.)

Test	Test Type	CMT Drain Rate	Steam Supply Pressure(s)	Comments
108				
301	CMT draindown at constant pressure	6	10	Low resistance steam supply line 2 utilized; drain rate controlled by discharge line resistance
302		6	135	
303		6	1085	
304		11	10	
305		11	135	
306		11	1085	
307		16	10	
308		16	135	
309		16	1085	
310		Max	10	
311		Max	135	
312		Max	1085	
317		6	45	
318		11	45	
319		16	45	
320		6	685	
321		11	685	
322		16	685	
323		Max	685	
401	CMT draindown during depressurization	6/16 gpm	1085, depressurization to 20	Steam line 2 used
402				
403		Rate controlled by supply line 1 resistance	2235, depressurization to 20	Resistance set for 6/16 gpm drain rate
404				
501	Natural circulation followed by draindown and depressurization	Discharge line resistance set for 6/16 gpm drain rate	1085, depressurization to 20	Natural circulation until 1/5 of CMT heated
502				
503				Natural circulation until 1/2 of CMT heated
504				
505				Natural circulation until

Table B.1-2 Matrix Tests, CMT Test (cont.)

Test	Test Type	CMT Drain Rate	Steam Supply Pressure(s)	Comments
506				CMT fully heated
507		Drain rate to be chosen based on results of tests 501-506	1835, depressurization to 20	1/5 CMT heated
508				1/2 CMT heated
509				CMT fully heated

Table B.1-3 Matrix Tests, Low-Pressure, 1/4-Height Integral Systems Test (OSU)

Test Category	Test Number	Description
Cold pre-operational tests	C01	CMT gravity drain
	C02	Accumulator tank drain
	C03	IRWST drain
	C04	CVS pump flow vs. pressure
	C05	RNS pump flow vs. pressure
	C06	SG feed flow vs. pressure
	C07	ADS 1-3 line flow test
	C08	ADS-4 line flow test
	C09	RNS injection flow test
	OSU-F-02	Reactor coolant forced circulation loop flow test
Hot pre-operational tests	HS01	Reactor power calorimetric
		Ambient heat loss determination
		PRHR loss determination
		SG performance test
		RCS heatup/cooldown test
	HS02	600-kW power level testing
		Reactor coolant natural circulation loop flow test
	HS03	Verify post-accident decay power
		Verify performance of ADS 2, 3, and 4
		Determine performance of IRWST and sump injection

Table B.1-3 Matrix Tests, Low-Pressure, 1/4-Height Integral Systems Test (OSU) (cont.)

Test Number	Description
SB01	2-inch cold-leg break, bottom of pipe, loop A with continuation into long-term cooling mode, fail one in ADS-4 stage
SB02	2-inch cold-leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB03	2-inch cold-leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB04	2-inch cold-leg break, bottom of pipe, loop A with nonsafety systems on, fail one in ADS-4 stage
SB05	1-inch cold-leg break, bottom of pipe, loop A, with continuation into LTC, fail one in ADS-4 stage
SB06	4-inch cold-leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB07	2-inch cold-leg small break, bottom of pipe, loop A, fail train of ADS 4-1
SB09	2-inch break on cold-leg balance line, horizontal loop, loop A, fail one in ADS-4 stage
SB10	DEG break of cold-leg balance line, horizontal loop, loop A with continuation into LTC, fail one in ADS-4 stage
SB11	DEG break of DVI line with continuation into LTC, fail one in ADS-4 stage
SB12	DEG break of DVI line, continuation into LTC, loss of one train of ADS-1 and ADS-3
SB13	2-inch break of DVI line, continuation into LTC, fail one in ADS-4 stage
SB14	Inadvertent ADS stage 1 open, with continuation into LTC, fail one in ADS-4 stage
SB15	2-inch hot-leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB18	2-inch cold-leg break, loop A, fail one in ADS-4 stage
SB19	SB01 with simulated containment backpressure, fail one in ADS-4 stage
SB21	Simulated long-term cooling, fail one in ADS-4 stage
SB23	1/2-inch cold leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB24	1/2-inch cold leg break, bottom of pipe, loop A, with nonsafety systems on, fail one in ADS-4 stage
SB25	Mid-loop operation test

Table B.1-3 Matrix Tests, Low-Pressure, 1/4-Height Integral Systems Test (OSU) (cont.)	
Test Number	**Description**
SB26	PRA multiple failures without PRHR
SB27	Inadvertent ADS-1, fail one in ADS-4 stage
SB28	PRA case DEG DVI line break
SB29	2-inch cold leg break, bottom of pipe, loop A, fail one in ADS-4 stage
SB31	Spurious S signal without ADS, fail one in ADS-4 stage

Table B.1-4 Matrix Tests, Low-Pressure Integral Systems Test, OSU-NRC

Test #	ID #	Simulation	Break (in.)	Loc.	ADS-1 (%)	ADS-2 (%)	ADS-3 (%)	ADS 4-1 (%)	ADS 4-2 (%)
NRC-1	5001	1" CL Break with Failure of ADS 1-3 (ROSA Counterpart)	0.1604	CL3	Failed Shut	Failed Shut	Failed Shut	100	100
NRC-2	5002	Station Blackout	None	NA	100(1)	100(1)	100(1)	50(1)	100(1)
NRC-2	5102	Station Blackout	None	NA	100(1)	100(1)	100(1)	50(1)	100(1)
NRC-3	5003	2" CL Break with Long Term Cooling	0.3208	CL3	100	100	100	50	100
NRC-4	5004	2" CL Break – Flow Oscillation Assessment	0.3208	CL3	100	100	100	50	100
NRC-5	5005	1/2" CL Break	0.053	CL3	100	100	100	50	100
NRC-5	5105	1/2" CL Break	0.053	CL4	100	100	100	50	100
NRC-6	5006	1" CL Break with Full Pressure ADS	0.1063	CL3	50	50	50	100	100
NRC-7	5007	1" CL Break without ACC Nitrogen Injection	0.1063	CL3	100	100	100	100	50
NRC-7	5107	1" CL Break without ACC Nitrogen Injection	0.1063	CL3	100	100	100	100	50
NRC-10	5010	1" CL Break with Failure of 3 of 4 ADS Valves	0.1063	CL3	100	100	100	100	Failed Shut
NRC-11	5011	2" CL Break with Revised ADS 1-3 Flow Area	0.3208	CL3	100	100	100	100	50
NRC-11	5111	2" CL Break with Revised 1-3 Flow Area	0.3208	CD	100	100	100	100	50
NRC-12	5112	2" CL Break	0.3208	CL4	100	100	100	100	50
NRC-14	5014	1" CL Break with Full Pressure ADS and Failure of 1 of 4 ADS-4	0.1063	CL3	50	50	50	50	100
NRC-15	6015	1" CL Break with Full Pressure ADS and Revised ADS Flow Area	0.1063	CD	50(1)	50(1)	50(1)	50(1)	100(1)
NRC-18	6018	2" CL Break with Reactor Pressure Vessel Bypass Holes Plugged	0.3208	CD	100	100	100	100	50
NRC-19	6019	1" CL Break with Reactor Pressure Vessel Bypass Holes Plugged	0.1063	CD	100	100	100	100	50
NRC-20	6020	DEDVI Line Break (W-SB-11 Counterpart)	DEDVI	DVI	100	100	100	50	100

Table B.1-4 Matrix Tests, Low-Pressure Integral Systems Test, OSU-NRC (cont.)

Test #	ID #	Simulation	Break (in.)	Loc.	ADS-1 (%)	ADS-2 (%)	ADS-3 (%)	ADS 4-1 (%)	ADS 4-2 (%)
NRC-21	6021	1" CL Break (ROSA AP-CL-03 and W-SB-5 Counterpart)	0.1063	CL3	100	100	100	50	100
NRC-22	6022	1" CL Break (ROSA AP-CL-03 and W-SB-5 Counterpart)	0.1063	CL3	100	100	100	50	100
NRC-23	6023	Inadvertent ADS with Hot CMTs	None	NA	100	100	100	100	100
NRC-24	6024	Inadvertent ADS with Cold CMTs	None	NA	100	100	100	100	100
NRC-26	7026	1" CL Break with Delayed Core Heatup	0.1063	CL3	Failed Shut	Failed Shut	Failed Shut	100	100
NRC-27	7027	1" Break with Degraded Sump	0.1063	CL3	100	100	100	100	50
NRC-28	7028	DEDVI with Failure of Intact CMT	DEDVI	DVI	Failed Shut	Failed Shut	Failed Shut	100	50
NRC-29	7029	DEDVI with Failure of Intact ACC	DEDVI	DVI	Failed Shut	Failed Shut	Failed Shut	100	50
NRC-31	7031	1" CL Break with High Decay Power and Degraded Sump	0.1063	CL3	100	100	100	100	50
NRC-32	7032	1' CL Break with Failure of PRHR (Top of Cold Leg)	0.1063	CL3	100	100	100	100	50
NRC-35	8035	Mode 5 Cold Shutdown with Loss of RNS Cooling	None	NA	Failed Shut	Failed Shut	100	100	50
100NRC-13 Return to Saturation Oscillation Test Series									
NRC-13	5013	Oscillation Test	0.3208	CL3	Failed Shut	Failed Shut	Failed Shut	50	100
NRC-13	6113	Oscillation Test	0.3208	CL3	Failed Shut	Failed Shut	Failed Shut	50	100
NRC-13	6213	Oscillation Test	0.3208	CL3	Failed Shut	Failed Shut	Failed Shut	50	100

Table B.1-4 Matrix Tests, Low-Pressure Integral Systems Test, OSU-NRC (cont.)

Test #	ID #	Simulation	Break (in.)	Loc.	ADS-1 (%)	ADS-2 (%)	ADS-3 (%)	ADS 4-1 (%)	ADS 4-2 (%)
NRC-25 No Reserve Core Uncovering Test Series									
NRC-25	6025	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	50	Failed Shut
NRC-25	6125	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	50	Failed Shut
NRC-25	6225	200 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	50	Failed Shut
NRC-25	6325	200 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	50	Failed Shut
NRC-25	6425	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	Failed Shut	100
NRC-25	7525	200 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	50	Failed Shut
NRC-25	7625	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	100	Failed Shut
NRC-25	7725	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	100	Failed Shut
NRC-25	7825	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	Failed Shut	50
NRC-25	7925	100 psia ADS-4 Blowdown	None	NA	Failed Shut	Failed Shut	Failed Shut	Failed Shut	50
NRC-34 Nitrogen Transport Test Series									
NRC-34	7034	1" CL Break with Argon-41 Tracer	0.1063	CL3	100	100	100	100	50
NRC-34	7134	1" CL Break with Argon-41 Tracer	0.1063	CL3	100	100	100	100	50
NRC-34	7234	1" CL Break with Argon-41 Tracer	0.1063	CL3	100	100	100	100	50

Note:

1. Based on nominal sizes for ROSA ADS.

Table B.1-5 Matrix Tests, Full-Pressure, Full-Height Integral Systems Test (SPES-2)

Test Category	Test Number	Description
Cold shakedown tests	C-01	Single-phase flow through the pressurizer surge line, four flow rates
	C-02A, B	Single-phase flow through the pressurizer to CMT balance lines, four flow rates per balance line
	C-03A, B	Single-phase flow through the cold leg to CMT balance lines, four flow rates per balance line
	C-04A, B	CMT draindown using cold leg to CMT balance line
	C-05A, B	CMT gravity draindown using pressurizer to CMT balance line
	C-06A, B	SI accumulator blowdown
	C-07A, B	IRWST gravity draindown, three water levels
	C-08	CVS, RNS, and SFWS pump flow rate verification
	C-09	Operation of primary system with two RCPs running
	C-10A, B	Operation of primary system with one RCP running
Hot shakedown test	H-01	Facility heated and heat at five constant temperatures
	H-02	Starting from nominal conditions, power will be shut off and SGs isolated
	H-03	Facility operated at normal full-pressure, temperature, and power
	H-04	Facility transitioned from full power operating conditions to hot shutdown/natural circulation mode of operation
	H-05	Low-pressure safety system actuation using the ADS with CMT draindown and accumulator delivery
	H-06	Full-power, full-pressure safety system actuation initiated by the opening of the first stage of ADS

Table B.1-5 Matrix Tests, Full-Pressure, Full-Height Integral Systems Test (SPES-2) (cont.)

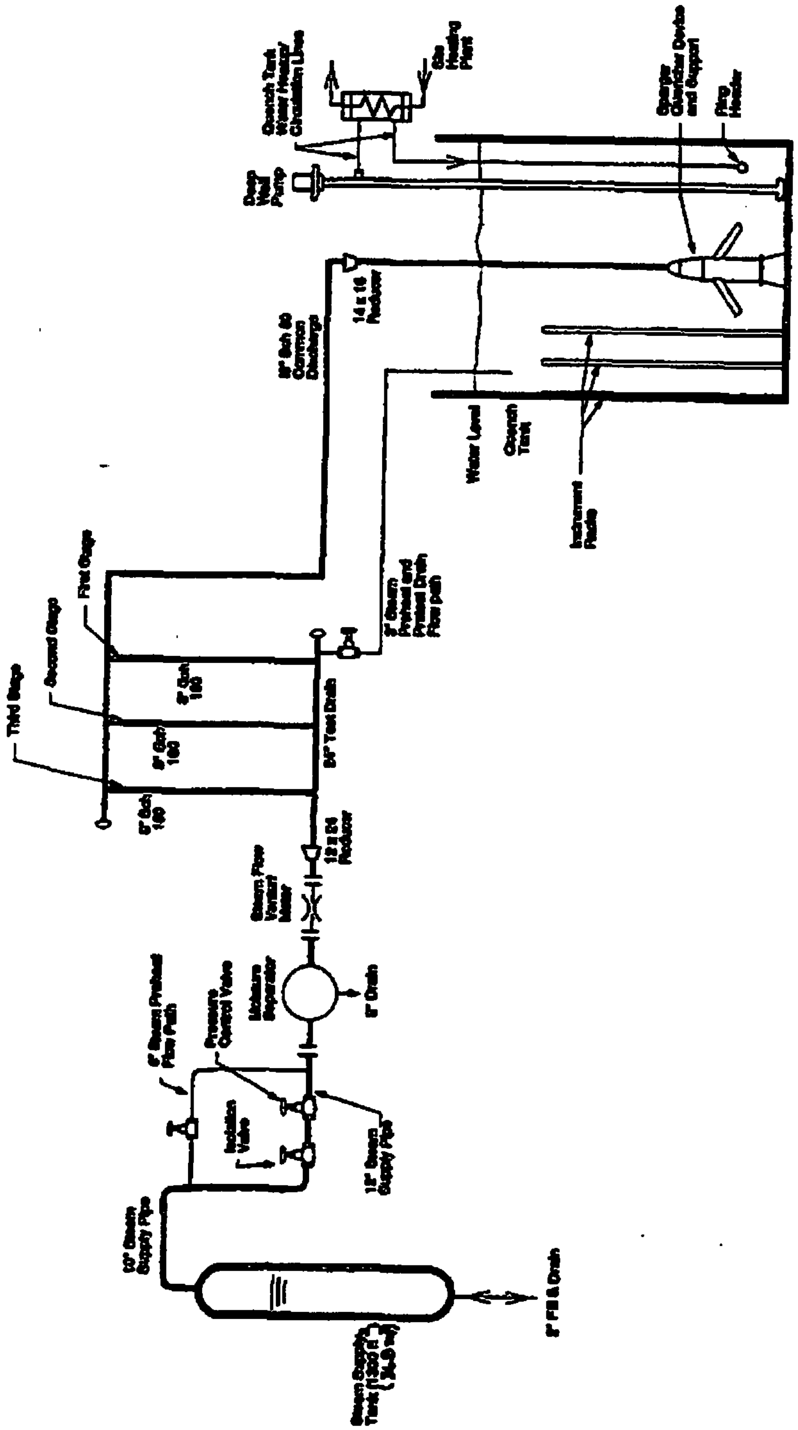
Test Number	Description
3	2-inch cold leg break with nonsafety systems off
1	1-inch cold leg break with nonsafety systems off
4	2-inch cold leg break with nonsafety systems on
5	2-inch DVI line break with nonsafety systems off
6	DEG break of the DVI line with nonsafety systems off
7	2-inch break of cold leg to CMT balance line with nonsafety systems off
8	DEG break of cold leg to CMT balance line with nonsafety systems off
9	Design basis SGTR with nonsafety systems on and operator action to isolate SG
10	Design basis SGTR with nonsafety systems on and no operator action
11	Design basis SGTR with manual ADS actuations
12	Large SLB

Table B.1-6 Matrix Tests, Full-Pressure Integral Systems Test (ROSA-AP600)

No.	Test	Test Description
1	AP-CL-03	1-Inch Bottom-Oriented Cold Leg (CL) SBLOCA(1). SPES configuration & ADS Stages 1, 2, 3 One-Valve Operation.
2	AP-AD-01	Inadvertent Opening of ADS Stage(1). SPES configuration.
3	AP-CL-04	1/2-Inch Bottom-Oriented CL SBLOCA(1). **AP600** plant configuration.
4	AP-PB-01	2-Inch Pressure Balance Line (PBL) SBLOCA(1). SPES configuration.
5	AP-CL-05	1-Inch Bottom-Oriented CL SBLOCA with Failure of ADS Stages 1, 2, & 3. **AP600** plant configuration.
6	AP-PB-02	1-Inch PBL SBLOCA, P-Loop CMT Check Valves Failed Closed, C-Loop Loop Seal Bypass Open. **AP600** plant configuration.
7	AP-DV-01	Direct Vessel Injection (DVI) Line Double-Ended-Guillotine Break (DEGB)(1). **AP600** plant configuration with revised coolant pump coastdown.
8	AP-CL-06	1-Inch Top-Oriented CL SBLOCA(1). SPES configuration & ADS Stages 1, 2, 3 One-Valve Operation.
9	AP-B0-01	Station Blackout(2). **AP600** plant configuration with revised coolant pump coastdown.
10	AP-SG-01	Steam Generator Tube Rupture (SGTR): 1-3/4 Tubes Ruptured(1). **AP600** plant configuration with revised coolant pump coastdown.
11	AP-SL-01	Main Steam Line Break with 5-Tube SGTR(1). **AP600** plant configuration.
12	AP-CL-07	1-Inch Bottom-Oriented CL SBLOCA with Failure of 75 percent of ADS Stage 4 (Only 25 percent of ADS Stage 4 in C-Loop)(3),(4). SPES configuration & ADS Stages 1, 2, 3 One-Valve Operation.
13	AP-CL-08	2-Inch Bottom-Oriented CL SBLOCA(1),(4),(5). **AP600** plant configuration with revised coolant pump coastdown.
14	AP-CL-09	1-Inch Bottom-Oriented CL SBLOCA with Chemical Volume Control System (CVCS) Makeup Pump Injecting Into P-Loop Crossover Leg, 1 Accumulator (P-Loop), No CMTs, 50 percent of ADS, & 1 of 2 IRWST Gravity Drain Lines (P-Loop). **AP600** plant configuration with revised coolant pump coastdown.

Notes:

1. One Stage 4 ADS valve failed in C-Loop.
2. Core power decay curve includes G-Factor henceforth.
3. PRHR heat exchanger bundle reduced from 45 tubes to 21 tubes.
4. Steam separators installed on ADS Stage 4 discharge lines.
5. IRWST Feed & Bleed system used.



B.1-1 ADS Phase A Test Facility

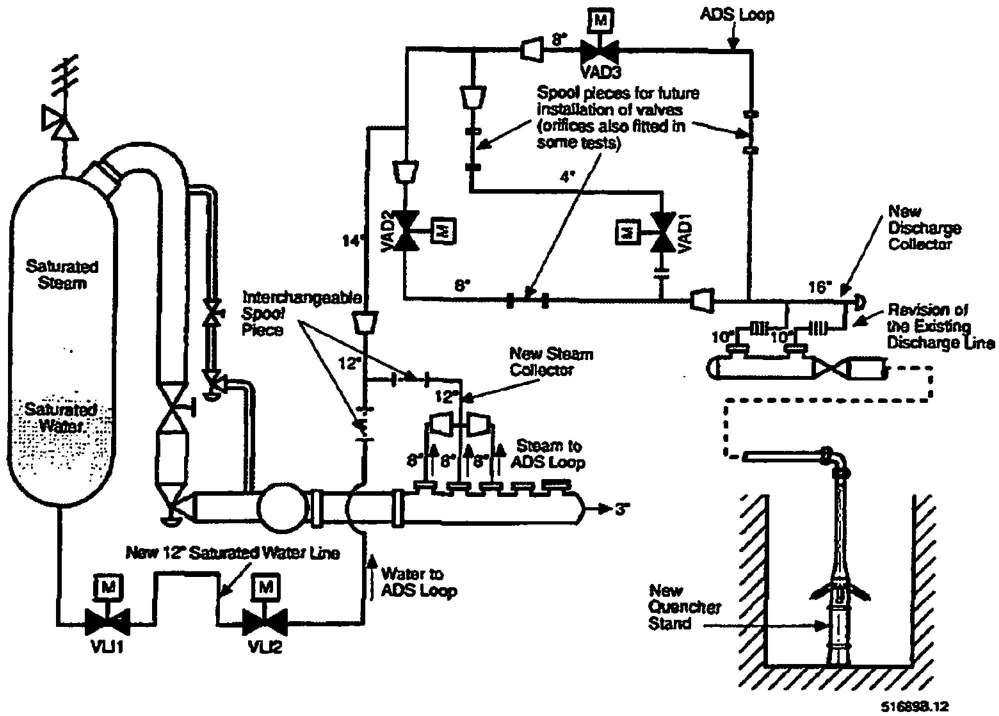


Figure B.1-2 ADS Phase B Test Facility

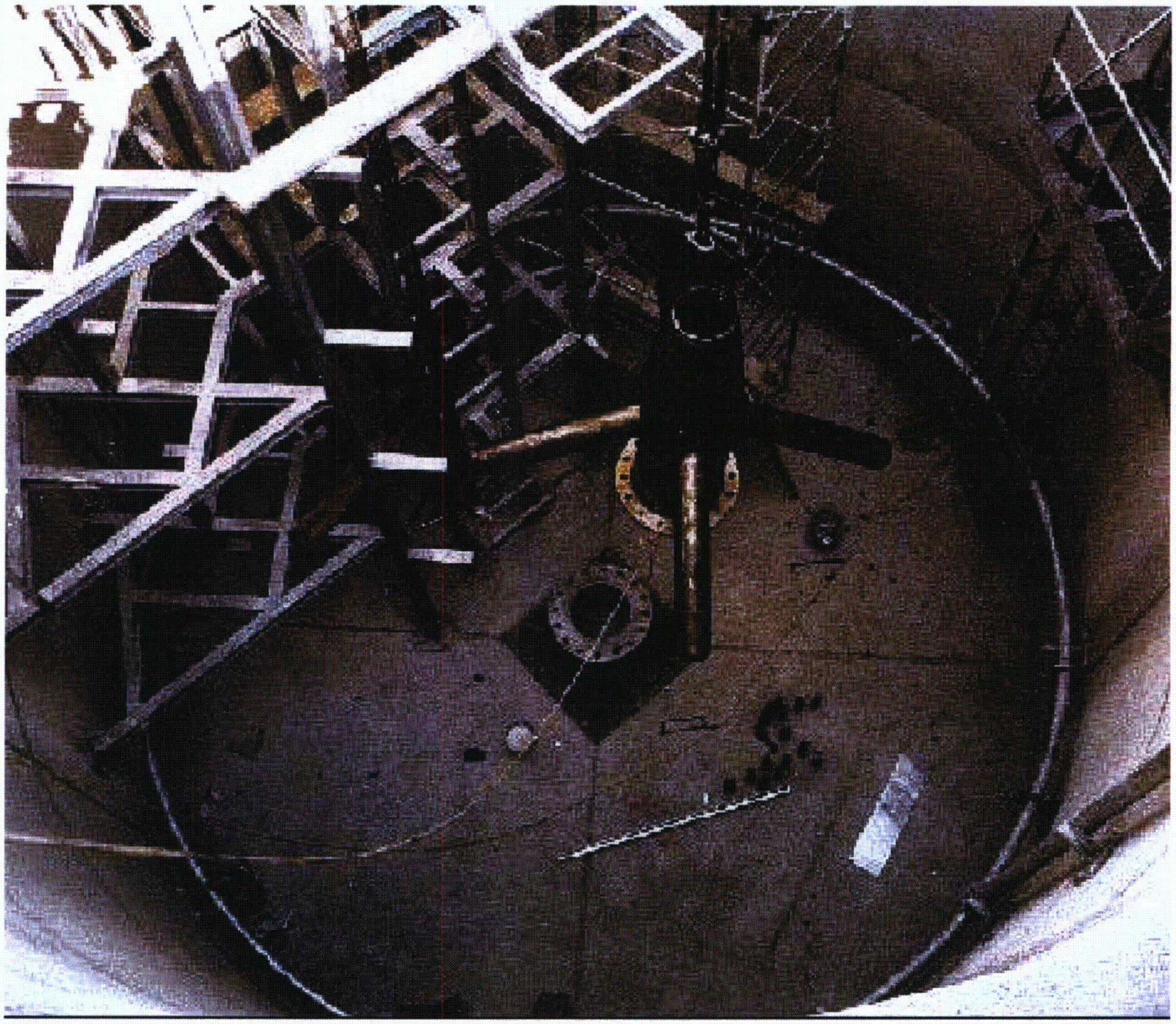


Figure B.1-3 ADS Test Facility – Prototypic Sparger in Quench Tank

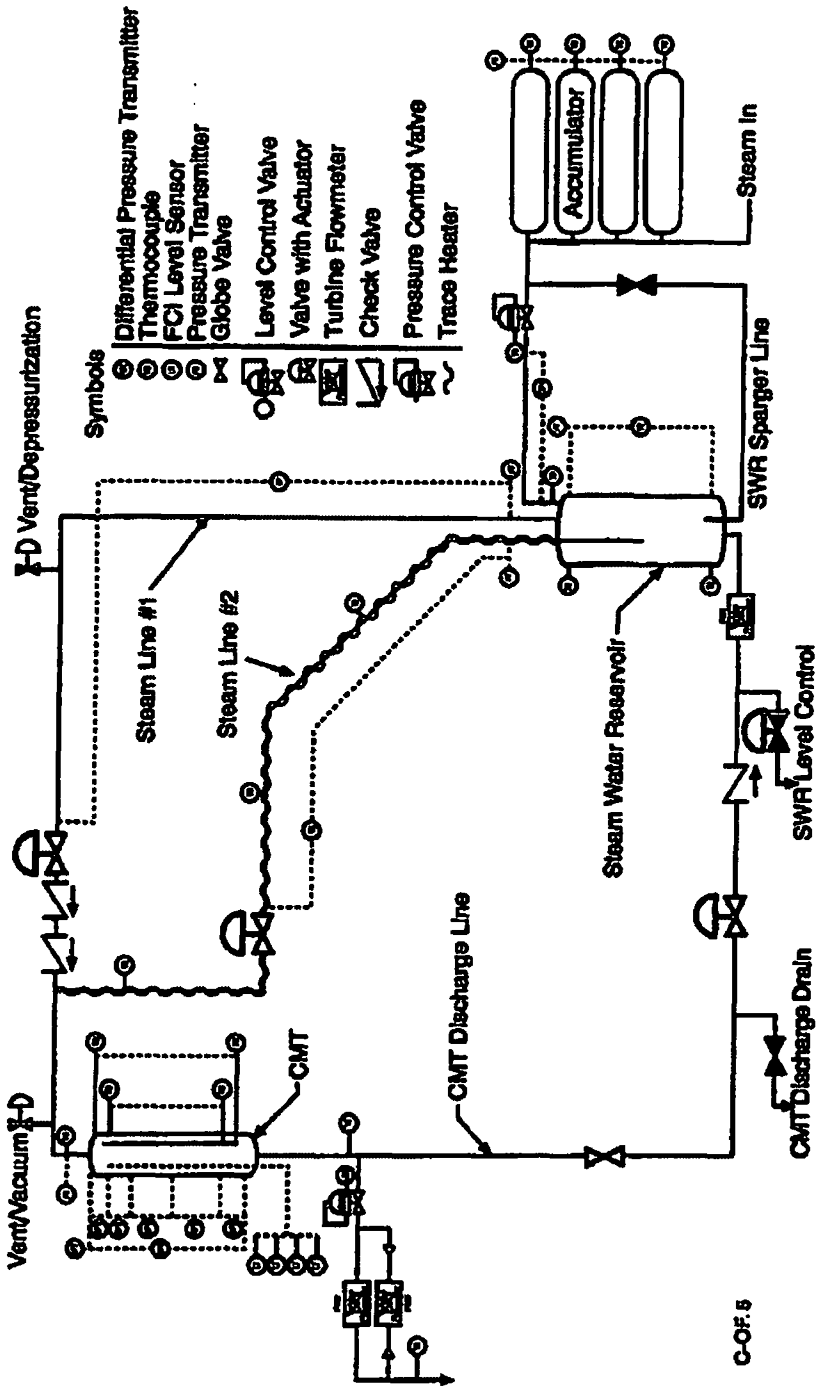


Figure B.1-4 CMT Test Facility Schematic

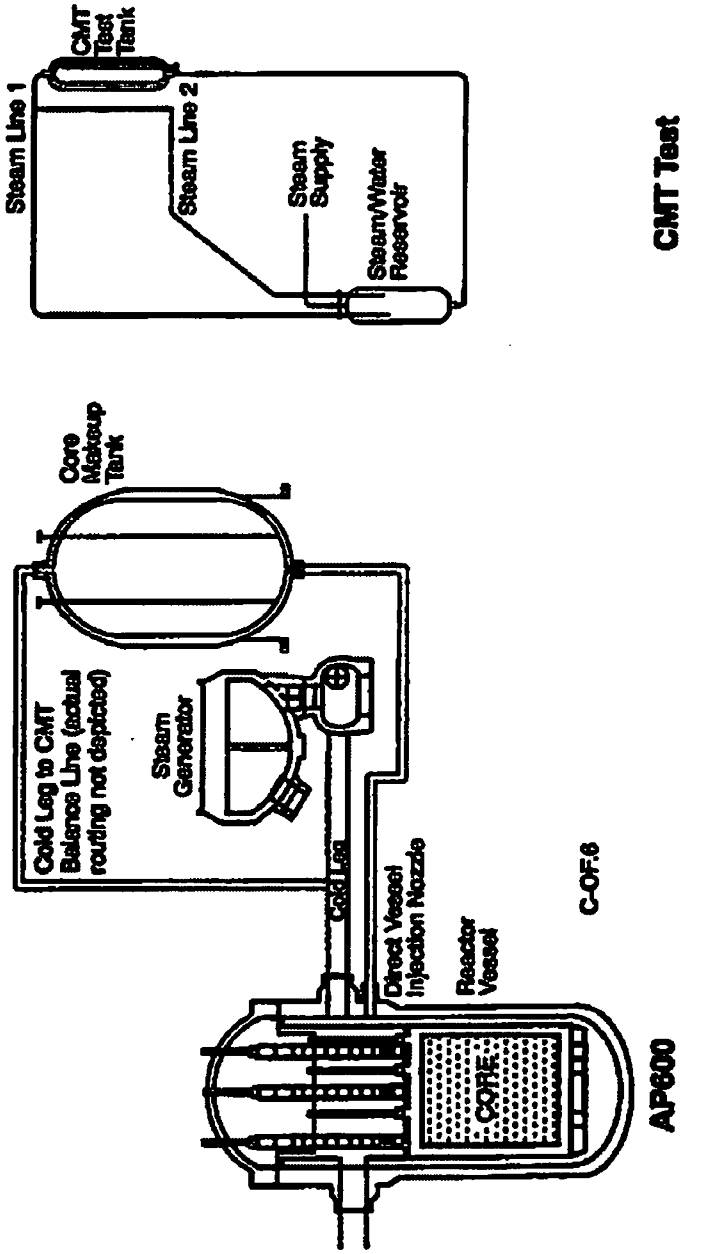
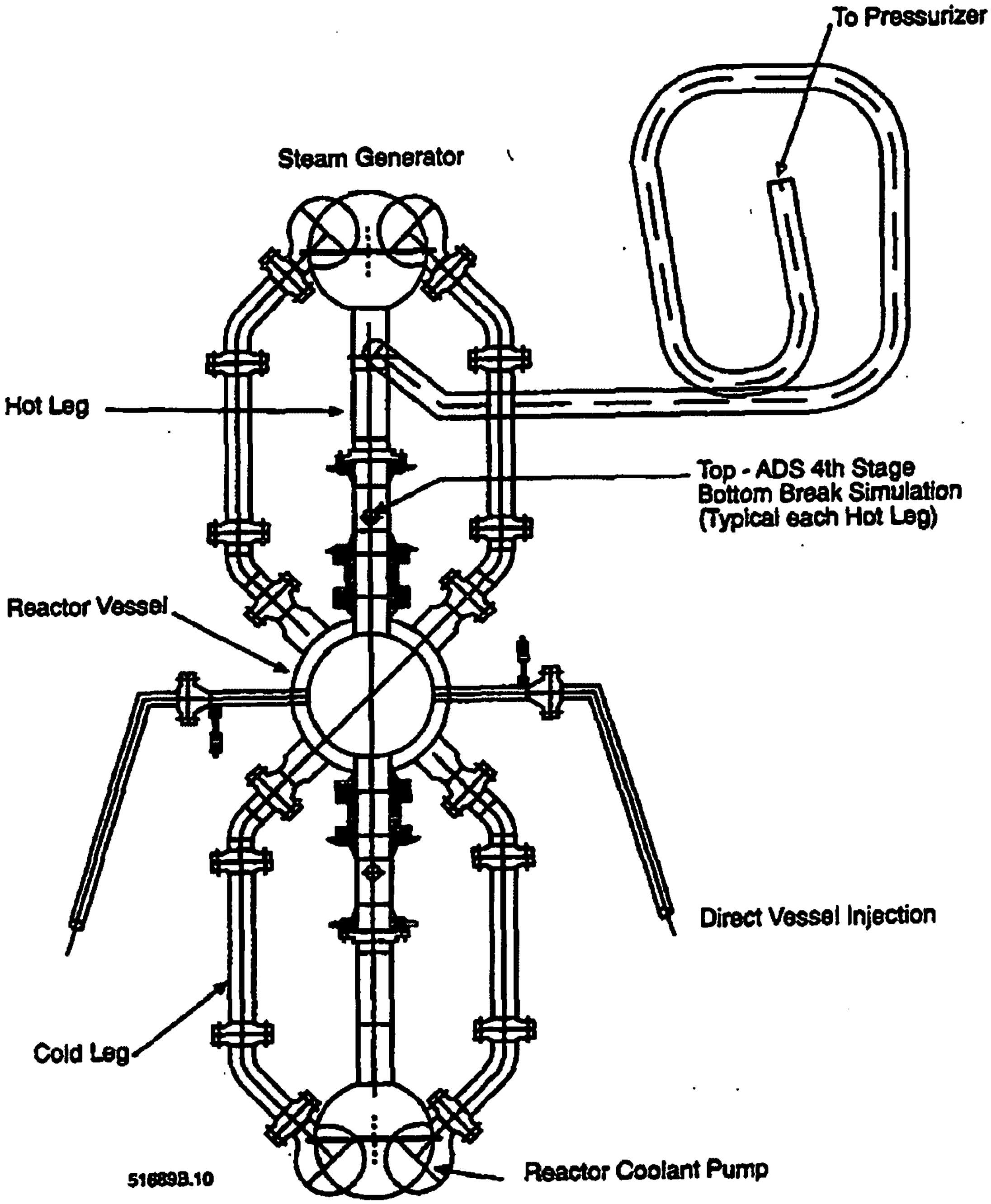
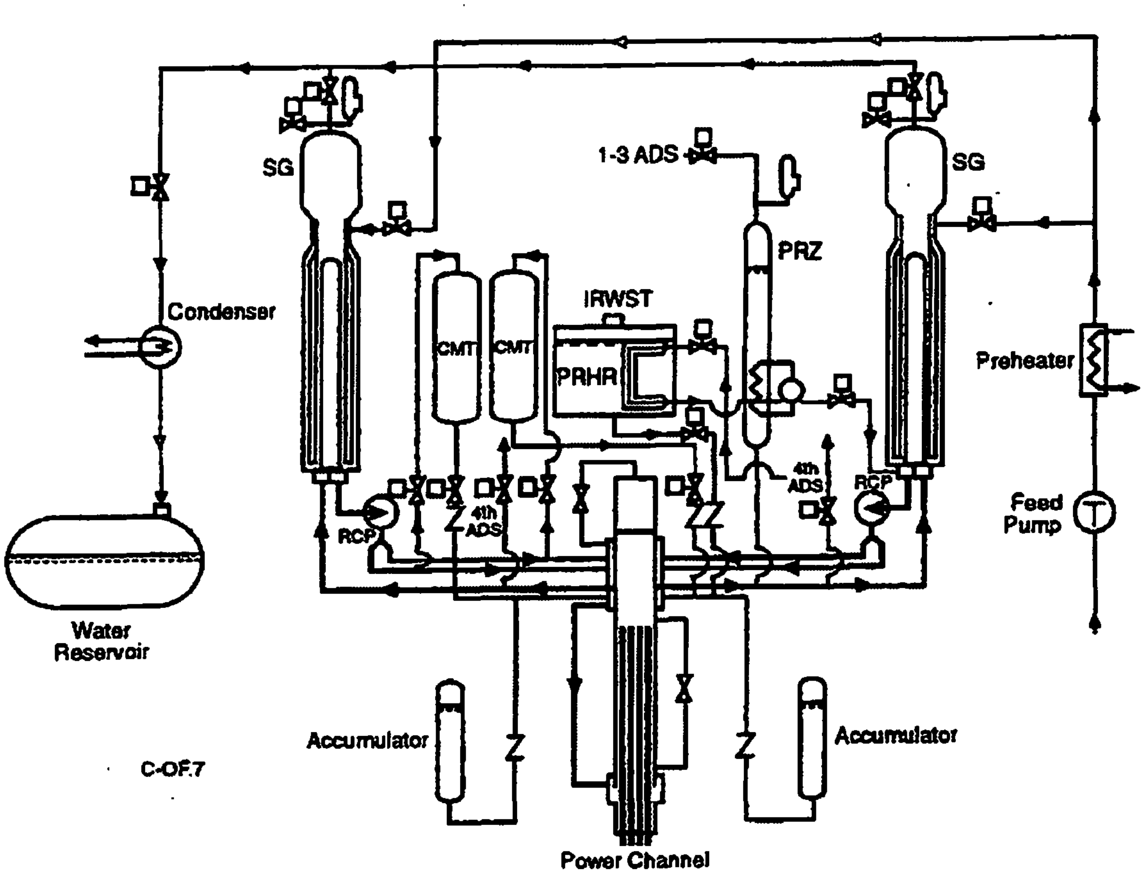


Figure B.1-5 AP600 Plant CMT and RCS Layout and CMT Test Tank and Steam/Water Reservoir



B.1-6 OSU Test Facility Primary System Schematic



B.1-7 SPES-2 Facility Primary System

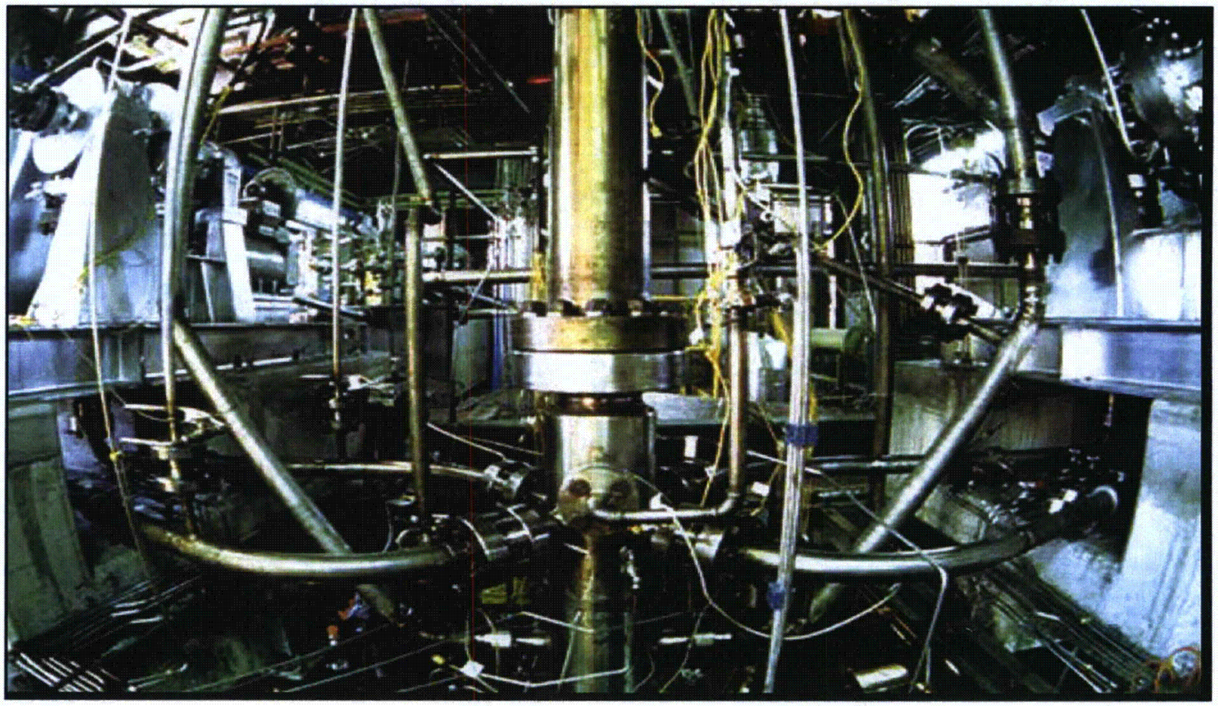


Figure B.1-8 SPES-2 Facility Upper Portion of Reactor Vessel

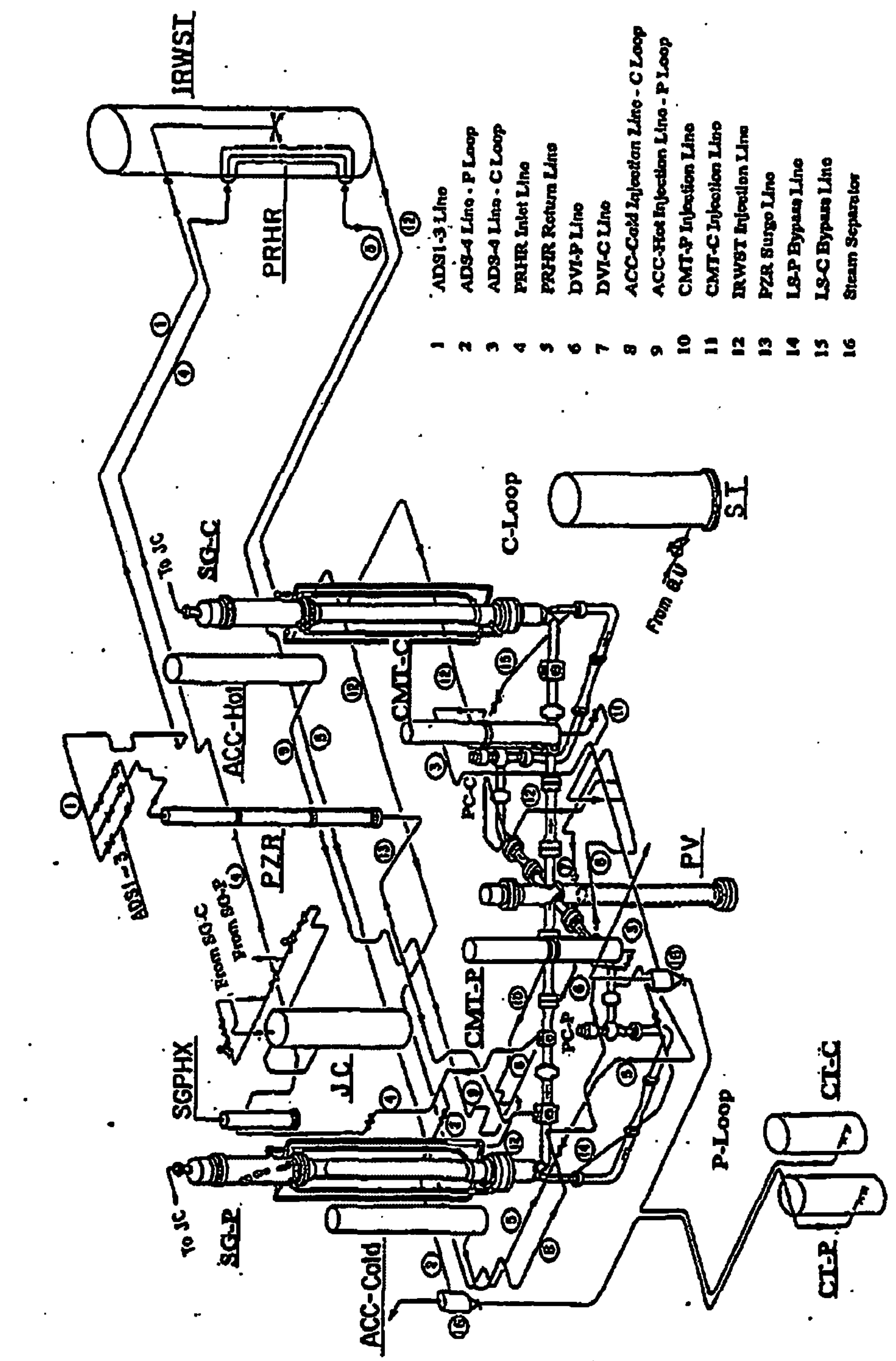


Figure B.1-9 ROSA/AP600 Schematic

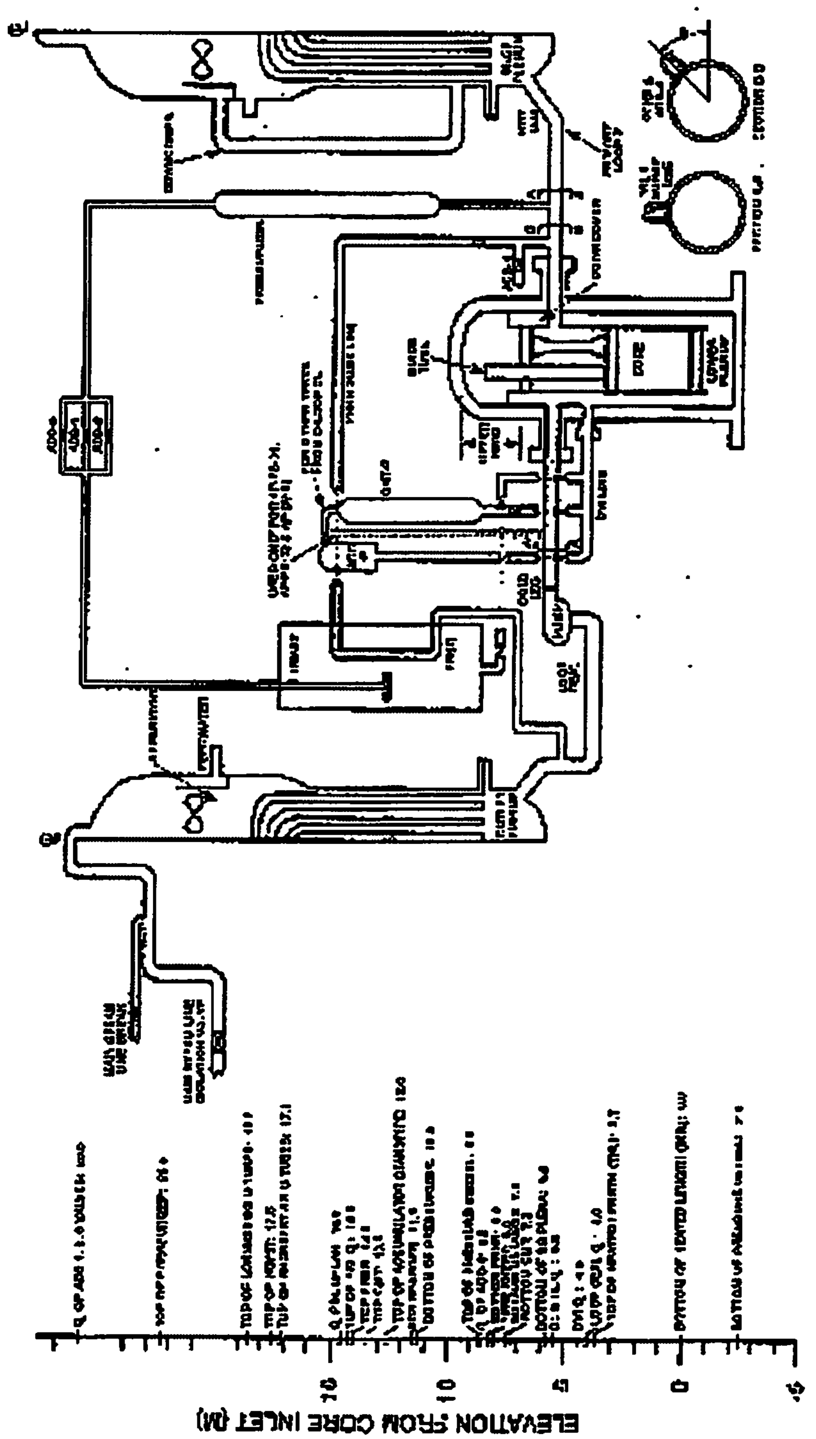


Figure B.1-10 ROSA/AP600 Elevations (Sheet 1 of 2)

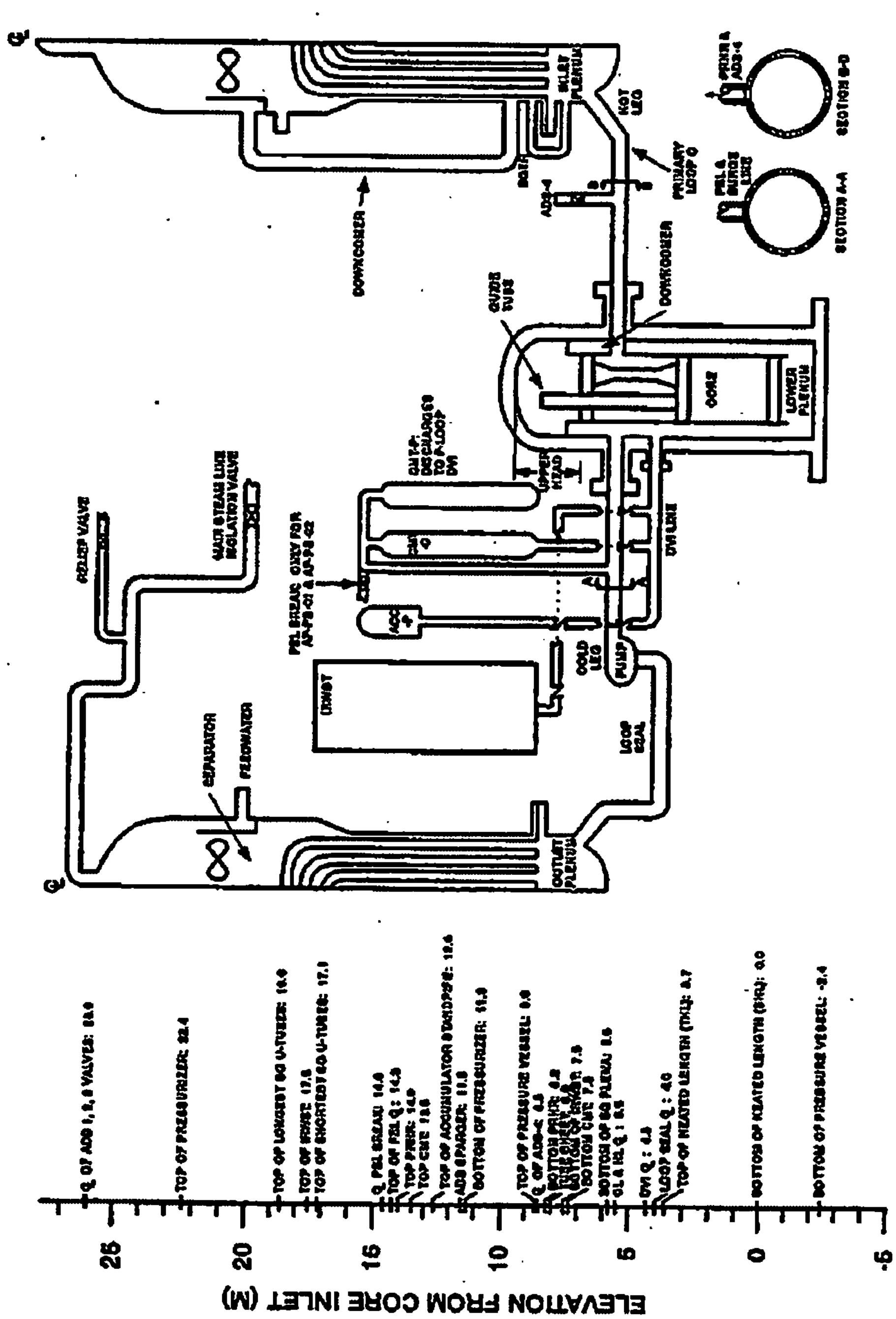


Figure B.1-10 ROSA/AP600 Elevations (Sheet 2 of 2)

B.2 PASSIVE CONTAINMENT COOLING SYSTEM (PCS) TEST SUMMARIES

The following tests were performed for the PCS:

- Air flow path pressure drop test (subsection B.2.1)
- Water film formation test (subsection B.2.2)
- Wind tunnel bench experiment (subsection B.2.3)
- Condensation test (subsection B.2.4)
- PCS water distribution test (subsection B.2.5)
- PCS wind tunnel test (subsection B.2.6)
- Heated plate test (subsection B.2.7)
- Integral PCS test (subsection B.2.8)
- Large-scale integral PCS test (subsection B.2.9)

B.2.1 Air-Flow Path Pressure Drop Test

A one-sixth scale replica of a 14-degree section of the entire PCS air-flow path was constructed to quantify the air-flow path resistance, determine if aerodynamic improvements were needed, and demonstrate the effectiveness of these improvements.

The air-flow path was constructed of heavy plywood and sheet metal and used a blower at the outlet diffuser end to draw air through the model. The air-flow baffle surrounding the vertical sides of containment (downflow inlet/upflow outlet air flow divider wall) was modeled to reflect the corrugated sheets, reinforce and support beams, and support posts that maintain separation between the shield wall and hold the baffle and containment. The air flow above containment accurately modeled the PCS water storage tank support beam flanges, steel radiation shielding plates, wire grill, and chimney structure. The air flow Reynolds numbers were maintained below the scaled Reynolds number that would correspond to the actual design, throughout testing, to ensure that the measured f(L/D)s were conservative.

Instrumentation consisted of a series of wall pressure taps located throughout the air-flow path of the model. Each was located in the center of the air-flow path with care taken to maintain a smooth surface where penetrating the wall. The taps were connected to a pressure transducer via an electrically driven scanning valve. The voltage output of the transducers was measured and recorded at regular intervals by a data acquisition system (DAS). Flow velocities were measured using a wedge probe with both wedge side taps connected together.

Test Matrix/Results

The initial test results showed that the turning and inlet flow losses at the 180-degree turn into the bottom of the containment annulus and the losses in the containment annulus were the largest pressure losses. Therefore, several modifications were made:

- A rounded inlet was added at the containment annulus inlet.

- Since the turning radii for some streamlines at the annulus inlet would be relatively small, the rounded inlet was constructed using perforated metal to minimize flow separation.

- The air baffle sheet corrugations were made wedge-shaped at the inlet to lessen the tendency to contract the flow.

- The support posts from containment to the baffle were streamlined by adding fairings.

The results of this test showed that the total PCS air cooling path pressure loss coefficient was reduced by 45 percent by adding the streamlining features. This reduced loss coefficient was used in subsequent analyses of PCS performance.

Pressure drop in the air-flow path was quantified for the PCS. This test for the **AP600** plant demonstrated that the pressure coefficients in the air flow could be estimated, verified, and improved with simple design changes.

B.2.2 Water Film Formation Test

General Description/Purpose

A survey of coatings that could be used on the **AP600** plant containment was conducted to determine a coating that would provide corrosion protection and could be conducive to establishing a stable water film on the containment exterior surface. After selection of a coating candidate, a simple qualitative test was performed to demonstrate the wetability of the prototypic paint selected for use on the containment outer surface, and to characterize general requirements for forming a water film over a large surface area. The test apparatus consisted of a flat steel plate, 8 ft long in the flow direction and 4 ft wide. The plate was pivoted so that it could simulate nearly horizontal sections of the dome as well as the vertical containment sidewalls.

Test Matrix/Results

Water flow was supplied to the plate at a single point at the top center edge of the plate and was measured to simulate actual plant flow conditions. Various flow spreading devices were tried both to induce and observe uniform film behavior and to judge spreading requirements.

Summarized results of the test are:

- The selected paint readily wetted and rewetted after being dried.

- No rivulet formation was observed on this painted surface even at high point source flow rates and vertical orientation.

- With a point source of water, without additional distribution, most of the flow was in a 12-in. wide path down the 8-ft length.

- Several methods were able to create a water film across the entire width of the plate at various flow rates. Once formed, this water film was stable, did not form into rivulets, and wetted the entire length of the plate surface.

These results, combined with additional observation of film behavior in the tests described in subsections B.2.3 and B.3.5, were used to devise appropriate water distribution devices applicable to the actual containment structure.

B.2.3 Wind Tunnel Bench Experiment

General Description/Purpose

Bench wind tunnel tests of the PCS were conducted at the Westinghouse Science and Technology Center using 1/100-scale models of the **AP600** plant shield building, air inlets and outlets, annulus baffle, and containment. These tests were performed to establish the proper location of the air inlets and to confirm that wind will always aid containment cooling air flow. Two models were used: one consisted of only the shield building and diffuser discharge without inlets and internal flow; the second included the air inlets, air baffle, containment, tank support structure, and a fan to simulate convective air flow. Pressures were measured at the inlet, building side and top, bottom of inlet annulus, top of containment at the discharge of the air baffle, and in the chimney. Air flow was measured at the inlet to the containment baffle.

Test Matrix/Results

These tests were run with a uniform wind tunnel air velocity of 85 ft/sec. Test Reynolds numbers for the shield building and chimney were demonstrated to be in the transition region. The models used in this test were 10-inches in diameter and 18-inches in overall height. The model that included the containment and air baffle structures was instrumented with static pressure taps (SPTs) and an air velocity (anemometer) measurement. The instrumentation was located in a common vertical plane, and the model was rotated 360 degrees to obtain the air pressure profile around the entire structure.

The results from this test showed that when the air inlets are located on the top (roof) of the shield building, a "chimney" effect was created over a significant portion of top of the building (this effect became more pronounced when the wind direction was inclined upward), while air inlets located at the top of the shield building sidewalls overall provide the most positive wind- induced driving pressure versus air exit pressure.

Air pressure profiles in the shield building across the cooling air baffle to the air exit with external wind were developed. By comparison to a "no-wind" case where all the cooling air flow was induced by the fan, it was shown that, with the selected air inlet arrangement, the wind will always increase the containment cooling air-flow rate.

Other significant conclusions from this test were:

- Deep beams behind the air inlets (as provided in the PCS water storage tank structure in the original shield building design) significantly increased wind-induced containment air cooling flow.

- Containment air cooling flow was insensitive to wind direction and to a 15-degree downward wind inclination. Cooling flow was increased by a 15-degree upward wind inclination.

B.2.4 Condensation Test

General Description/Purpose

A series of condensation experiments to examine, in detail, condensation of air/steam mixtures flowing over cold surfaces were performed under Westinghouse funding to the University of Wisconsin. These experiments were used to develop improved models for the containment interior heat transfer.

Test Matrix/Results

The first series of tests examined condensation over a horizontal surface, as a reference. The next series of tests inverted the condensing surface so that it modeled the inside of the containment dome and sidewalls. The condensation rates were more than twice that of a flat horizontal surface. Finally, these experiments were rerun using a specially prepared surface coated with the same paint used inside containment for corrosion resistance. The condensation was reduced, but was still twice that for a horizontal surface.

These small-scale, well-instrumented tests provided the basis for computer code model improvements, so that the **AP600** plant containment interior heat transfer performance could be accurately predicted.

B.2.5 PCS Water Distribution Tests

General Description/Purpose

The PCS water distribution test was conducted to provide a large-scale demonstration of the capability to distribute water on the steel containment dome outer surface and top of the containment sidewall. The overall objectives of the PCS water distribution test were to quantify the effectiveness of the water distribution over the containment dome and top of the containment sidewall, and to provide data to finalize the design of the **AP600** plant containment water distribution. The results of the tests were used in the safety analysis of the **AP600** plant containment response.

The test was conducted in several phases. Phase 1 utilized a full-scale simulation of the center of the containment dome out to the 10-ft radius. The surface of the model was coated with the prototypic **AP600** plant containment coating. The test was used to evaluate water delivery to the dome. Water distribution measurements were obtained by collecting and measuring flow off the periphery of the model. In addition, the test evaluated the use of a surfactant to promote water film formation.

Phase 2 was conducted on a full-scale 1/8 sector of the containment dome at the Westinghouse Waltz Mill facility located in Madison, Pennsylvania. The phase 2 test modeled both the **AP600** plant water supply and a distribution system arrangement. The surface of the test model incorporated the maximum allowable weld tolerances between the steel plates and was coated with the prototypic **AP600** plant containment coating to provide similarity to the **AP600** plant design. Measurements of the water distribution were obtained by collecting and measuring the flow over defined areas and by selective measurement of film thicknesses using a capacitance probe. In addition, the test evaluated the use of a surfactant to promote water film formation.

Phase 3 was used to confirm the final design of the water distribution system. Measurements of the water distribution were obtained by collecting and measuring the flow over defined areas and by selective measurement of film thicknesses using a capacitance probe. The results of the phase 3 test were compared with the phase 2 results to verify the performance of the final water distribution system design.

Test Matrix/Results

Phase 1 tests were conducted over a range of water flow rates that bracketed the anticipated flows. Tests were also conducted with and without any distribution devices and with imposed surface tilts.

Phase 2 tests were also conducted both with and without prototypic spreading devices at flow rates, which simulated the expected water delivery from flow initiation to the 3-day delivery rate. As with the tests from phase 1, phase 2 tests showed a more even distribution with increasing flow rate. At high flow rates, water distribution on the dome was greater than 65 percent. At low flow rates, the coverage decreased to below 40 percent. The test also re-affirmed the need for a water distribution device on the containment dome.

Phase 3 tests were completed and used to verify the performance of the finalized distribution device design. The matrix for phase 3 testing was provided in Table B.2-1.

B.2.6 PCS Wind Tunnel Tests

General Description/Purpose

The PCS wind tunnel test was conducted primarily in a boundary layer wind tunnel at the University of Western Ontario. The overall objectives of the PCS wind tunnel test were to demonstrate that wind does not adversely affect natural circulation air cooling through the shield building and around the containment shell and to determine the loads on the air baffle. The test was conducted in four phases (1, 2, 4A, and 4B).

Phases 1 and 2 were conducted with a 1/100-scale model of the **AP600** plant shield building and surrounding site structures, including the cooling tower. The model of the shield building and surrounding structures was placed in the tunnel on a turntable, which permitted the entire assembly to be rotated to simulate the full 360 degrees of wind directions. The wind tunnel also allowed extended fetches of coarsely modeled upstream terrain to be placed in front of the building under test. The wind tunnel flow (about 75 ft/sec) then developed boundary layer characteristics representative of those found in full scale. For this testing, a boundary layer representative of open-country conditions (ANSI C) was developed.

Phase 1 modeled the site structures and external shield building only. No internal flow passages were provided. The shield building model was instrumented with pressure taps at the inlet locations and in the chimney. The purpose of phase 1 was to compare the pressure coefficients developed following changes to shield building and/or site structures with the pressure coefficients developed on the current plant design. Note that the base case was without the cooling tower.

Phase 2 used the model from phase 1 testing, modified to include a representation of the shield building air-flow path. The shield building model was instrumented with pressure taps inside the inlet plenum and in the chimney. In addition, pressure taps were located throughout the air-flow path to provide for approximate baffle wind loads at several locations. The purpose of phase 2 was to explore the effects of the flow path on the developed pressure coefficients and to determine wind loads on the air baffle.

Phase 3 was planned to provide an estimate of the amount of effluent that would be recirculated from the chimney of the shield building to the inlets. This phase of testing was cancelled.

Phase 4A was conducted at both the University of Western Ontario and the Canadian National. Research Council's (CNRC's) wind tunnel in Ottawa, Ontario, on both the 1/100-scale model and a 1/30-scale model. The primary objectives of the test were to confirm that the detailed phase 2 results at the University of Western Ontario conservatively represented those expected at full-scale Reynolds numbers and to obtain better estimates of baffle loads in the presence of a cooling tower.

The first portion of phase 4A was conducted at the University of Western Ontario using the existing 1/100-scale model of the shield building and site-surrounding structures. Additional instrumentation was added to the model to provide useful overall comparison of Reynolds number effects between the tests at the two facilities. For comparative purposes, the model was equipped with a sealing plate at the interior base of the chimney to prevent flow through the interior passages, when desired. Tests were also conducted with the flow path open in a uniform wind field to provide true instantaneous baffle loads for a tornado case.

The phase 4A tests at CNRC were conducted on a 1/30-scale model of the shield building. The model did not have complete internal passages; however, the chimney was open inside to its base, and a simple inlet manifold was included extending just below the inlets. This was connected to an additional internal volume designed to compensate for the frequency response of the volume of the blocked passages in the 1/100-scale model. Instrumentation on the model was similar to the 1/100-scale model on the exterior and inside the chimney to provide comparative results between the tunnels. A 1/100-scale model of the cooling tower was tested in the CNRC tunnel to provide a cooling tower waste pressure distribution and wake properties for application in the phase 4B testing.

The objectives of the phase 4B tests were to explore variations in site layout and topography to determine whether or when such variations significantly affect the net pressure difference between the inlet and chimney of the **AP600** plant and, by implication, the convected flow and net baffle loads. A small-scale model of the site buildings and local topography was built at a scale of about 1/800. This scale range ensured that both the reactor and cooling tower models were in the same Reynolds number range (subcritical), while remaining a size that allowed the use of straightforward modeling and instrumentation techniques.

Test Matrix/Results

The data from the phase 1 base case design indicated a significant positive pressure difference between the inlets and the chimney. Changes to the inlets only marginally reduced the pressure difference. Raising and lowering the chimney had little effect. Raising and lowering the turbine building also had little effect. The presence of the natural draft cooling tower significantly increased the turbulence at the shield building, resulting in larger fluctuating differential pressures. However, in all cases, the mean pressure difference remained positive. Removal of the deaerator from the turbine building roof showed no effect.

The majority of the tests for phase 2 were conducted at one wind angle with all site structures except the cooling tower. Pressure coefficients were measured across the baffle. Mean pressures from all taps on a particular level were compared to examine the uniformity of the pressures around the baffle. The data indicated that the distributions were fairly uniform, even at the top of the annulus. The presence of the cooling tower increased the pressure fluctuations, but the mean remained about the same.

The phase 4A tests at CNRC verified that the tests at the University of Western Ontario were independent of Reynolds numbers.

Phase 4B site geography testing conducted at the University of Western Ontario consisted of the following cases:

- A reference case-consisting of the current site layout, including all site buildings and a cooling tower on flat open-country terrain.
- A series of other cases-idealized sites based on Diablo Canyon and Trojan and/or Indian Point.
- The Diablo Canyon type site addressed speedup due to an escarpment. The Trojan/Indian Point site looked at the effects of a river valley site.

B.2.7 PCS Heated Plate Test

General Description/Purpose

In the PCS concept, heat transfer from the outside of the vessel was performed by forced convection heat transfer from the steel containment surface to air (including some radiation to the divider wall) and evaporation of a water film on the wetted outside area of the containment surface above the operating deck elevation. In order to obtain data for the heat and mass transfer processes, and to observe film hydrodynamics including possible formation of dry patches due to surface tension instabilities,

experiments were performed on a thick steel plate heated on one side and with an evaporating water film and ducted air flow on the other side.

The experimental apparatus consisted of a 6-ft long, 2-ft wide, and 1-in. thick steel plate coated with the same coating planned for use on the containment vessel. An air duct was formed over the plate by side walls and a Plexiglas cover for flow visualization. A four-speed blower ducted through a set of turning vanes provided air-flow velocities which simulated the full range of both natural draft in the containment cooling duct and flows induced by a high wind. Water, preheated in an automatically controlled water heater, was supplied at a metered rate to a simple distributor located at the upper end of the plate.

To simulate the heating of the containment wall that would occur in an actual plant following a postulated accident, the test plate was heated from the back side using a high temperature heat transfer fluid, **UKON™**[3] HTF 500. The heat transfer fluid flowed through copper heating tubes that were soldered into grooves in the back of the plate. The heat transfer fluid was electrically heated in a drum with an automatic temperature control and pumped through a flow meter to the tube inlet manifold. All hot parts, except the front of the plate, were insulated to minimize heat loss.

The plate could be placed in a vertical position to simulate the containment side wall or inclined somewhat from horizontal to simulate the different slopes on the elliptic containment dome. Plate temperatures and heat fluxes were measured at six locations by pairs of thermocouples. In addition, air inlet and outlet temperatures were measured together with duct velocity. An electronic watt meter registered total heater power. Water outlet flow and temperature were also measured. Temperature and power data were recorded on a data acquisition system.

Test Matrix/Results

Experiments were performed with no water on the plate and for a range of water film flow rates simulating the high water flow on the upper part of containment down to the lower part of containment where the water was nearly completely evaporated at the high heat flux. A series of tests to isolate and observe the effect of air velocity at one representative film flow was completed. Tests at high air velocities were performed to examine the high wall shear effects for a number of film flow rates. A limited set of tests was performed at 15-degree inclination to horizontal to provide data for the thicker films that flow on the dome. A summary of test conditions is provided in Table B.2-2.

The evaporation rate of water from the heated plate was shown to agree with or exceed those expected and confirmed the overall heat transfer capability of the PCS concept. The following conclusions were drawn from the test results:

- Water film evaporation and resultant heat removal agreed with or exceeded expected values.
- Heat transfer from the water film to air was performed by forced convection plus mixing with hotter evaporated water vapor.

3. **UKON™** is trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow.

- Radiation to the air baffle wall and subsequent heat transfer to the cooling air occurred and accounted for some of the heat transfer.

- Heat transfer from containment to the air with no water film agreed very well with expected values.

- Water film flowing on the coated steel surface was wavy laminar flow not susceptible to instabilities that lead to dry patch formation at any heat flux density or plate surface temperature encountered.

- A water film was easily formed on the coated steel surface even in the vertical orientation. Once formed, the film showed no instability or tendency to form rivulets. This was true at all tested water flow rates.

- The water film was not adversely affected by the countercurrent cooling air flow up to the maximum air velocity of the test (e.g., no water-film stripping occurred).

B.2.8 Small-Scale Integral PCS Test

General Description/Purpose

This test simulated PCS heat transfer processes occurring on both the inside and outside containment surfaces. The test apparatus included a 3-ft diameter, 24-ft high steel pressure vessel internally heated by steam supplied at various pressures. A transparent wall around the pressure vessel was used to create a 15-inch wide annulus for fan-driven or natural circulation air flow. In order to simulate a full range of possible air temperatures and humidities, the incoming air was heated by a steam heating coil and humidified with steam. Instrumentation to measure internal steam condensing rates, external water evaporation rates, containment wall inner and outer temperatures, water film and air temperatures, humidities, and air velocities was provided. Speed control of the draft fan at the diffuser section permitted simulation of a full range of air-flow conditions in the air annulus.

Test Matrix/Results

The tests were conducted with varying steam supply flow rates, water film flow rates, inlet air temperatures, and inlet air humidities (Table B.2-3). Instrumentation was provided to measure internal steam condensation rates, external water evaporation rates, containment wall inner and outer temperatures, water film temperatures, air temperatures, humidities, and air velocities.

The following conclusions and observations were drawn from this test:

- The heat removal capability from the external surface of the test vessel for both wetted and dry conditions agreed well with previous heated plate experiments and analytic predictions and supported the **AP600** plant containment analysis.

- The overall heat removal capability from the test vessel with a wetted surface and well- mixed air and steam inside agreed well with analytical predictions.
- The local heat removal rate at the top of the vessel where "cool" water was first applied was significantly higher than the vessel average heat removal rate.
- The water film behavior was stable and predictable even at evaporating heat fluxes three times higher than is likely to be encountered in actual application.
- A uniform water film was easily formed on the coated steel containment surface using simple weirs even after extended exposure to weather effects.
- The water film on the vertical side walls of the coated steel surface of the vessel had no tendency to become less uniform or form rivulets, so that no water film redistribution was required on the vertical walls.

B.2.9 Large-Scale Integral PCS Test

General Description/Purpose

The large-scale PCS test consisted of a 1/8-scale model of the **AP600** plant containment in which both internal steam/air non-condensable gas conditions and external PCS operation were simulated in order to demonstrate the **AP600** plant PCS heat transfer capability. The purpose of this test was to examine, on a large scale, the natural convection and steam condensation on the interior of the **AP600** plant containment combined with exterior water film evaporation, air cooling heat removal, and water film behavior. The PCS heat transfer test results provided data for the verification of the computer model used to predict the containment response. Also, these test results combined with the PCS smaller-scale integral test provided insight on the ability of the computer model to predict results at two different test scales.

The test facility was located at the Westinghouse Science and Technology Center in Churchill, Pennsylvania. The facility consisted of a 20-ft high by 15-ft diameter pressure vessel with a 7/8-in. wall thickness (Figures B.2-1 through B.2-3) and the supporting hardware. The larger test vessel made it possible to study in-vessel phenomena such as non-condensable mixing, steam release jetting, condensation, and flow patterns inside containment. The vessel contained air or helium when cold and was supplied with steam for testing. A transparent acrylic cylinder installed around the vessel formed the air-cooling annulus. Air flow up (and/or water flow down) the annulus outside the vessel cooled the vessel surface, resulting in condensation of the steam inside the vessel. Superheated steam was throttled to a variable, but controlled, pressure and was supplied to the test vessel.

To establish the total heat transfer from the test vessel, measurements were recorded for steam inlet pressure, temperature, and condensate flow and temperature from the vessel. Thermocouples located on both the inner and outer surfaces of the vessel indicated the temperature distribution over the height and circumference of the vessel. Thermocouples placed throughout the inside of the vessel on a movable rake provided a measurement of the vessel bulk steam temperature as a function of position.

An axial fan at the top of the annular shell tested the apparatus at higher air velocities than can be achieved during purely natural convection. The temperature of the cooling air was measured at the entrance of the annular region and on exit of the annulus in the chimney region prior to the fan. The cooling-air velocity was measured in the cooling-air annulus using a hot wire anemometer.

The test facility provided the following critical data for the interpretation of the test performance:

- Containment wall heat flux measurements to provide local heat transfer rates
- Air baffle wall temperatures
- Vessel internal temperatures
- Air/helium concentration measurements
- Instrumentation to measure (to support a heat balance of) the PCS external air and water, and steam and condensate flows and temperatures

Test Matrix/Results

The large-scale PCS test was performed in two phases: baseline tests and confirmatory tests. The baseline tests were conducted to support the June 1992 **AP600** plant SSAR submittal. The confirmatory tests were completed in November 1993 and are described in Table B.2-4.

Key results and observations for the PCS large-scale heat transfer test are:

- The heat removal capability from the external surface of the test vessel for both wetted and dry conditions agreed well with previous heated plate experiments and analytic predictions and supported the **AP600** plant containment analysis.
- A uniform water film was easily formed on the coated steel containment surface using simple weirs even after extended exposure to weather effects.
- Helium mixed well inside the test vessel; no helium stratification was observed.
- The presence of helium had a negligible effect on heat transfer removal rates.
- Condensation and evaporation mass transfer were the only significant mechanisms for rejecting energy from containment to the PCS.
- Non-condensable distribution and internal velocity were important to the condensation rate.
- Tests simulating LOCAs show that internal velocities are sufficiently low, free convection dominates, and momentum does not carry from above to below the simulated operating deck.

- Tests simulating MSLB events show that internal velocities are significant, mixed convection exists, and momentum is transported from above to below simulated operating deck (which induces uniform concentrations).

Table B.2-1 Water Distribution Test, Phase 3

Test	Test Number	Description
Weir performance tests	1	Test of weir performance with initial water flow rate
	2	Test of weir performance with 24-hour water flow rate
	3	Test of weir performance with excessive water flow rate
	4	Test of weir performance with 3-day water flow rate
	5	Test of tilted weir performance with initial water flow rate
	6	Test of tilted weir performance with 3-day water flow rate
	7	Test of weir performance with initial water flow rate and plugged drainage holes
	8	Test of weir performance with initial water flow rate and plugged drainage holes
	15	Test of weir performance with initial water flow rate and baffle support plates
	16	Test of weir performance with 3-day water flow rate and baffle support plates
Film thickness tests	9	Test to measure film thickness and flow rate at initial water flow rate
	10	Test to measure film thickness and flow rate at 3-day water flow rate
	11	Test to measure film thickness and flow rate at excessive water flow rate
	12	Test to measure film thickness and flow rate at 24-hour water flow rate
	13	Test to measure film thickness with tilted weir and initial water flow rate
	14	Test to measure film thickness with tilted weir and 3-day water flow rate

Table B.2-2 Test Conditions, Test No., and Average Heat Flux (Btu/hr-ft^2)

Water Film Flow Rate lbm/hr/ft of nominal	Air Velocity (ft/sec)						
	5.9	1 12.4	18.8	23.7	28.5	33.2	38.7
	Dry Plate Tests, Vertical Except 15 Degrees from Horizontal						
0		1	2	4	5	6	7
		680	860	930	1040	1100	1210
			3* 420				
	Water Film (Except Partially Dry) on Vertical Plate						
15	8		9				
	3120		3270				
60		10	11				
		3490	3640				
			12				
			2120				
110							
	13	14	15	18	19	20	21
	3340	3610	3540	3570	3670	3670	3650
			16				
			3580				
			17				
170			3490				
		22	23				
310		3520	3570				
			24				
			2030				
			25	26			
			3560	3530			
	Water Film on Plate 15 Degrees from Horizontal						
60			27 3500 2800 1960				
110		29 3580	30 3590 31 2020				
310		32 3510					

Table B.2-3 AP600 Plant PCS Small-Scale Integral Test Matrix						
Test No.	Steam Outlet	Steam/Air Pressure (prig)	Cooling Air Velocity (ft/sec)	Water Film Flow (gpm)	Cooling Air Temp (°F)	Air Relative Humidity
1	Uniform	10	8	0	Ambient	Ambient
2	Uniform	20	8	0	Ambient	Ambient
3	Uniform	30	16	0	Ambient	Ambient
4	Uniform	40	16	0	Ambient	Ambient
5	Uniform	10	16	2.5	130	Ambient
6	Uniform	30	16	2.5	130	Ambient
7	Uniform	40	16	2.5	130	Ambient
8	Uniform	10	16	2.5	130	95°F wet bulb
9	Uniform	20	16	2.5	130	95°F wet bulb
10	Uniform	30	16	2.5	130	95°F wet bulb
11	Uniform	40	16	2.5	130	95°F wet bulb
12	Uniform	10	8	2.5	130	Ambient
13	Uniform	20	8	2.5	130	Ambient
14	Uniform	20	8	2.5	130	95°F wet bulb
15	Uniform	10	8	1.0	130	Ambient
16	Uniform	20	8	1.0	130	Ambient
17	Uniform	30	16	4.0	130	Ambient
18	Uniform	40	16	4.0	130	Ambient
19	Uniform	10	8	1.0	130	95°F wet bulb
20	Uniform	40	16	4.0	130	95°F wet bulb
21	Uniform	20	16	2.5	130	Ambient
22	Uniform	80	20	0	Ambient	Ambient
23	Bottom inlet	40	16	0	Ambient	Ambient
24	Bottom inlet	10	8	1.0	130	Ambient
25	Bottom inlet	10	8	1.0	130	90°F wet bulb
26	Bottom inlet	40	16	4.0	130	Ambient
27	Bottom inlet	20	16	2.5	130	Ambient

Table B.2-3 AP600 Plant PCS Small-Scale Integral Test Matrix (cont.)

Test No.	Steam Outlet	Steam/Air Pressure (psig)	Cooling Air Velocity (ft/sec)	Water Film Flow (gpm)	Cooling Air Temp (°F)	Air Relative Humidity
28	Bottom inlet	30	16	4.0	130	Ambient
29	High inlet	10	8	1.0	130	Ambient
30	High inlet	10	8	1.0	130	95°F wet bulb
31	High inlet	20	16	4.0	130	Ambient
32	High inlet	20	16	4.0	130	95°F wet bulb
33	High water	10	8	1.0	130	Ambient
34	High water	10	8	1.0	130	95°F wet bulb
35	High water	40	16	4.0	130	Ambient
36	High water	20	16	2.5	130	Ambient

Table B.2-4 Large-Scale Heat Transfer Test, Phase 2

Test	Test Number	Description
Pre-operational test	Video recording	Videos of water distribution on top of vessel
	Cold annulus velocity	Low temperature annulus startup velocity
	Water distribution	Calibrate water distribution for three different levels of coverage on the vessel
	Condensate system	Check operation of condensate system
	Velocity sensors	Check operation and determine location of velocity meters for future tests
	Cold helium injection	Inject helium into cold vessel and sample to determine helium distribution at selected time intervals following injection
	Delayed water injection	Provide delayed water distribution flow to the surface of hot vessel and video tape performance
Matrix tests	202.3	Constant vessel pressure
	203.3	Constant high vessel pressure
	213.1	Three steam flow levels with reduced water flow and coverage area

Table B.2-4 Large-Scale Heat Transfer Test, Phase 2 (cont.)

Test	Test Number	Description
Matrix tests (cont.)	214.1	Constant steam flow, reduced water flow and coverage area, and variable air cooling flow
	216.1	Constant steam flow with reduced water flow over sections of the vessel
	215.1	Constant steam flow, reduced water flow and coverage area, and variable air cooling flow
	212.1	Three steam flow levels with reduced water flow and coverage area; non-condensable gas samples taken
	217.1	Constant steam flow with helium injection; reduced water flow and coverage area
	220.1	Transient blowdown steam flow, reduced water flow and coverage area, non-condensable gas samples taken
	218.1	Constant steam flow with helium injection; reduced water flow and coverage area; each steam flow maintained for about 1 hour and non-condensable measurements taken
	219.1	Constant steam flow with helium injection; reduced water flow and coverage area; each steam flow maintained for about 1 hour and non-condensable measurements taken
	221.1	Transient blowdown steam flow with helium addition sampling; reduced water flow and coverage area

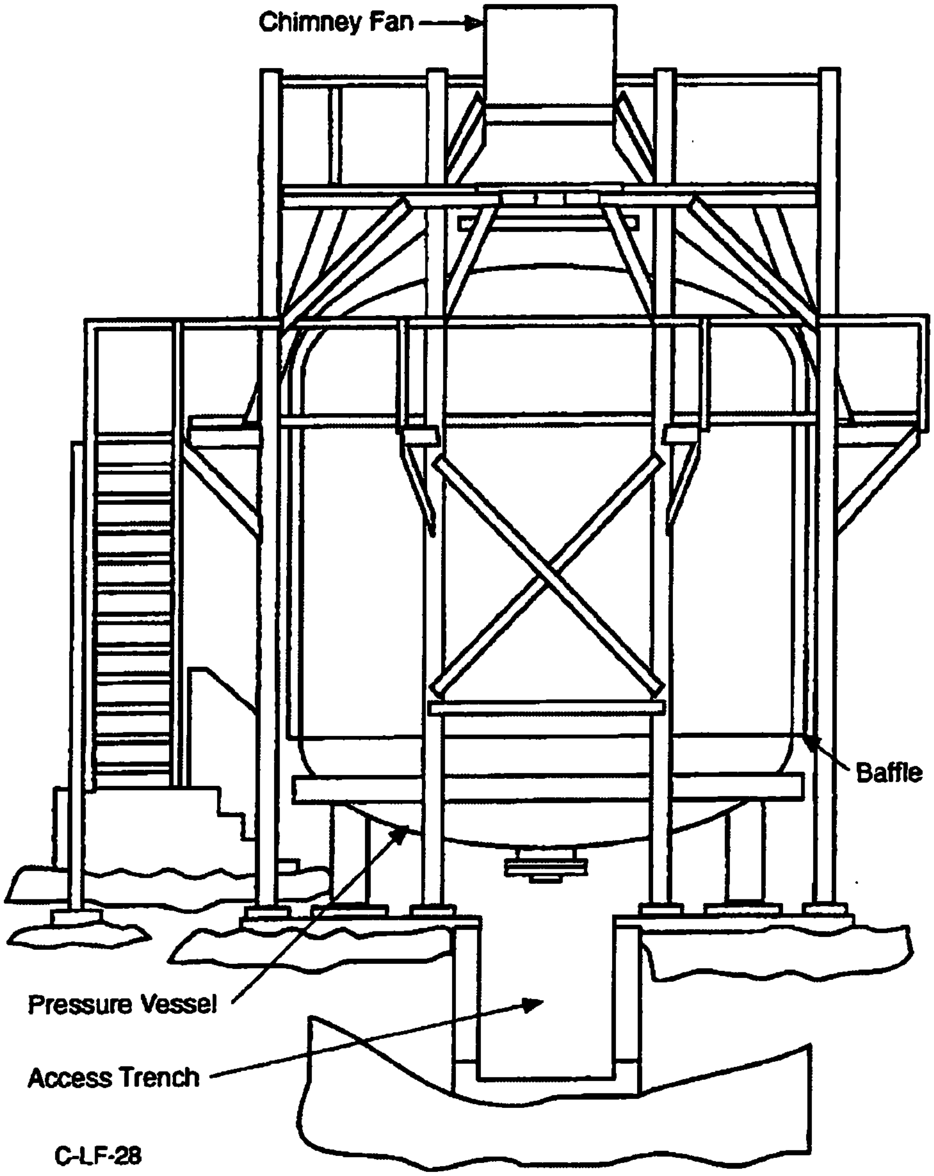


Figure B.2-1 Large-Scale PCS Test Facility

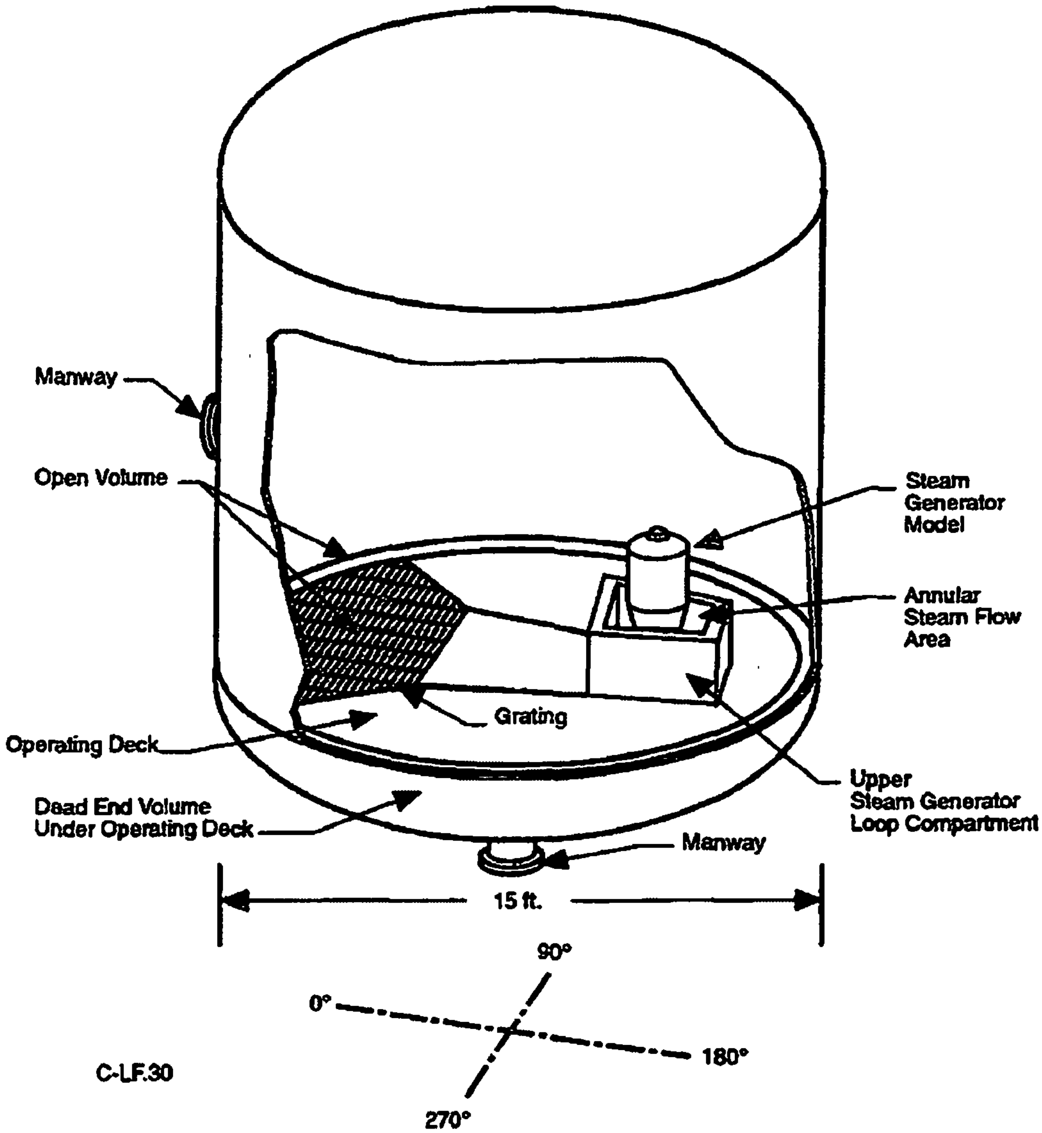


Figure B.2-2 Large-Scale PCS Test Facility

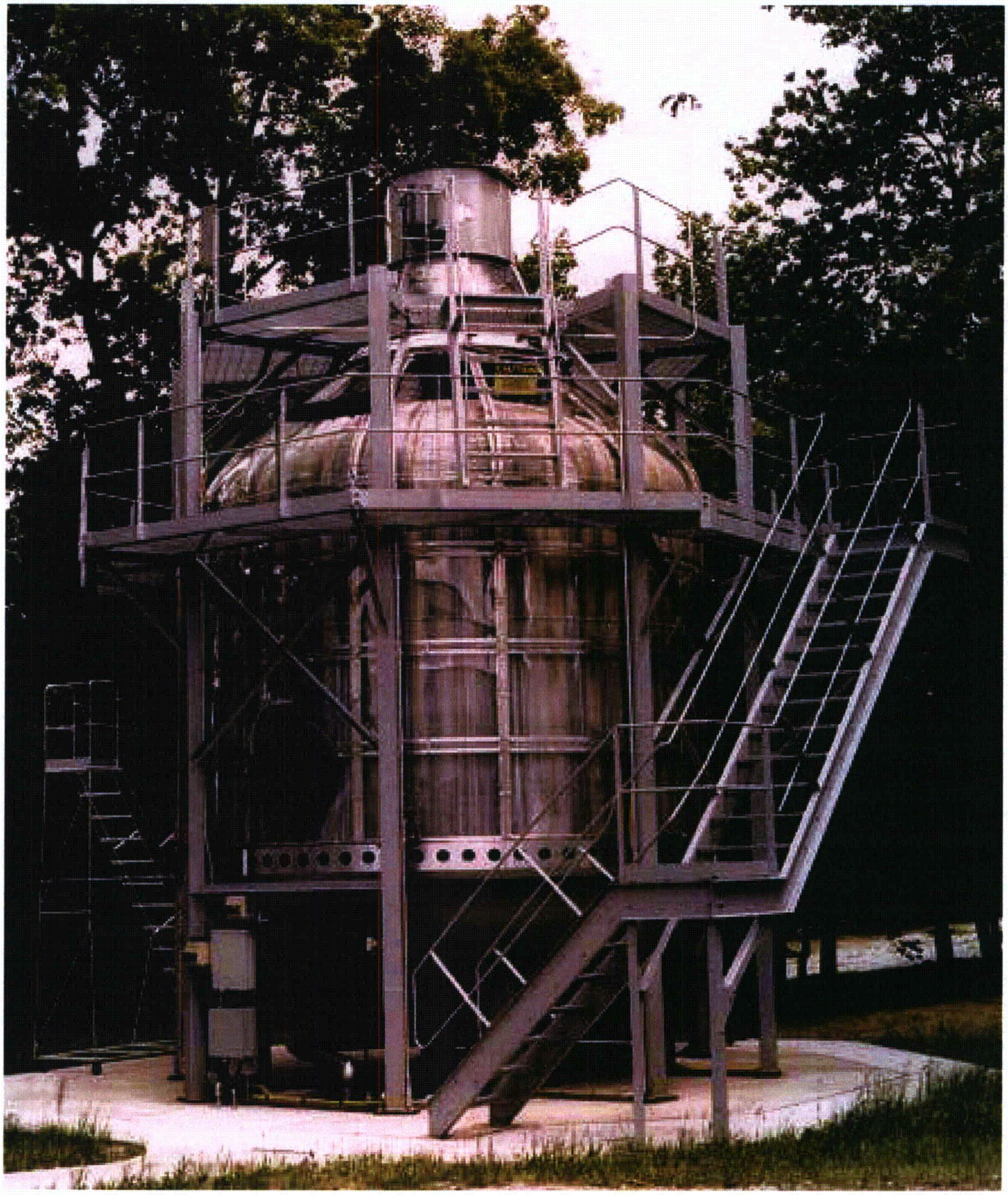


Figure B.2-3 Large-Scale PCS Test Facility

B.3 EQUIPMENT DESIGN VERIFICATION TESTS

The following tests were performed for equipment design verification.

- Normal residual heat removal suction nozzle test (subsection B.3.1)
- RCP/SG channelhead air flow test (subsection B.3.2)
- RCP high-inertia rotor/journal and bearing test (subsection B.3.3)
- In-core instrumentation EMI test (subsection B.3.4)
- Reactor Vessel air-flow visualization test (subsection B.3.5)
- Boron transportation simulation test (subsection B.3.6)
- PXS check valve hydraulic test (subsection B.3.7)
- Operating plant check valve test (subsection B.3.8)

B.3.1 Normal RHR (RNS) Suction Nozzle Test

General Description/Purpose

In order to ensure that the **AP600** plant hot-leg RNS suction nozzle configuration was optimized and that loss of the RHR function during mid-loop operation will not be a concern in the **AP600** plant, a series of tests were performed using an existing test facility.

The test model was made of clear plastic material to allow for visual viewing of the water behavior. The model consisted of a simulated reactor vessel with a 1/4.25-scale hot leg and RHR suction pipe. The Froude number was used to scale the test pump flow rates. A void meter and a strip chart recorder were used to measure the percentage of air entrainment by volume in the pump suction piping continuously, and all test runs were recorded on video tape. Two suction nozzle orientations and two potential vortex "breaker" arrangements were tested. For each configuration tested, the critical vortexing water level was measured as a function of both Froude number and loop water level.

Test Matrix/Results

The following configurations were tested:

- A scaled 10-inch RHR pipe in the bottom of the hot leg.

- A "step" nozzle at the bottom of the hot leg and a 10-inch RHR pipe at bottom of the step nozzle. Different diameters (14 to 20 in.) and lengths were investigated for the step nozzle.

These configurations were compared with previous test results obtained with an RHR suction nozzle placed at 45 degrees below the horizontal, the typical configuration on current Westinghouse PWRs.

Among the different nozzle arrangements tested, the optimum arrangement was a step nozzle. As the hot-leg level was further reduced, vortex formation in the hot leg stopped, as water just spilled into and filled the large nozzle. Air entrainment during the "spill" mode was small and would not result in unstable pump/system operation.

B.3.2 RCP SG Channel Head Air-Flow Test

General Description/Purpose

The air-flow test was performed to identify effects on pump performance due to non-uniform channel head flow distribution, pressure losses of the channel head nozzle dam supports and pump suction nozzle, and possible vortices in the channel head induced by the pump impeller rotation.

The air test facility was constructed as an approximate 1/2-scale mockup of the outlet half of the channel head, two pump suction nozzles, and two pump impellers and diffusers. The channel head tubesheet was constructed from clear plastic to allow smoke flow stream patterns to be seen.

Test Matrix/Results

The results of the test confirmed that no adverse flow condition, anomalies, or vortices in the channel head were induced by the dual impellers.

B.3.3 RCP High-Inertia Rotor/Journal and Bearing Tests

General Description/Purpose

An effective way to provide flow during coastdown of a pump during a loss-of-power transient was to add rotational inertia to the pump shaft at a bearing location.

The reference design **AP600** plant canned motor RCP provides a rotating inertia of 5000 lb/ft^2. To achieve this inertia with minimum drag loss, the impeller-end journal contains a 26-inch diameter by 14.5-inch long high-density (depleted uranium alloy) insert. The insert was enclosed in stainless steel for corrosion protection, and the enclosure was hardfaced at the bearing running surfaces for better wear resistance.

The resulting journal diameter was 28 inches, twice the diameter of any previously built water lubricated RCP bearing. Because of the size and unique construction, manufacturing and testing of the journal and bearing assemblies was undertaken. This engineering test program experimentally confirmed theoretical predictions of the parasitic and bearing losses arising from the "high-inertia" rotor concept applied to canned motor pumps. The test program also verified manufacturability and confirmed the adequacy of the design of both the thrust and journal bearings.

One important objective of this effort was to experimentally confirm the theoretical predictions of the parasitic and bearing losses arising from the high-inertia rotor concept applied to canned motor pumps. Theoretical calculations based on empirical drag laws are not sufficiently accurate to permit a final design to be made without accurate experimental verification. The viability of the high-inertia concept depends on limiting the losses to acceptable values. Additional important objectives were to confirm the satisfactory performance of the radial and thrust bearings, and to demonstrate the manufacturability and integrity of a full-scale encapsulated depleted-uranium journal.

In order to measure the losses accurately, a special friction dynamometer was designed, constructed, and put into operation.

Tests of the high inertia RCP were conducted in three phases.

Test Matrix/Results

Phase 1 testing successfully demonstrated the design and construction of a full-scale encapsulated high-inertia journal. Five thousand pounds of depleted-uranium 2-percent molybdenum alloy were cast, machined, encapsulated in stainless steel, precision-clad with hard-facing (Stellite), and balanced at all speeds up to and including 2000 rpm (13 percent overspeed).

The program was completely successful in demonstrating satisfactory performance under load of one of the largest water-lubricated, high-speed pivoted-pad journal bearings ever built. The journal, pivoted-pad radial bearing, thrust bearing, and friction-dynamometer test rig operated smoothly with no significant vibration over the entire speed and load range.

Success was achieved in the accurate measurement of the parasitic drag losses of the complete bearing assembly. These losses were higher than expected. Both radial load and thrust load were shown to have only a minor affect on losses, with speed being the major variable.

The largest contributors to the increase in losses over those originally expected were believed to be the balance cutouts and canopy welds on the journal. Other possible contributors to the losses were identified for investigation in phase 2.

The first objective in phase 2 was to measure the losses with smooth-end covers fitted over the canopy weld and balance cutout areas. The second objective was to determine the effect on the losses by removing the flow plugs blocking the ports of a six-hole centrifugal pump in the rotor. The third objective was to determine the effect on losses by increasing the gap between the outboard end of the motor and the bumper plate.

Smooth-end covers were successfully fabricated and fastened to the canopy weld and balance cutout areas of the high-inertia rotor. However, the resultant loss measurements were higher than those obtained previously in phase 1. Thus, the first try at smoothing these areas was not successful. The phase 2 tests were successful in determining the effect of removing the flow plugs and increasing the axial gap. Neither of these changes produced a large difference in the measured losses. Removal of the bumper plate reduced the losses by about 9 hp. The most significant finding was that there was no difference in measured losses between the two directions of rotation.

Phase 3 tests were performed to investigate a change in the design and location of the radial bearings in order to reduce the drag losses. The design change removed the radial bearing function from the high-inertia rotor and onto the pump shaft. The objective of the current testing was to measure the losses with the radial bearing pads removed and a cylindrical shroud installed to give an annular space with a radial gap of 0.5 inches.

The seven radial bearing pads were removed from the test housing and replaced by a continuous annular space having an average radial clearance of about 0.5 inches. Dynamic analysis predicted that the high-inertia test rotor and shaft would continue to exhibit stable operation. The testing verified the prediction; the test facility remained stable throughout the full speed range to 1761 rpm. Noncontacting displacement transducers were added to measure the relative radial positions of the rotor and housing. These transducers worked very well to provide information to enable the rotor to be kept well-centered in the housing. The program was completely successful in obtaining a large reduction in power losses with the removal of the radial bearing pads, as predicted prior to testing.

B.3.4 In-Core Instrumentation Electro-Magnetic Interference (EMI) Tests

General Description/Purpose

A test was performed to demonstrate that the system would not be susceptible to EMI from the nearby control rod drive mechanisms (CRDMs). The test was performed by mocking up instrument cables, bringing them into close proximity with an operating CRDM, and measuring the resulting noise induced on simulated flux signals.

Test Matrix/Results

The tests demonstrated that induced currents in the fixed in-core detector (FID) cables were acceptably small compared to the FID signals.

B.3.5 Reactor Vessel Air-Flow Visualization Tests

General Description/Purpose

A 1/9-scale model of the **AP600** reactor vessel and the four cold legs was constructed at the University of Tennessee. This model was used to visualize the vessel lower plenum to determine if vortices were present and, if so, the effect on them from surrounding features. The model was designed for flow visualization in the lower plenum, so the flow region from the SG outlet through the core support plate was accurately scaled. This included representations of the cold legs, downcomer, lower plenum, and support plate, including the hot-leg segments and the radial support keys in the downcomer and the vortex suppression ring in the lower plenum. Acrylic plastic was used for the cold legs, reactor vessel, and lower plenum, so flow visualization techniques could be employed in these areas. Flow in the model was provided by a blower that exhausted air vertically from the upper plenum region. The flow rate was controlled by a gate valve immediately upstream of the blower. This velocity was measured in each of the four cold legs using low-pressure drop orifices located near the cold leg nozzles.

Test Matrix/Results

These tests confirmed that vortices were effectively eliminated by the design. The absence of adverse effects was confirmed.

B.3.6 Boron Transport Simulation Test

General Description/Purpose

The principal objective of this test program was to simulate the transport of borated water from the SI nozzles to the core inlet region in support of the **AP600** reactor design. This information was important when predicting the consequences of any reactivity transients that are terminated by boron injection. The scenario likely to produce the greatest amount of reactivity feedback occurs when one SG was being depressurized to atmospheric pressure. In this case, the loop associated with the faulted SG will have flow driven by natural circulation, while the other loop could be completely stagnant. Gravity-driven SI flow will be initiated as the secondary cooldown reduces the primary system pressure. This scenario could result in a highly asymmetric cooldown of the core and significant reactivity addition until the injected boron migrates to the core.

To determine the characteristics of fluid transport in the reactor, a scaled experiment was performed at the University of Tennessee. For this test program, the reactor was modeled in 1:9 scale. The model included accurate reproductions of the cold legs, downcomer, SI nozzles, vortex suppression ring and secondary core support, lower plenum, and core support plate. Side and top view drawings of the scaled model are shown in Figures B.3-1 and B.3-2. Air was used as the working fluid, with a dense gas serving as the injected fluid. A detailed scaling analysis of the **AP600** reactor was performed to determine model flow velocities necessary to accurately model the effects of convection, diffusion, turbulence, and gravity as they apply to fluid transport in the reactor system.

The tests were performed by initially setting a steady-state flow rate in the model reactor vessel, determined by scaling the reactor flow rates. At a known time, injection of the dense gas was triggered. The concentration of the injected gas was measured as a function of time at 24 points immediately downstream of the core support plate.

Test Matrix/Results

The reactor conditions tested represented two different SLB scenarios, as follows:

1. System pressure = 973 psia
   Loop 1 flow: 3926.3 gpm @ 432°F
   Loop 2 flow: 8021.8 gpm @ 350°F
   SI flow: 221.3 gpm @ 132.1°F

2. System pressure = 786 psia
   Loop 1 flow: 0.0 gpm
   Loop 2 flow: 10226.3 gpm @ 303°F
   SI flow: 169.7 gpm @ 123.5°F

Converting these flow rates to reactor system flow velocities allowed scaling to model velocities. As dictated by the scaling report, model velocities were scaled to 0.44, 1.0, and 9.0 times the reactor velocity when using carbon dioxide as the injected gas, while a model velocity of 1.3 times the reactor velocity was used with sulfur hexafluoride. These cases are illustrated in Table B.3-1.

The first four test series simulated the first SLB scenario over the range of model velocities, while the next four series simulated the second scenario. Series 9 was added to provide benchmark data for a case where all loop flows were equal rather than asymmetric. Each test series was composed of five repetitions of six different groupings of gas concentration probe positions, resulting in a total of 30 runs per test series.

The result of averaging the loop and injection flow test data was given in Table B.3-2. For each test series, the expected flow rate and the average achieved flow rate in actual cubic feet per minute are given on the first line of the table box. The second line gives the maximum and minimum flow rates recorded at any time during the five repetitions of each test. The tests results are currently being evaluated.

B.3.7 PXS Check Valve Hydraulic Test

General Description/Purpose

The **AP600** plant PXS uses check valves that operate at low differential pressure during gravity-drain injection. The **AP600** plant PXS line from the containment sump to the reactor vessel injection includes three check valves in series.

The PXS check valve test conducted at the Westinghouse Waltz Mill site used an hydraulic test facility configured to model the **AP600** plant PXS line from the containment sump to the reactor vessel injection connection. The check valve test facility was equipped with two pumps capable of providing a total maximum flow rate of 1000 gpm at about 100 psig discharge head. The pumps were connected to a common discharge header using isolation valves to permit individual or parallel operation, as required, to provide the specific test flow rates. One pump, equipped with a variable frequency drive, was able to satisfy all specified test flow rates (0 to 750 gpm), because of the relatively low-pressure drop associated with the check valves and facility piping.

The test facility also included a flow bypass line, control valves, and metering sections to permit flow control and measurement over the full specified flow. Flow metering sections consisted of calibrated electromagnetic flow meters; 1-inch, 4-inch, and 6-inch flow meters were used to cover the entire specified range of flow rates. The flow meters were installed in parallel vertical metering sections downstream of the check valve test section and in the test section of the loop return line to permit installation of longer lengths of straight pipe upstream.

The check valves were installed between removable piping spool sections of appropriate length to assure fully developed flow upstream and downstream of the check valve test section. The check valve test section was designed to model the **AP600** plant PXS line from the containment sump to the reactor vessel injection connection. The 6-inch valves were installed in series in the main 6-inch line. Flanged connections were provided to permit replacement of each 6-inch check valve with a corresponding length of straight pipe. The 4-inch check valve was installed in a separate 4-inch line that branched into the main 6-inch line via a reducing tee to simulate the proposed plant piping configuration. Isolation valves were provided to permit configuration of the piping to flow through the 4-inch line into the 6-inch line or to bypass the 4-inch line and flow directly through the 6-inch line.

Tests were conducted on individual 4-inch and 6-inch check valves typical of those utilized in the **AP600** plant PXS, with the check valves arranged in various configurations. Pressure taps for measuring differential pressure across the valves were installed. Transparent valve bonnets machined from clear acrylic plate were installed in place of the standard steel bonnets to permit observation and video recording of the valve opening and operational characteristics throughout the range of test flow rates.

Test Matrix/Results

Check valve configurations tested include one 4-inch check valve in series with two 6-inch check valves, two 6-inch check valves in series, and each of two 6-inch check valves individually.

Tests were performed over the range of flow rates between 0 and 750 gpm. Test flow rates were selected to characterize check valve operation when the check valve was fully open and pressure drop was a function of flow velocity, and when the check valve disc position was between fully closed and fully open and pressure drop was a function of the flow area associated with disc position.

The following characteristics were observed during testing and are applicable to each of the tested check valves, whether installed alone or in series:

At lower flow rates, with velocities not sufficient to support the check valve disc beyond 20 percent of the full-open swing, no disc fluctuation was observed.

At higher flow rates, with velocities sufficient to support the check valve disc beyond 20 percent of the full-open swing, but not sufficient to hold the disc in a wide-open position, slight disc fluctuation was observed. The amplitude and frequency of the disc fluctuation were not measured; however, both were sufficiently small that no flow variation was observed, and no valve damage would be expected.

Test flow rates corresponding to the minimum velocities for the tested valves were determined to be about 520 gpm (6.3 ft/sec) for the 4-inch check valve and 510 gpm (7.72 ft/sec) for the 6-inch check valves. At flow rates greater than the minimum value, the valve disc was held in a stable position against the valve stop. At flow rates lower than the minimum value, slight disc fluctuation, as described previously, was observed.

Examination of the check valves at the end of the test program showed no indications of wear.

The NRC staff position on passive failures (SECY 94-084) proposes "to define check valves except for those whose proper function can be demonstrated and documented, in the passive systems as active components subject to single failure consideration." The current PXS arrangement on the IRWST injection lines and the sump recirculation lines meets this position. The **AP600** plant PXS design using simple check valves provides a good design when considering operability (leakage probability/consequences), safety reliability, construction, maintenance, and in-service inspection (ISI)/in-service testing (IST).

Westinghouse has developed an IST plan for **AP600** plant passive system components (including check valves), based on utility input.

B.3.8 Operating Nuclear Plant Check Valve Tests

General Description/Purpose

The **AP600** plant PXS utilizes check valves that operated at low differential pressure during gravity-drain injection. The line from the containment sump to the reactor vessel injection connection includes two 6-inch check valves in series. Tests were conducted at two domestic nuclear power plants to assess the opening performance of check valves after prolonged exposure to reactor coolant system temperature, pressure, and chemistry conditions.

Test Matrix/Results

These tests were conducted to investigate the differential pressure required to open a reactor coolant boundary check valve after a full cycle of operation. The valves tested were 6-inch swing valves typical of those that could be utilized in the **AP600** plant PXS. These tests approximated both normal upstream and downstream pressure and temperature conditions of the check valves. Detailed data on valve opening and flow versus differential pressure was obtained.

Westinghouse modified the **AP600** plant design to incorporate squib valves to reduce the chance of leakage. This change eliminates the differential pressure seen by these check valves during standby operation. As a result, the operating conditions for these check valves is well within the range experienced in operating plants. This testing was not used to support licensing of **AP600** plant.

Table B.3-1 Boron Transport Simulation Test Series

Test Series	Loop 1 Cold- Leg Flow Rate (ft^3/min-leg)	Loop 2 Cold- Leg Flow Rate (ft^3/min-leg)	SI Flow Rate (ft^3/min)	SI Gas Species
1	1.48	3.02	0.32	CO_2
2	3.36	6.87	0.74	CO_2
3	4.37	8.93	0.96	SF_6
4	30.26	61.81	6.63	CO_2
5	0.0	3.85	0.25	CO_2
6	0.0	8.76	0.57	CO_2
7	0.0	11.38	0.73	SF_6
8	0.0	78.80	5.09	CO_2
9	39.40	39.40	5.09	CO_2

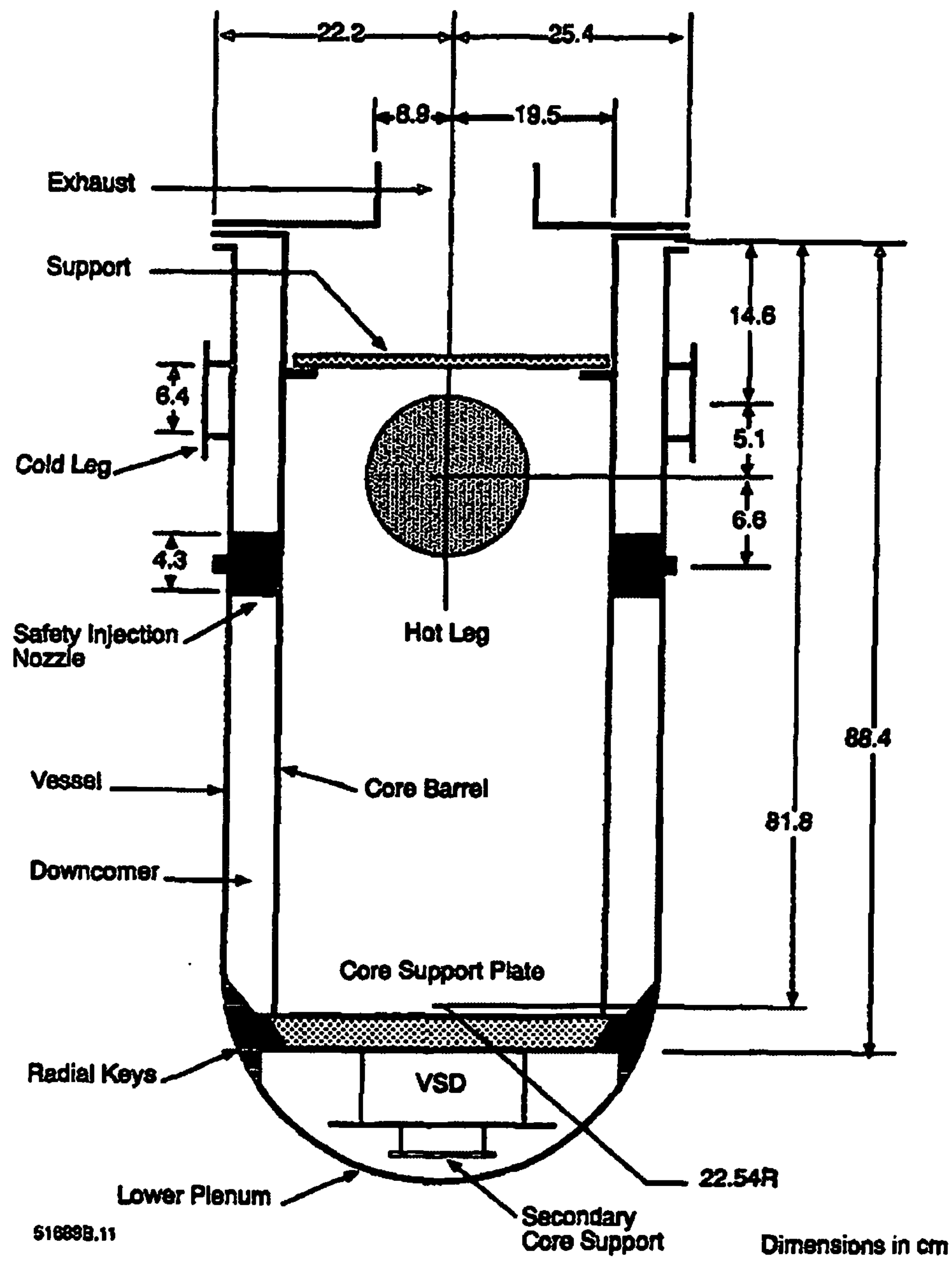


Figure B.3-1 Boron Transport Simulation Test Reactor Vessel Scale Model, Side View

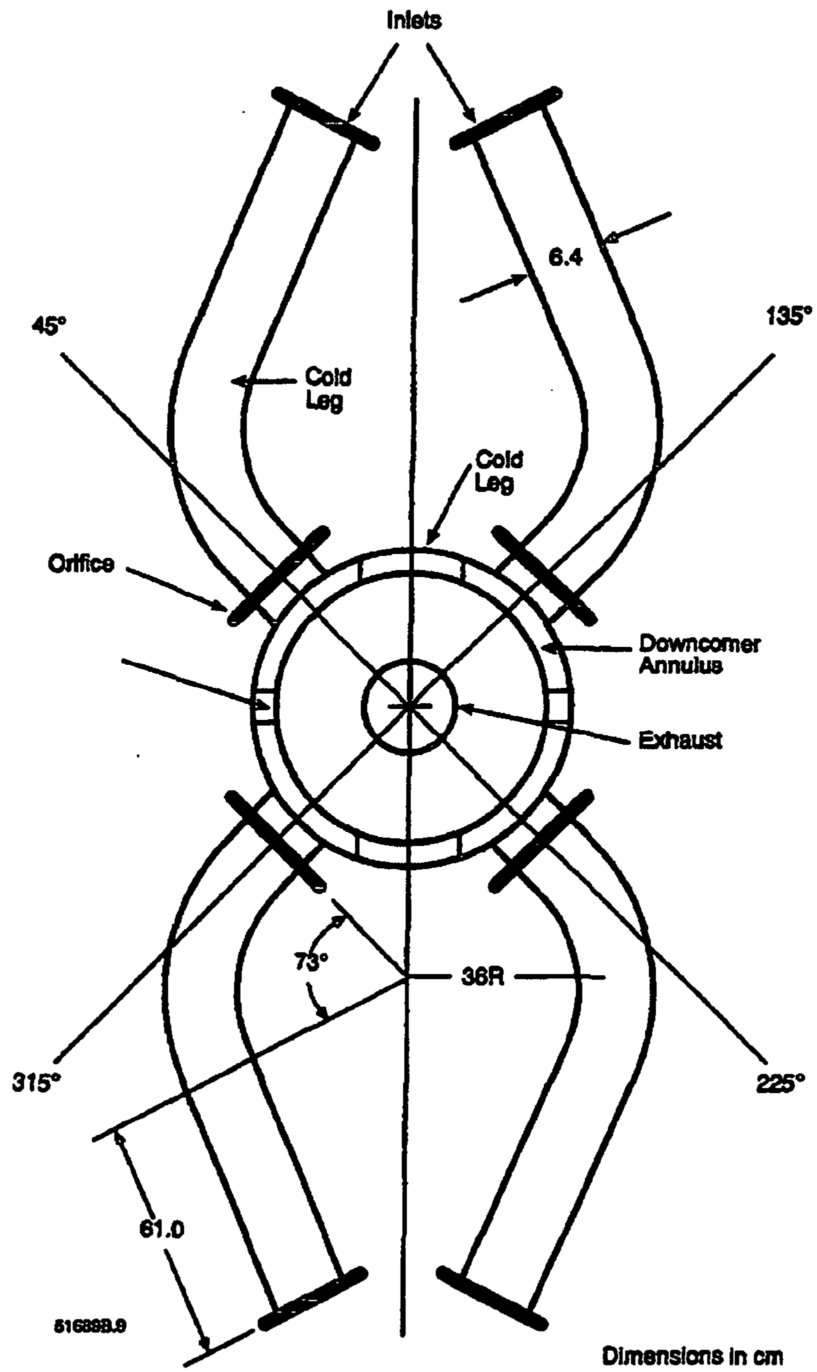


Figure B.3-2 Boron Transport Simulation Test Reactor Scale Model, Top View

APPENDIX C
USNRC RAIs AND RESPONSES

All Requests for Additional Information (RAIs) identified with "RAI-TR-SBLOCA-PIRT-" and "RAI-W SMR Test Plan and Scaling-" numbering have been included for completeness as portions of them are inter-related.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-01
Revision: 0

Question:

Please provide the latest detailed W-SMR design information supporting the Westinghouse Licensing Topical Report (LTR) for the W-SMR Small-break Loss of Coolant Accident (SBLOCA) PIRT.

Westinghouse Response:

Please see the attached plant parameter information.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[(1)]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[(1)]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[(1)]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter[1]	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
SMR Plant Parameters (cont.)

a,c,e

Input/Parameter(1)	Input/Parameter Value	Notes

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2
Containment Volume & ICP Surface Area as a Function of Containment Elevation

a,c,e

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-02
Revision: 0

Question:

Please provide the In-containment Pool (ICP) tank normal operating pressure and describe any inventory of non-condensable gases.

Westinghouse Response:

The In-Containment Pool (ICP) tanks are a set of 8 tanks that comprise two In-Containment Pools. Each ICP has a Sump Injection Tank (SIT) connected to it. The ICP tanks and SITs are all part of the same closed system, which is isolated from the Containment Atmosphere by rupture discs and Isolation Valves and from the Reactor Vessel (RV) by check and air-operated valves.

[ ]a,c,e

Any non-condensable gas can be vented from the high point of the SIT as well as from each ICP. [ ]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-03
Revision: 0

Question:

Please provide the rupture disk rupture pressure difference for the rupture disk at the top of the Sump Injection Tanks (SITs).

Westinghouse Response:

At the top of each of the Sump Injection Tanks (SITs), there are rupture disks. These rupture disks serve as a protection against both over-pressurization and under-pressurization of the SITs and the In-Containment Pool (ICP) Tanks. [ ][a,c,e]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-04
Revision: 0

Question:

Please provide detailed inputs (including assumptions, initial conditions, Emergency Core Cooling System [ECCS] setpoints, credited Engineered Safety Features [ESFs], operator actions, etc.) and analysis results (including event sequences, etc.) for the SBLOCA simulations.

Westinghouse Response:

The attachments provide both the Westinghouse proprietary and non-proprietary responses to this request for additional information.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

WESTINGHOUSE-SMR Direct Vessel Injection (DVI) LINE DOUBLE-ENDED GUILLOTINE BREAK LOCA ANALYSIS

1. INTRODUCTION

The Westinghouse Small Modular Reactor (SMR) is an 800 MWt (> 225 MWe) integral pressurized water reactor with all primary components, including the steam-generator and the pressurizer located inside the reactor vessel (Figure 1). The integration of pressurizer into the reactor vessel eliminates the need for a separate component. A single compact once-through straight tube steam generator produces saturated mixture from which steam is later separated in a steam drum outside the containment. Eight horizontally-mounted axial-flow pumps provide the driving head for the reactor coolant system while eliminating the need for pump seal injection.

The reactor core of Westinghouse SMR is made up of partial-length 17x17 Robust Fuel Assembly (RFA) design used in the **AP1000**®[1] reactor core. The fuel cycle is extended to 24 months. Within the reactor, internal control rod drive mechanisms provide a mix of reactor shutdown and control.

Containment is a compact steel vessel fabricated by a fully modular construction approach. It is designed to be able to sustain high pressures and is completely submerged in a pool of water, which acts as a heat sink during postulated accidents.

The Westinghouse SMR containment houses the integral reactor vessel and the passive safety system (PXS), which is illustrated in Figure 2. The SMR PXS, which is based largely on the passive safety systems used in the **AP1000** design, provides mitigation of all design basis accidents without the need for AC electrical power for at least seven days. The key components of the passive safety system are four core makeup tanks (CMTs) with an integrated passive residual heat removal (PRHR), heat exchanger two in-containment pool (ICP) tanks and associated Sump Injection Tanks (SITs), an automatic depressurization system (ADS), a boric acid storage tank (BAST), an outside-containment pool (OCP), and two ultimate heat sink (UHS) tanks [1].

The integral design of the reactor cooling system (RCS) contains no large bore piping and all penetrations in the reactor vessel are limited to 3-inch equivalent diameter, significantly reducing the flow area of postulated loss of coolant accidents. The vertical arrangement of the plant allows for a safe transition to natural circulation in the event of

1. AP1000 is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

a disruption to the forced reactor coolant flow and inherently places the majority of the RCS water directly above the core for use in cooling of the reactor during an event. These design features enhance the passive safety features of the plant.

These features and the PXS components combined provide the protection required to mitigate various initiating faults. In Reference 2, preliminary studies were presented for a DVI line double-ended guillotine (DEG) type break. In Reference 3, the study is expanded to include different break sizes and types, 0.5 inch split break, 1.0 inch split break, 2.0 inch split break, 3.0 inch split break and 3.0 inch DEG break on the DVI line to demonstrate how the passive cooling system will perform in a postulated LOCA event. In this report, the input model and a double-ended guillotine break scenario on one of the DVI lines are described. Note that the following input model description and results are preliminary.

The LOCA analysis was performed using a new generation of realistic LOCA safety evaluation code, WCOBRA/TRAC-TF2, which is capable to address LOCA safety analysis from the smallest break size to the largest break size (i.e., FULL SPECTRUM™[2]) and post-LOCA Long Term Core Cooling (LTCC). The details of code and its assessment and validation are provided in References 4 and 5.

2. THE WCOBRA/TRAC-TF2 CODE

The previous generation of Westinghouse realistic safety analysis code, WCOBRA/TRAC, was the Westinghouse evolution of the original COBRA/TRAC code by combining the COBRA-TF code and the TRAC-PD2 code [6]. The COBRA-TF code, which has the capability to model three-dimensional flow behavior in a reactor vessel, was incorporated to replace the TRAC-PD2 vessel model. Westinghouse continued the development and validation of COBRA/TRAC and the code was renamed WCOBRA/TRAC. WCOBRA/TRAC code has been shown to adequately model large break LOCA phenomena and the **AP1000** post-LOCA LTCC [7].

In order to address the small break LOCA analysis, the WCOBRA/TRAC code was subjected to a significant number of changes which led to the creation of the advanced WCOBRA/TRAC-TF2 (WCT-TF2) safety analysis code. The WCOBRA/TRAC-TF2 code is the combination of the 3D module of the current WCOBRA/TRAC and the TRAC-PF1. Thus, the original TRAC-PD2 five-equation drift-flux formulation was replaced with the more mechanistic six-equation, two-fluid formulation of TRAC-PF1. As part of the development of WCT-TF2, the 3D module (two-fluid, three-field model) was upgraded by including one additional mass conservation equation for the non-condensable species [5].

2. FULL SPECTRUM is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

A significant number of fluid dynamics and heat transfer models were developed or improved in WCT-TF2. Major developments and improvements are listed below:

- Break (critical) flow model
- Core void distribution (mixture level)
- Core heat transfer model
- Fuel rod deformation model
- Horizontal flow regime in the loops
- Cold-leg/downcomer condensation
- Loop seal clearance

The code assessment approach for the WCT-TF2 code includes the large set of experiments used for the original WCOBRA/TRAC assessment, and a new set of Separate Effects Tests (SETs) and Integral Effects Tests (IETs) for scenarios/phenomena identified in the FULL SPECTRUM™ LOCA PIRT [8]. The assessment also includes modeling of standard numerical problems and analytical benchmarks which are available in the literature. The results of the various test simulations demonstrated that WCOBRA-TRAC-TF2 is capable of simulating with sufficient accuracy, the key thermal-hydraulic phenomena that might occur during both large break and small break LOCA events in a PWR.

In summary, the WCOBRA/TRAC-TF2 code is a state-of -the-art LOCA safety evaluation code based on proven code and methodologies with two decades of continuous development and extensive experience for real applications in the industry.

3. WESTINGHOUSE SMR WCT-TF2 MODEL DESCRIPTION

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

3.1. Primary Reactor Coolant System

3.1.1. 3D Vessel Model

[

]a,c,e

3.1.2. Westinghouse SMR Core Model

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

3.1.3. Central Primary Riser and SG Primary Side

[

]a,c,e

3.1.4. Pressurizer Surge Plate

[

]a,c,e

3.1.5. Pressurizer

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

3.1.6. Reactor Coolant Pumps (RCP)

[

]a,c,e

3.2. Steam Generator Secondary System

[

]a,c,e

3.3. Passive Safety Systems

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

3.3.1. CMT Balance Lines

[

]a,c,e

3.3.2. ADS1 Valves

[

]a,c,e

3.3.3. ADS2 Valves

[

]a,c,e

3.3.4. Core Make-Up Tanks and PRHR

[

]a,c,e

3.3.5. Ultimate Heat Sink (UHS) Loop

[

]a,c,e

[

]a,c,e

3.3.6. Lower ICP/SIT, ICP Injection Lines

[

]a,c,e

[

]a,c,e

3.3.7. CMT Actuation Valves and Check-Valves

[

]a,c,e

3.3.8. Boric Acid Storage Tank

[

]a,c,e

3.3.9. DVI Lines

[

]a,c,e

3.4. Containment Vessel and the Outside Containment Pool

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

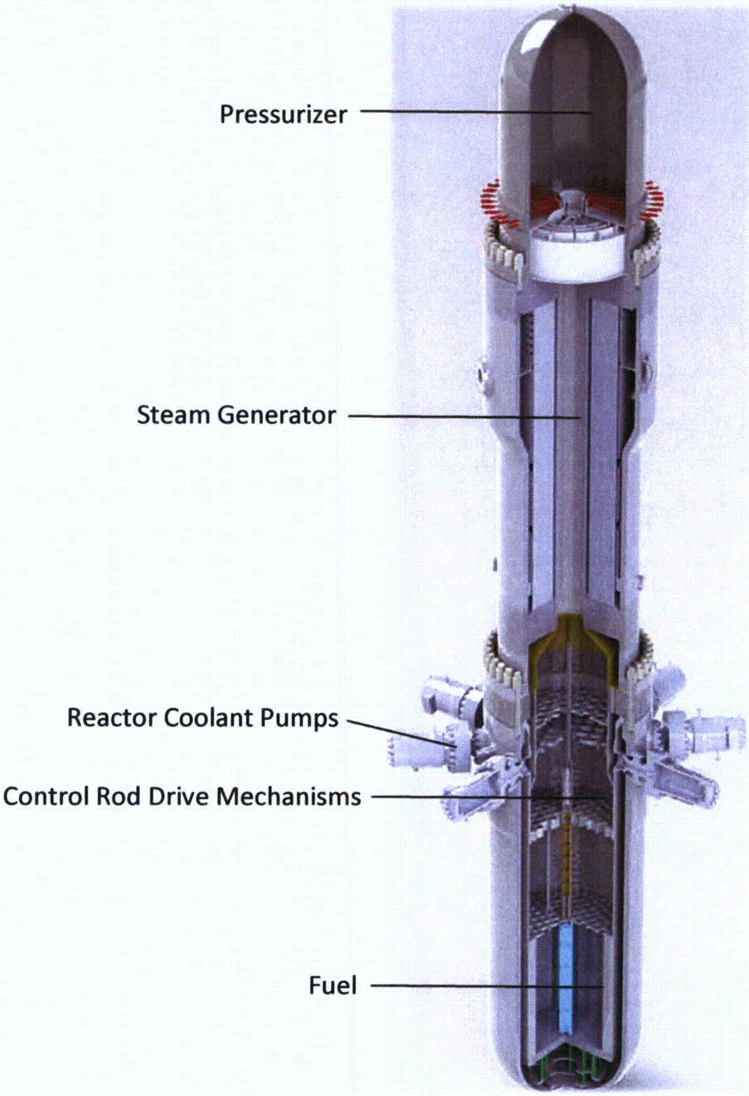


Figure 1: Westinghouse SMR Integral Reactor Vessel

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 2: Sketch of the Westinghouse SMR Passive Safety System

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 3: Westinghouse SMR WCT-TF2 Model VESSEL Input Noding

a,c,e

Figure 4: Gaps in Sections 6 through 10

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 5: Westinghouse SMR Core Configuration

a,c,e

Figure 6: Westinghouse SMR WCT-TF2 Model Input Noding

a,c,e

Figure 7: SMR Noding on the Central Primary Riser and SG Primary Side Region

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 8: Westinghouse SMR Secondary Side Noding Diagram

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 9: Lower ICP Noding Diagram

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 10: Illustration of ICP, Sump Injection Tank, Sump Line, ICP Injection Line Arrangement

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 11: Containment Vessel and the Outside Containment Pool Components

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

4. DVI LINE BREAK LOCA ANALYSIS

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

Table 1: Westinghouse SMR Signals and Actuations

a,c,e

[redacted]	[redacted]	[redacted]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2: Sequence of Events for Westinghouse SMR DVI Line DEG Break

a,c,e

[redacted]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 12: RCS and Containment Pressures

a,c,e

Figure 13: RCS and Containment Pressures

a,c,e

Figure 14: Break Flow, Vessel Side

a,c,e

Figure 15: Break Flow –CMT Side

a,c,e

Figure 16: DVI Injection Flow

a,c,e

Figure 17: DVI Injection Flow, First 2000 Seconds

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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[ ]

Figure 18: ADS1 Flows

a,c,e

[ ]

Figure 19: ADS2 Flows

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

[ ]

Figure 20: SIT Injection Flow

a,c,e

[ ]

Figure 21: Boric Acid Tank Injection Flows

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 22: Sump Circulation Flow

a,c,e

Figure 23: ADS2 Exit Quality

a,c,e

Figure 24: Heat Removal Rates

a,c,e

Figure 25: Heat Removal Rates

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 26: Vessel Inventory

a,c,e

Figure 27: Upper Plenum Collapsed Liquid Level

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

REFERENCES

1. M.C. Smith and R.F. Wright, "Westinghouse Small Modular Reactor Passive Safety System Response to Postulated Events," *Proc. of ICAPP'12,* Chicago, U.S.A. (2012).

2. J. Liao, V. N. Kucukboyaci, L. Nguyen and C. Frepoli, "Preliminary LOCA Analysis of the Westinghouse Small Modular Reactor Using the WCOBRA/TRAC-TF2 Thermal-Hydraulics Code," *Proc. of ICAPP'12,* Chicago, U.S.A. (2012).

3. V. N. Kucukboyaci and J. Liao, "LOCA Break Spectrum Analysis of the Westinghouse Small Modular Reactor," to be presented/published at the 21st International Conference on Nuclear Engineering, ICONE21, July 29-August 2, 2013, Chengdu, China.

4. C. Frepoli and K. Ohkawa, "The Development of a Realistic LOCA Evaluation Model Applicable to the Full Range of Breaks Sizes: Westinghouse Full Spectrum LOCA (FSLOCA™) Methodology," *Proc. of the 14th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics*, Toronto, Canada (2011).

5. C. Frepoli, K. Ohkawa and M. E. Nissley, "Development of WCOBRA/TRAC-TF2 Computer Code: Coupling of the 3D Module (COBRA-TF) with the 1D Module of TRAC-PF1/MOD2", *Proceedings of the 17th International Conference on Nuclear Engineering ICONE17,* Brussels, Belgium (2009).

6. C. Frepoli, "Review Article - An Overview of Westinghouse Realistic Large Break LOCA Evaluation Model," *Science and Technology of Nuclear Installations*, Vol. 2008, Hindawi Publishing Corporation, Article ID 498737 (2008).

7. Westinghouse AP1000 Design Control Documentation (DCD), Rev. 19, Chapter 15, Westinghouse Electric Company (2011).

8. C. Frepoli, K. Ohkawa, et al., *Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM™ LOCA Methodology),* WCAP-16996-NP, Revision 0, Westinghouse Electric Company (2010).

Westinghouse

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WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-05
Revision: 0

Question:

Please provide the analysis results for the SBLOCA simulations presented in pages A4-1 through A4-30 during the audit on May 2, 2013 in electronic format. The event progression and description is essential for understanding the scenario and for the review of the Westinghouse LTR on the SBLOCA PIRT.

Westinghouse Response:

The response to RAI-TR-SBLOCA-PIRT-4 has been provided electronically on a CD. Please note the CD contains proprietary information and has been marked as such.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-06
Revision: 0

Question:

Please provide the setpoints for the activation of all ECCS components. This includes the activation setpoints for various valves that are involved in the SBLOCA progression and the time delays between various Automatic Depressurization System Stage One (ADS-1) and ADS-2 openings. This information is also requested in electronic format for easy reference during PIRT Panel deliberations.

Westinghouse Response:

Table 1 provided in the response to RAI-TR-SBLOCA-PIRT-4 contains the ECCS component activation setpoints and delays. The response to RAI-TR-SBLOCA-PIRT-4 has been provided electronically on a CD. Please note the CD contains proprietary information and has been marked as such.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-07
Revision: 0

Question:

Please provide description, accompanied by a schematic diagram, of the connections (e.g., rupture disk, valves, etc.) at the top of the two SITs (also called "upper ICP tanks"). Also explain the purpose, function, and operational characteristics of each connection. Clarify whether the SITs are "water-solid" during normal operation, if this is the case; please explain how the rupture disk can function if it discharges into a water solid tank. If SITs are not water solid, provide the volume of the gas space at the top of the SITs.

Westinghouse Response:

[

]a,c,e

Reference:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

a,c,e

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-08
Revision: 0

Question:

Please clarify the operation of the SIT/ICP during injection. It would seem from the SBLOCA PIRT LTR that SIT/ICP flow begins when RPV pressure is low enough and the upper SIT rupture disc opens due to Containment Vessel (CV) over-pressure. But, the audit indicates that an S signal opens the SIT upper vent valve (maybe an Air Operated Valve (AOV)) and another AOV on the ICP injection line. Please provide more information on the operation and design of this system. In particular,

a) What is the arrangement of valves in the SIT/ICP system?

b) What types of valves are used? If the valves are AOV, is air required to open the valves?

c) How often is the system vented to remove non-condensable gases (NCGs)?

d) If the SIT/ICP is water solid, it is likely to have a cooling requirement. What is this requirement? How is it achieved? Could a single failure remove cooling to both SITs?

Westinghouse Response:

a) and b):

[

]a,c,e

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c,e

[

]a,c,e

c) [ ]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

d) [

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-09
Revision: 0

Question:

Please clarify the modeling of the AOV in the ICP injection line. It does not appear that the AOV in the ICP injection line is simulated in the WEC analysis.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-10
Revision: 1

Question:

Since the SIT vents, or appears to vent to CV, please specify the expected inventory of NCG in the CV.

Westinghouse Response:

Revision 0 (superseded by Revision 1 response):

[

]a,c,e

Revision 1:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-11
Revision: 0

Question:

The diagrams of the Core Makeup Tank (CMT) piping indicate a pressure balance line local high point. Please clarify how the accumulation of NCG in the high point of the piping is managed.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-12
Revision: 0

Question:

Please specify the maximum and (if non zero) normal flow rate in the Spray Line from the Reactor Coolant Pump (RCP) discharge to Pressurizer spray.

Westinghouse Response:

The spray flow rate can range from [ ]a,c,e depending on the spray demand flow based on the PZR level/pressure program. The [ ] a,c,e flow corresponds to the spray control valve completely closed and the only flow through the spray line nozzle into the PZR is that associated with flow through the [ ] a,c,e

a,c,e

[ ]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-13
Revision: 0

Question:

Please confirm that the only path for injection of water from the sump to the downcomer is via the lower ICP tanks, i.e., water from the sump enters the lower ICP tanks through the Sump Coupling Valves (SCVs), and subsequently enters the reactor vessel via the sump injection valves

Westinghouse Response:

[

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Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-14
Revision: 0

Question:

Various schematic diagrams presented during the audit on May 2, 2013 show the SCVs to be located at an elevation below the sump injection valves. Please confirm that this is an accurate description of the actual layout and provide the elevations for these valves from a specified datum.

Westinghouse Response:

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-15
Revision: 0

Question:

Has Westinghouse performed any sensitivity analyses using the computational models for W-SMR to determine/alter the importance ranking of phenomena in the W-SMR SBLOCA PIRT? If yes, please provide a description of the sensitivities and their impact on the importance rankings. If sensitivity calculations have not been performed, please provide the rationale for arriving at the various importance rankings, and the reasons for not supporting the rankings with sensitivity analyses.

Westinghouse Response:

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-16
Revision: 0

Question:

Please describe the type of debris anticipated in the W-SMR containment during an SBLOCA event? If possible, please compare and contrast with the debris profile that was the subject of GSI-191. Please explain the planned approach for demonstrating the effect of debris on blockage in the core, carryover of solids via ADS-2 and long term cooling performance. Please provide the bases for the type and quantity of debris being considered for any relevant testing.

Westinghouse Response:

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-17
Revision: 0

Question:

Please describe how the presence of debris and its retention was considered during the simulation of the SBLOCA that was used to inform Westinghouse's W-SMR SBLOCA PIRT. Please provide the values and the bases for the loss coefficients used for the sump screen and "trash rack."

Westinghouse Response:

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RAI-TR-SBLOCA-PIRT-16 describes the planned approach for GSI-191.

Reference:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-18
Revision: 0

Question:

Please describe the process that will be followed by Westinghouse to change the importance rankings in the W-SMR SBLOCA PIRT based on the results of the planned integral and separate effects tests.

Westinghouse Response:

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-19
Revision: 0

Question:

Please provide length and spring force of the plenum spring. Does the plenum spring have the same length and spring force as for the full-length assembly? If yes, what is its impact on the fuel pellets in a shorter stack?

Westinghouse Response:

The SMR plenum spring will be designed to have design margins equivalent to those of the **AP1000**®[1] PWR plenum spring. No excessive spring forces will be applied to the shorter pellet stack. The SMR fuel rod is constructed similar to the **AP1000** PWR fuel rod – except for the active fuel stack length. However, the plenum spring design is currently not completed. [

]a,c,e This design optimization will be completed to support submission of the SMR DCD, Revision 0.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-20
Revision: 0

Question:

Please provide design pressure of the containment.

Westinghouse Response:

The Westinghouse SMR containment design pressure is 250 psig.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-21
Revision: 0

Question:

Please describe and clarify the reactor trip after the SBLOCA initiation. Does the SBLOCA WEC analysis presume coincident Loss of Offsite Power (LOOP)? If so, does the reactor trip on LOOP? What is the assumed transient power?

Westinghouse Response:

In the SBLOCA scenario, the reactor is assumed to be at 100% power at the beginning of the transient. When the LOCA occurs, the reactor coolant system (RCS) inventory decreases; and consequently, the RCS pressure and pressurizer water level decrease. [

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-22
Revision: 0

Question:

The ADS-2 wet steam quality seems high for the SBLOCA simulation with the Direct Vessel Injection (DVI) line break. Please also describe how the steam quality was determined for the RSG outlet.

Westinghouse Response:

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Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-23
Revision: 0

Question:

Please list and describe the automatic trips of the RCPs.

Westinghouse Response:

The following lists the automatic reactor coolant pumps (RCPs) trips credited in the safety analyses.

RCP Trips
[

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Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-24
Revision: 0

Question:

Please discuss the extent of RCP vibration and countermeasures, including monitoring, trips, etc.

Westinghouse Response:

[

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-25
Revision: 0

Question:

Please clarify and provide detailed information on how the specific separate and integral effects tests planned for the W-SMR, i.e., the test plan or test matrix, correlate with the "gaps" in knowledge identified with the W-SMR SBLOCA PIRT.

Westinghouse Response:

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Response to Request For Additional Information (RAI)

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Response to Request For Additional Information (RAI)

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Response to Request For Additional Information (RAI)

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Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-26
Revision: 0

Question:

Please provide the information presented in pages B1-1 through B1-8 during the audit on May 2, 2013 in electronic format. The "gaps" in knowledge identified with the W-SMR SBLOCA PIRT are required to understand important SBLOCA phenomena.

Westinghouse Response:

The response to RAI-TR-SBLOCA-PIRT-25 – which provides the requested information – has been provided electronically on a CD. Please note the CD contains proprietary information and has been marked as such.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-27
Revision: 0

Question:

Please clarify what, if any, separate effects experiments are planned for the prototypic sump screen and "trash rack" to determine the fouling, pressure drop and debris non-retention in those components due to W-SMR specific debris (see Question #16 on type of debris). If no tests are planned, please provide the basis for the design of these components.

Westinghouse Response:

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Reference:

None.

Design Control Document (DCD) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-28
Revision: 0

Question:

Please provide clarification on whether the sump screen and "trash rack" will be included in the integral effects testing. If yes, please provide information on the scaling methodology for these components (note that information on the prototypic design is sought above). If not, please provide the rationale for the exclusion of these components.

Westinghouse Response:

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-29
Revision: 0

Question:

Please explain the approach for determining the prototypic pressure drops or loss coefficients in the core and the primary circuit. Please provide information on how these parameters will be scaled in the test facility during integral testing.

Westinghouse Response:

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-30
Revision: 0

Question:

Please provide detailed inputs (including assumptions, initial conditions, ECCS setpoints, credited ESFs, operator actions, etc.) and analysis results (including event sequence, etc.) for the following potential limiting events for consideration:

a) *Loss of forced reactor coolant flow (e.g., limiting trip of multiple RCPs)*

b) *Limiting decrease in Reactor Coolant Pressure Boundary (RCPB) temperature event (e.g., inadvertent Steam Generator Dump Valve (SGDV) opening or recirculation pump overspeed)*

c) *Limiting increase in RCPB temperature event (e.g., Main Steam Isolation Valve (MSIV) closure)*

d) *Steam Generator Tube Rupture (SGTR)*

e) *Inadvertent ADS Actuation*

f) *Inadvertent pressurizer Safety or Relief Valve (RV) opening*

g) *Malfunction of the Chemical and Volume Control System (CVCS)*

h) *Main steam line break inside CV*

i) *Control Rod (CR) ejection accident*

j) *Inadvertent/Uncontrolled Rod Withdrawal*

k) *Station Blackout*

l) *Anticipated Transient Without Scram (ATWS)*

Westinghouse Response:

The responses to the questions above are attached. Please note however for consistency, the order of the events discussed has been modified from that requested with the "Main steam line

break inside CV" discussed last due to the differences in the computer model used. The revised order that the response is presented in is:

a) Loss of forced reactor coolant flow (e.g., limiting trip of multiple RCPs)

b) Limiting decrease in Reactor Coolant Pressure Boundary (RCPB) temperature event (e.g., inadvertent Steam Generator Dump Valve (SGDV) opening or recirculation pump overspeed)

c) Limiting increase in RCPB temperature event (e.g., Main Steam Isolation Valve (MSIV) closure)

d) Steam Generator Tube Rupture (SGTR)

e) Inadvertent ADS Actuation

f) Inadvertent pressurizer Safety or Relief Valve (RV) opening

g) Malfunction of the Chemical and Volume Control System (CVCS)

h) Control Rod (CR) ejection accident

i) Inadvertent/Uncontrolled Rod Withdrawal

j) Station Blackout

k) Anticipated Transient Without Scram (ATWS)

l) Main steam line break inside CV

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

WESTINGHOUSE-SMR NON-LOCA ANALYSES

1. INTRODUCTION

The Westinghouse Small Modular Reactor (SMR) is an 800 MWt (> 225 MWe) integral pressurized water reactor with all primary components, including the steam-generator and the pressurizer located inside the reactor vessel (Figure 1). The integration of pressurizer into the reactor vessel eliminates the need for a separate component. A single compact straight tube steam generator produces saturated mixture from which steam is later separated in a steam drum outside the containment.
Eight horizontally-mounted axial-flow pumps provide the driving head for the reactor coolant system while eliminating the need for pump seal injection.

The reactor core of Westinghouse SMR is made up of partial-length 17x17 Robust Fuel Assembly (RFA) design used in the **AP1000**®[1] reactor core. The fuel cycle is extended to 24 months. Within the reactor, internal control rod drive mechanisms provide a mix of reactor shutdown and control.

The containment vessel is compact and fabricated by a fully modular construction approach. It is designed to be able to sustain high pressures and is completely submerged in a pool of water, which acts as a heat sink during postulated accidents.

The Westinghouse SMR containment houses the integral reactor vessel and the passive core cooling system (PXS), which is illustrated in Figure 2. The SMR PXS, which is based largely on the passive safety systems used in the **AP1000** plant design, provides mitigation of all design basis accidents without the need for AC electrical power. The key components of the passive safety system are four core makeup tanks (CMTs) with integrated passive residual heat removal heat exchanger (PRHR HX),
two in-containment pools (ICPs) and associated sump injection tanks, an automatic depressurization system (ADS), a boric acid storage tank (BAST), an outside containment pool (OCP), and two ultimate heat sink (UHS) pools (Reference 1).

The integral design of the reactor cooling system (RCS) contains no large bore piping. The vertical arrangement of the plant allows for a safe transition to natural circulation in the event of a disruption to the forced reactor coolant flow and inherently places the majority of the RCS water directly above the core for use in cooling of the reactor during an event. These design features enhance the passive safety features of the plant. These features and the PXS components combined provide the protection required to mitigate various initiating faults.

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The Non-LOCA analyses were performed using the RETRAN-3D thermal-hydraulic analysis code (Reference 2), which is capable of addressing the various Non-LOCA safety analyses addressed in Chapter 15 of the Design Control Document. The details of code and its assessment and validation are provided in Volumes 1 through 4 of Reference 2.

2. THE RETRAN-3D CODE

RETRAN-3D is a best-estimate transient thermal-hydraulic code designed to analyze operational transients, anticipated transients without scram, natural circulation, long-term transients, and events involving limited nonequilibrium conditions in light water reactors. It can also be used to analyze the steady-state and transient response of any thermal-hydraulic system using water as the cooling fluid.

The field equations solved include the integral form of the one-dimensional, homogeneous equilibrium mixture equations for the conservation of continuity, momentum and energy, with options to also use (1) a slip equation based on either dynamic or algebraic models, and (2) a slip equation and a vapor mass equation. The addition of a slip equation in the second and third options allows each phase in a two-phase mixture to move with a separate velocity. This is important in the analysis of many two-phase flow transients. The fluid in the homogeneous mixture and slip equation option is treated using an assumption of equilibrium thermodynamic conditions. In the third field equation option (referred to as the “five-equation” option), non-equilibrium conditions are allowed for a two-phase mixture, with the vapor phase in the mixture constrained to saturation conditions.

To all of the above options is added an additional mass conservation equation for non-condensables (when present). Non-condensables and/or water-vapor are lumped together to create what is referred to as the “gas” or “gas-phase.” The components of this gas phase are always well mixed and at a single temperature. Slip equations, when used, treat this gas phase as a second fluid that “slips” relative to the liquid phase. When homogeneous equilibrium assumptions are used, all of the phases (regardless of composition) exist at a single temperature. When non-equilibrium conditions are permitted, the gas temperature is mass weighted between the liquid temperature and the saturation temperature. That is when the gas contains solely non-condensables, its temperature is the liquid temperature; when the gas contains solely water vapor, its temperature is the saturation temperature. Between these endpoints the gas temperature is mass weighted, linearly, as a function of vapor mass to total gas mass. Input models for the code are developed by assembling the basic building blocks consisting of fluid control volumes, flow paths or junctions, and components (e.g., heat conductors, pumps, energy sources, valves, and control systems) into a representative model of the system to be analyzed. Node and component number assignments for the building blocks may be assigned in random order which allows the addition or deletion of components to be done with relative ease.

Overview of RETRAN-3D

RETRAN-3D has options to use the following features:

- iterative solution of the steady-state field equations and the control system and other component equations;
- an implicit, two-surface heat conduction model that allows internal power generation;
- models for one-dimensional and point reactor kinetics;
- trip logic;
- control system models;
- two sets of heat transfer correlations;
- flow and pressure boundary conditions;
- component models for pressurizers, steam separators, centrifugal pumps, valves, and accumulators; and
- special purpose models for modeling the movement of a temperature front or impurities.

Implicit solution methods are used for the steady-state and transient form of the field equations. Both linear and iterative nonlinear solutions of the transient field equations are available. The iterative transient solution method includes a number of algorithms used to provide automated time-step size control.

The equation-of-state properties are generally valid between 100 and 6000 psi, allowing for the analysis over a wide range of operating conditions. Separate numerical algorithms (algebraic and finite difference in form) are also used for the solution of other equations (e.g., equation of state, heat conduction, neutron kinetics, control system, and pump behavior) as required. The running times required to analyze a particular transient with RETRAN are dependent on the detail of the geometric model, the type of event to be analyzed, and the computer performing the calculation. The solution of the steady-state field equations typically requires between four and ten iterations for a PWR and between fifteen and thirty iterations for a BWR. An iteration in the solution of the steady-state equations is approximately equivalent to a time step for the transient equations. The time required for the solution of the transient field equations is dependent on the equations being solved (three-, four-, or five-equation and/or noncondensable options), the conditions for the problem (e.g., slowly varying or rapidly varying conditions), and the duration of the transient to be analyzed.

In summary, the RETRAN-3D code is an NRC approved (Reference 2) Non-LOCA transient thermal-hydraulic analysis code based on proven code and methodologies with two decades of continuous development and extensive experience for real applications in the industry.

3. WESTINGHOUSE SMR RETRAN-3D INPUT MODEL

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4. NON-LOCA ANALYSES

The RETRAN-3D based Non-LOCA safety analyses are listed below:

- Loss of Flow
- Limiting decrease in RCPB temperature
- Limiting increase in RCPB temperature
- Steam Generator Tube Rupture (SGTR)
- Inadvertent ADS Actuation
- Inadvertent Opening of Pressurizer Relief valve
- Malfunction of CVS
- Rod Ejection Event (Not applicable to design as discussed in attached.)
- Inadvertent/Uncontrolled Rod Withdrawal
- Station Blackout
- Anticipated Transient Without SCRAM (ATWS)

Each analysis is detailed in a separate section and provides a brief description of the event as modeled as well as figures depicting the transient response of the key system parameters. Tables 1 and 2 presented below provide a listing of the various actuation signals and signal delays utilized in the Non-LOCA analyses presented herein.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

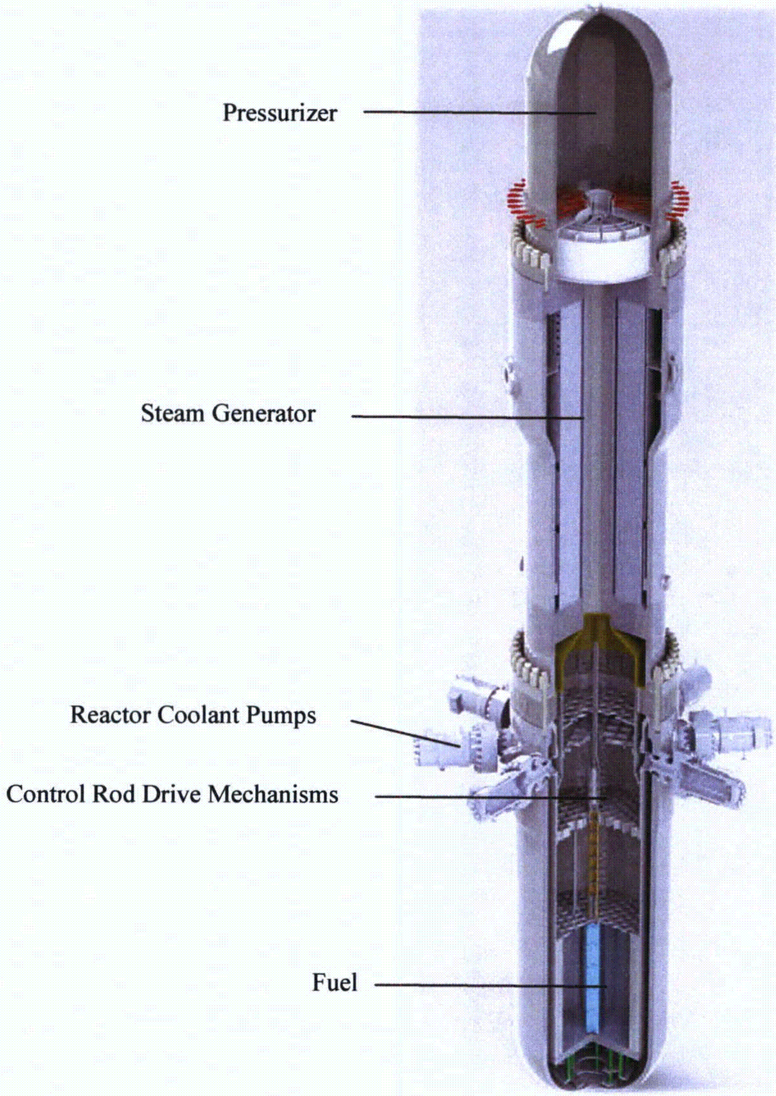

Figure 1: Westinghouse SMR Integral Reactor Vessel

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Figure 2: Sketch of the Westinghouse SMR Passive Safety System

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Figure 3: Westinghouse SMR RETRAN Primary Side Input Noding

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Figure 4: Westinghouse SMR RETRAN Secondary Side Input Noding

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

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Figure 5: Westinghouse SMR Core Makeup Tank Noding

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1: Reactor Trip Signals and Actuations

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2: Engineering Safeguards Control System Setpoints

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

A. Loss of Forced Reactor Coolant Flow

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table A-1: Sequence of Events for CLOF

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Figure A-1: Normalized Core Power vs. Time

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Figure A-2: RCP Flow vs. Time

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Figure A-3: RCP Speed vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Figure A-4: RCS Pressure vs. Time

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Figure A-5: RCS Temperature vs. Time

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Response to Request For Additional Information (RAI)

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Figure A-6: Pressurizer Level vs. Time

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Response to Request For Additional Information (RAI)

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Figure A-7: Secondary Side Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

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Figure A-8: Secondary Side Level vs. Time

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Response to Request For Additional Information (RAI)

B.1 Limiting Decrease in RCPB Temperature Event

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Figure B-1: MSL Limiting Break Location

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table B-1: Sequence of Events for the MSL Break Event

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Figure B-2: Normalized Core Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure B-3: Pressurizer Pressure vs. Time

a,c,e

Figure B-4: RCS Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure B-5: Pressurizer Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure B-6: Secondary Side Pressure vs. Time

a,c,e

Figure B-7: Secondary Side Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure B-8: Steam Flow vs. Time

[ ]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

C.1 Limiting Increase in RCPB Temperature Event (AOO)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table C.1-1: Sequence of Events for MSIV Closure

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure C.1-1: Core Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure C.1-2: RCS Pressure vs. Time

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Response to Request For Additional Information (RAI)

a,c,e

Figure C.1-3: RCS Temperature vs. Time

a,c,e

Figure C.1-4: Pressurizer Level vs. Time

a,c,e

Figure C.1-5: Steam Drum Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure C.1-6: Steam Drum Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

C.2 Limiting Feedline Break Event (PA)

[

]a,c,e

WESTINGHOUSE SMR REVIEW

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Table C.2-1: Sequence of Events for the FLB Event

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure C.2-1: Core Power vs. Time

a,c,e

Figure C.2-2: RCS Pressure vs. Time

a,c,e

Figure C.2-3: RCS Temperature vs. Time

WESTINGHOUSE SMR REVIEW
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a,c,e

Figure C.2-4: Pressurizer Level vs. Time

a,c,e

Figure C.2-5: Steam Drum Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure C.2-6: Steam Drum Level vs. Time

a,c,e

Figure C.2-7: RFW Line Break Flow vs. Time

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Response to Request For Additional Information (RAI)

D. Steam Generator Tube Rupture

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table D-1: Sequence of Events for the Steam Generator Tube Rupture Event

a,c,e

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-1: Core Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-2: RCS Pressure vs. Time

a,c,e

Figure D-3: RCS Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-4: Secondary Side Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-5: Secondary Side Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-6: Steam and Feed Flows vs. Time

a,c,e

Figure D-7: Recirculation Feedwater (RFW) Flow vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-8: Break and Makeup Flow vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-9: Pressurizer Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-10: Steam Drum Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-11: Secondary Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure D-12: CMT Flow vs. Time

E. Inadvertent ADS Actuation

[

]a,c,e

F.1 Inadvertent Opening of a PSV

[

]a,c,e

F.2 Pressurizer Spray Malfunction

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table F.2-1: Sequence of Events

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure F.2-1: Core Power vs. Time

a,c,e

Figure F.2-2: RCS Pressure vs. Time

a,c,e

Figure F.2-3: RCS Temperature vs. Time

a,c,e

Figure F.2-4: Pressurizer Level vs. Time

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c,e

Figure F.2-5: Steam Drum Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure F.2-6: Steam Drum Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure F.2-7: PZR Spray Flow vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

G. CVS Malfunction (Borated Water)

[

]a,c,e

H. Rod Ejection Event

[

]a,c,e

I. Inadvertent/Uncontrolled Rod Withdrawal

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
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Table I-1: Sequence of Events for the Rod Withdrawal Event

a,c,e

a,c,e

Figure I-1: Core Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure I-2: RCS Pressure vs. Time

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c,e

Figure I-3: RCS Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure I-4: Pressurizer Level vs. Time

a,c,e

Figure I-5: Steam Drum Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure I-6: Steam Drum Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

J. Station Blackout– Long Term Loss of Normal Feedwater with Loss of AC

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table J-1: Sequence of Events

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-1: Core Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-2: RCS Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-3: RCS Temperatures vs. Time

a,c,e

Figure J-4: Pressurizer Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-5: Steam Drum Pressure vs. Time

a,c,e

Figure J-6: Steam Drum Level vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-7: CMT #1 Flow vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure J-8: CMT #1 Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

K. Anticipated Transient Without Scram (ATWS)

K.1 General Background

[

]a,c,e

K.2 Anticipated Transients Without Scram in the Westinghouse SMR

[

]a,c,e

K.3 Sample ATWS Transient Response

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure K.3-1: RCS Pressure vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure K.3-2: RCS Temperature vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

References

1. M.C. Smith and R.F. Wright, "Westinghouse Small Modular Reactor Passive Safety System Response to Postulated Events," *Proc. of ICAPP'12,* Chicago, U.S.A. (2012).

2. **EPRI Report NP-7450(A)**, "RETRAN-3D --- Program for transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems," Volumes 1 through 4.

3. [ ]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

WESTINGHOUSE SMR WET STEAMLINE DOUBLE-ENDED GUILLOTINE BREAK INSIDE CONTAINMENT VESSEL ANALYSIS

1. INTRODUCTION

The break of wet steamline inside the containment vessel is considered as a challenge to the design pressure of the containment vessel due to the large size of the wet steam line and the compact size of containment vessel. The accident is mitigated by the core trip, the passive containment cooling provided by the containment vessel wall, outside containment pool (OCP) and passive heat sinks inside the containment, and the passive core cooling provided by the natural circulation through PRHR heat exchangers.

2. WESTINGHOUSE SMR WCOBRA/TRAC-TF2 MODEL DESCRIPTION

The wet steamline break accident analysis is performed using the WCOBRA/TRAC-TF2 safety evaluation code, which is employed for the SMR LOCA analysis (detailed description in the LOCA analysis report).The wet steamline break accident analysis shares the same nodalization used in the SMR LOCA analysis. Thus, a consistency on the containment response between the LOCA and wet steamline accident is maintained. The detailed input nodalization has been provided in the LOCA analysis document, and is not repeated in the document. However, the nodalization related to the steam generator is shown in Figure 1 to illustrate the SGs secondary side design and the location of the wet steamline break. [

]a,c,e

Initial conditions used in the wet steamline break analysis are shown in Table 1.

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Response to Request For Additional Information (RAI)

Table 2: Initial Condition of Wet Steamline Break inside Containment Vessel

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

[ ]

Figure 1: The Break Location of the Steamline DEG Accident; The Break Is Inside the Containment Vessel

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

3. WET STEAMLINE DEG BREAK ACCIDENT ANALYSIS

In this report, double ended guillotine (DEG) break at the wet steamline inside the containment is selected as the reference case to demonstrate the SMR containment pressure response and core cooling during this postulated accident. The nominal design values of the initial and operating conditions of the Westinghouse SMR are used for the simulation as seen in Table 1. The single failure assumed in this analysis is the [ ]^{a,c,e} which covers the mitigation of containment peak pressure and a part of the long term core cooling stage.

[

]^{a,c,e}

The simulation results of DEG break wet steamline inside the containment using WCOBRA/TRAC-TF2 are shown in Figures 2 through 10. Figure 2 shows that the steam generator secondary side pressure drops rapidly when the postulated accident occurs.

[

]^{a,c,e}

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2: Westinghouse SMR Signals and Actuations

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 3: Sequence of Events for Westinghouse SMR Wet Steamline DEG Break

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 2: Steam Generator 2ndary Side Pressure

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

[ ]

Figure 3: Containment Pressure

a,c,e

Figure 4: Break Flow - Steam Generator Side

a,c,e

Figure 5: Break Flow - Steam Drum Side

a,c,e

Figure 6: Flow Rate of SG Recirculation Line

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

[ ]

Figure 7: SG Secondary Side Collapsed Liquid Level

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Response to Request For Additional Information (RAI)

a,c,e

Figure 8: Primary Side RCS Pressure (extended time scale)

a,c,e

Figure 9: DVI Injection Flow Rates of 4 Trains

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Response to Request For Additional Information (RAI)

a,c,e

Figure 10: Comparison between Core Decay Heat and Heat Removals through SG and through PRHR

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-31
Revision: 0

Question:

Please provide the information presented in pages C-1 through C-90 and C.h-1 through C.h-10 during the audit on May 2, 2013 including all tables, such as Table 1 for Trip Signals and Actuations and Table 2 for Control System Setpoints, etc., in electronic format. The event progressions and descriptions are essential for identifying limiting events for the PIRT reviews and for confirming the scope of the SBLOCA PIRT LTR.

Westinghouse Response:

The response to RAI-TR-SBLOCA-PIRT-30 – which provides the requested information – has been provided electronically on a CD. Please note the CD contains proprietary information and has been marked as such.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-32
Revision: 0

Question:

The uncontrolled rod withdrawal accident analysis is presented in pages C-71 through C-77 of a document made available during the audit on May 2, 2013. The event analyzed therein was an uncontrolled rod withdrawal from hot full power. Please provide the rationale for simulating the event from full power. In addition, provide similar uncontrolled rod withdrawal accident analyses from other power levels including hot zero power and subcritical conditions. Specifically, the staff is interested in the uncontrolled rod withdrawal scenario that provides the limiting 'high startup rate' and the conditions under which this rate occurs. Please also provide the power (or count rate) at which the detector threshold condition is met for detection of this event.

Westinghouse Response:

[

]^{a,c,e}

Table 32-1 lists the sequence of events. Figure 32-1 illustrates the DNBR versus Time trace; and Figure 32-2 illustrates the Maximum RCS Pressure vs. Time trace for the Uncontrolled Rod Withdrawal event.

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Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Table 32-1
Uncontrolled Rod Withdrawal Sequence of Events

a,c,e

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Response to Request For Additional Information (RAI)

a,c,e

Figure 32-1: Uncontrolled Rod Withdrawal DNBR vs. Time

a,c,e

Figure 32-2: Uncontrolled Rod Withdrawal RCS Pressure vs. Time

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-33
Revision: 0

Question:

Please describe how the maximum reactivity insertion rate is determined for inadvertent CR withdrawal. Is there an associated design or Technical Specification (TS) that determines this rate? What feedback parameters are considered in the analysis? Were the analyses done with point or multi-dimensional kinetics? Are the consequences worse at Cold Zero Power (CZP)?

Westinghouse Response:

Maximum reactivity insertion rate was determined for two inadvertent control rod withdrawal transient categories:

1. Rod withdrawal at power (RWAP)
2. Rod withdrawal from subcritical (RWFS)

The maximum reactivity insertion rate was determined through [

]a,c,e

RWAP:

[

]a,c,e

The SAC limit is set to bound all potential future fuel cycle designs. The reload safety analysis checklist process confirms that the SAC limit for a specific reload core design is met.

[

]a,c,e

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Response to Request For Additional Information (RAI)

[

]a,c,e

RWFS:

[

]a,c,e

The SAC limit is set to bound all potential future fuel cycle designs. The reload safety analysis checklist process will confirm that the SAC limit for a specific reload core design is met.

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-34
Revision: 0

Question:

Please provide a description of each of the 'reactor modes' for the W-SMR.

Westinghouse Response:

MODES

MODES	TITLE	REACTIVITY CONDITION (k_{eff})	% RATED THERMAL POWER[(a)]	AVERAGE REACTOR COOLANT TEMPERATURE (°F)
1	Power Operation	≥ 0.99	> 5	Function of power level[(d)]
2	Startup	≥ 0.99	≤ 5	Function of power level[(d)]
3	Hot Standby	< 0.99	N/A	> 420
4	Safe Shutdown[(b)]	< 0.99	N/A	$420 \geq T_{avg} > 200$
5	Cold Shutdown[(b)]	< 0.99	N/A	≤ 200
6	Refueling[(c)]	N/A	N/A	N/A

Notes:

(a) Excluding decay heat.

(b) All reactor vessel closure bolts fully tensioned.

(c) One or more reactor vessel closure bolts less than fully tensioned.

(d) [

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

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PRA Revision:

None.

Technical Report (TR) Revision:

None.

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Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-35
Revision: 0

Question:

Please provide Departure from Nucleate Boiling Ratio (DNBR) plots that demonstrate the conclusion that DNBR criteria are met for the transients with Min DNBR acceptance criteria.

Westinghouse Response:

The following pages contain the DNBR plots for the following bounding transients:

- Figure 35-1 – Feedwater Malfunction event
- Figure 35-2 – Pressurizer Spray Malfunction event
- Figure 35-3 – Main Steamline Break event
- Figure 35-4 – Recirculation Steamline Break event
- Figure 35-5 – Complete Loss of Flow event

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 35-1: Feedwater Malfunction DNBR vs. Time

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Response to Request For Additional Information (RAI)

a,c,e

Figure 35-2: PZR Spray Malfunction DNBR vs. Time

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c,e

Figure 35-3: Main Steamline Break DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 35-4: Recirculation Steamline Break DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 35-5: Complete Loss of Flow DNBR vs. Time

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Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-36
Revision: 0

Question:

Please provide sequence of events for the Pressurizer Spray Malfunction and Uncontrolled Rod Withdrawal events.

Westinghouse Response:

Table 36-1 lists the Uncontrolled Rod Withdrawal at Power sequence of events.

Table 36-2 lists the Uncontrolled Rod Withdrawal at Subcritical sequence of events.

Table 36-3 lists the Pressurizer Spray Malfunction event sequence of events.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Table 36-1
Uncontrolled Rod Withdrawal at Power Sequence of Events

a,c,e

Time (sec)	Description

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Response to Request For Additional Information (RAI)

Table 36-2
Uncontrolled Rod Withdrawal at Subcritical Sequence of Events

Time (sec)	Description

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 36-3
PZR Spray Malfunction Sequence of Events

a,c,e

Time (sec)	Description

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Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-37
Revision: 0

Question:

Please clarify why the Loss of Recirculation Feedwater event is the bounding Station Blackout (SBO).

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-38
Revision: 0

Question:

Please provide the point kinetics data used to support the transient analyses (reactivity coefficients, delayed neutron fractions, decay constants, etc.).

Westinghouse Response:

The following point kinetics data appears in the Safety Analysis Checklist (SAC) interface document to support the transient analyses:

a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

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Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

a,c,e

Figure 1: SMR Trip Reactivity Shape SAC Limit

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-39
Revision: 0

Question:

Please describe normal alignment of the CVCS. Is there a possible normal alignment of the CVCS that could result in unborated water injection?

Westinghouse Response:

The normal CVS alignment includes charging pumps that can draw water from both the demineralized water system and the boric acid storage tank. Two control valves blend these two streams to achieve the desired boron concentration to a common charging pump header. The charging pump output controls flowrate from the CVS to the primary system. Because the charging pumps are connected to the demineralized water system, it is possible to inject unborated water. This risk is being mitigated by mechanically limiting charging pump flow rate below a value that could cause a boron dilution event during plant modes other than refueling. Potential dilution sources will be isolated (closed valves) during refueling operations.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-40
Revision: 0

Question:

Westinghouse's response to RAI-TR-SBLOCA-PIRT-3 states that the opening pressure of the rupture disk is [ ]^{a,c,e}. The reviewers' understanding is that the rupture disk opens on a pressure differential. It is understood that since the SITs are initially at [

]^{a,c,e}. However, the SIT pressure can change during a transient. Please clarify whether the value in the response can be considered to be the differential pressure for the opening of the rupture disk throughout the transient. If not, please provide the relevant value and/or clarify.

Westinghouse Response:

The rupture disks provide both over-pressure protection and under-pressure protection for the sump injection tanks (SITs). The subsystem comprising the SITs and the in-containment pools (ICPs) is isolated from the reactor coolant pressure boundary (RCPB). This subsystem is designed to provide safety injection when the pressure in the reactor coolant system (RCS) is less than the driving head from the SITs, when the subsystem pressure has equalized with containment. For normal SIT actuation, air-operated valves (AOVs) located on top of the tank equalize the pressure with containment at a pressure lower than the design pressure. This happens when the containment pressure increases and prevents the system from becoming under-pressurized. The rupture disk serves as an over-pressure and under-pressure relief device for the SITs and SIT/ICP subsystem. Rupture disks open when the differential pressure across them is greater than the pressure rating of the disk itself. [

]^{a,c,e}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-41
Revision: 0

Question:

Please provide clarification to the following items related to your response to RAI TR SBLOCA PIRT-4:

a. *Section 10 of the nodalization of the W-SMR vessel in WCOBRA-TRAC-TF2 is described as representing [ ]^{a,c,e} The ADS 1 lines are located at the top of the CMTs. Please explain the necessity and purpose of [ ]^{a,c,e}*

b. *Does the ADS 1 opening on [ ]^{a,c,e}*

c. *If the pressurizer heaters were credited to operate during the simulation please provide the capacity for all heaters (backup and proportional) and the corresponding activation setpoints?*

d. *The description of LOCA event states (on page 24 of 38 of the response) that [ ]^{a,c,e}. The "ADS attached to lines off the CMT" is believed to refer to the ADS 1. [ ]^{a,c,e} Please clarify.*

e. *If the boron in the CMT tanks and the BAST was credited during the LOCA simulation, please provide the corresponding concentrations.*

Westinghouse Response:

[ ]^{a,c,e}

WESTINGHOUSE SMR REVIEW
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[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-42
Revision: 0

Question:

Westinghouse's response to RAI TR SBLOCA PIRT-23 provided a list of the credited automatic RCP trips. Please provide the corresponding setpoints.

Westinghouse Response:

The following are the setpoints associated with the reactor coolant pump trips referred to in RAI-TR-SBLOCA-PIRT-23.
[

][a,c,e]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-43
Revision: 0

Question:

Westinghouse's response to RAI TR SBLOCA PIRT-24 states that [

]a,c,e please provide additional information on design features and countermeasures that prevent catastrophic RCP failure due to excessive vibration that may result in a large break LOCA.

Westinghouse Response:

[

]a,c,e

a,c,e

[ ]

Figure 43.1. Depiction of RCP flange bolts connected to the RCP vessel

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-44
Revision: 0

Question:

Westinghouse's response to RAI TR SBLOCA PIRT-30 does not provide a table listing the sequence and timing of events during the ATWS simulation. Please provide such a table.

Westinghouse Response:

Consistent with the response to RAI-TR-SBLOCA-PIRT-30l – and based on the sample anticipated transient without scram (ATWS) transient cited – Table 44-1 lists the corresponding sequence of events.

Table 44-1 – ATWS (PIRT 30l) Sequence of Events

a,c,e

[ ]

Reference:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-45
Revision: 0

Question:

Please supplement the supplied response to RAI TR SBLOCA PIRT-30 by explaining the purpose and activation of the Recirculation Feed Line (RFL) bypass.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-46
Revision: 0

Question:

Please supplement the supplied response to RAI TR SBLOCA PIRT-34 by briefly explaining how the water temperature control function is monitored and controlled.

Note: The NRC verbally clarified that the "water" referred to in the above question is reactor coolant system water.

Westinghouse Response:

[

]a,c,e

[ ]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-47
Revision: 0

Question:

Please supplement the supplied response to RAI TR SBLOCA PIRT-35 by identifying the limiting DNBR criteria used in the Westinghouse SAC.

Westinghouse Response:

[

]^{a,c,e}

Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-48
Revision: 0

Question:

Please supplement the supplied response to RAI TR SBLOCA PIRT-38 by providing the prompt neutron lifetime and the 6 group λ and β values

Westinghouse Response:

The prompt neutron lifetimes used in the safety analyses (in seconds) are:
[

]^{a,c,e}

The six-group delayed neutron time constants λ (in units of sec^{-1}) are:
[
]^{a,c,e}

The six-group delayed neutron yields – scaled to percentages of β_{eff} – are:
[

]^{a,c,e}

The bounding β_{eff} values are:
[
]^{a,c,e}

Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-49
Revision: 0

Question:

It is recognized that the neutronics methodology used by Westinghouse for rod withdrawal events in their PWR designs is well established and validated. However, based on the response to RAI TR SBLOCA PIRT-32, please clarify what Westinghouse has done to validate the methodology for the rod withdrawal event in the W-SMR considering the change in reactor geometry (e.g., shorter core) and composition (e.g., different reflectors) relative to PWR designs.

Westinghouse Response:

The methodology used to calculate the maximum differential rod worth for the Westinghouse SMR rod withdrawal event (see response to RAI-TR-SBLOCA-PIRT-33) is [

]^{a,c,e}

The Westinghouse SMR fuel is [

]^{a,c,e}.

The effect of the shorter core height is [
]^{a,c,e}. The Westinghouse SMR radial reflector is [

]^{a,c,e}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-50
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-30 would appear to indicate that the inadvertent ADS-1 or ADS-2 actuation event is considered a LOCA. Please clarify why these events are considered accident scenarios as opposed to anticipated operational occurrences.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-51
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-4 would appear to indicate that the DVI line break analyzed is a double-ended guillotine break. However, the model includes the CMT discharge actuation valve. If this valve is closed at the onset of the accident or during the accident, the break would appear to be single ended for at least a portion of the event. Please clarify the expected operation of this valve during a postulated DVI line break accident.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

Westinghouse

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-52
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-30 Part J considers a loss of AC power; however, the response appears to indicate that [

]a,c,e Please clarify the response.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse Non-Proprietary Class 3

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-53
Revision: 0

Question:

The revised response to RAI TR SBLOCA PIRT-10 indicates that [ ]a,c,e. Please provide additional details as to how [ ]a,c,e.

Westinghouse Response:

1. Nominal containment vessel (CV) pressure is maintained less than or equal to [ ]a,c,e
2. The initial CV pressure increase from NCGs is included in the plant response during Design Basis Accidents (DBAs).
3. The following Technical Specification will exist: When CONDITION CV pressure remains above [ ]a,c,e, an ACTION will require the containment pressure to be restored to within the limits or the plant to move to a higher mode (shutdown) within an appropriate COMPLETION TIME.
4. [ ]a,c,e

Reference:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Westinghouse

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WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-54
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-25 states that [

]a,c,e provide beginning and ending times for the different phases for the representative DVI line break accident described in response to RAI TR SBLOCA PIRT-4. To further assist the staff in reviewing the RAI TR SBLOCA PIRT-4 and RAI TR SBLOCA PIRT-25 responses, provide updated versions of Table 2 and Figure 26 with the start and end times for [ ]a,c,e indicated.

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 1. Sump Recirculation Flows and Sump Injection Tank Collapsed Liquid Levels

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1: Sequence of Events for Westinghouse SMR DVI Line DEG Break

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

Figure 2: Vessel Inventory

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-55
Revision: 0

Question:

Figure 15 in the response to RAI-TR-SBLOCA-PIRT-04 shows [

]a,c,e

Westinghouse Response:

[

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-56
Revision: 0

Question:

Please provide the timing of the following events from the DVI line break analysis performed by Westinghouse (follow-on RAI to RAI TR SBLOCA PIRT-4):

a. *Transition of break, ADS-1 and ADS-2 flow from sonic to sub-sonic,*
b. *Complete drainage of the liquid from the pressurizer,*
c. *Collapsed water level falling below the top of the riser (i.e. termination of loop-wide natural circulation).*

Westinghouse Response:

a. [

]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 1 Pressurizer Collapsed Liquid Level

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-57
Revision: 0

Question:

Please provide the following additional information regarding the Loss of Recirculation Feed Water that is analyzed as a surrogate for the SBO event (follow-on RAI to RAI TR SBLOCA PIRT-30):

a. *Was the scenario simulated for the coping period of 72 hours? If not, please provide a rationale for not extending the period of simulation beyond 1 hour.*
b. *Will re-filling of the UHS be necessary during the 72 hour period? If so, will this be credited in the simulation?*

Westinghouse Response:

[

]a,c

Reference:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-58
Revision: 0

Question:

The responses to RAIs TR SBLOCA PIRT-32 and 33 [ ]^a,c,e^. Please provide analysis results for such an event.

Westinghouse Response:

The responses to RAIs TR-SBLOCA-PIRT-32 and 33 [ ]^a,c^

Figure 58-1 illustrates the average neutron flux transient for the uncontrolled rod withdrawal transient at subcritical conditions. [ ]^a,c^ The heat flux response [ ]^a,c^ is shown in Figure 58-2. [ ]^a,c^ The minimum DNBR remains above the design limit value throughout the transient. The calculated sequence of events is shown in Table 58-1. Note that this sequence of events was previously provided in response to RAI-TR-SBLOCA-PIRT-36.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

[ ]a,c

Figure 58-1: Uncontrolled Rod Withdrawal from Subcritical Nuclear Power vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 58-2: Uncontrolled Rod Withdrawal from Subcritical Heat Flux vs. Time

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Table 58-1
Uncontrolled Rod Withdrawal at Subcritical Sequence of Events

Time (sec)	Description

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-59
Revision: 0

Question:

Was reverse flow from the break into the reactor vessel (i.e. flooding of the break) noted during the analysis of the various breaks performed by Westinghouse? If yes, please provide information about the break location, the time in the accident when the break is flooded and the type of flow (critical or sub-sonic) out of the break at the time of flooding.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-60
Revision: 0

Question:

It appears that [
]a,c,e. Please elaborate on the importance of this phenomenon and the approach used to determine that the [ ]a,c,e.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-61
Revision: 0

Question:

Please explain the method for dealing with any hydrogen and oxygen generated due to radiolysis and released during accidents.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-62
Revision: 0

Question:

Please provide update on W-SMR Test Plan and Schedule.

Westinghouse Response:

[

]d

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-63
Revision: 0

Question:

Please clarify status and schedule of the non-LOCA PIRTs for the W-SMR. Does Westinghouse plan to submit the non-LOCA PIRTs to NRC for review?

Westinghouse Response:

[

]^{d}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-64
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-30 Part C considers a Recirculation Feed Line Break (RFLB) event. Please provide clarifications and additional information on the following items:

a. *Please confirm that the location of the RFLB is outside the containment.*
b. *It appears that [*

   ]a,c,e
c. *Please demonstrate that long term cooling through PRHR HX is effective for RFLB.*
d. *Please discuss purpose and significance of [*

   ]a,c,e

Westinghouse Response:

a. The recirculation feedline break (RFLB) presented in response to RAI-TR-SBLOCA-PIRT-30 Part C reflects a break [

   ]a,c

b. [

   ]a,c

   Table 64-1 provides an updated time sequence of events which provides the information requested.

c. The scenario was simulated for [

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]^{a,c}

d. The "RFL Pump Bypass Opens" statement in Table C.2-1 of RAI-TR-SBLOCA-PIRT-30 [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 64-1: Sequence of Events for the FLB Event

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-65
Revision: 0

Question:

Please clarify the following apparent inconsistences in Table 1 (page 27 of 38) and Table 2 (page 28 of 38) provided with the response to RAI-TR-SBLOCA-PIRT-04:

a. *According to Table 1 the reactor trip should occur with a [*

]a,c,e

b. *According to Table 1, [ ]a,c,e. Table 2 shows the [*

]a,c,e

Westinghouse Response:

There is an inconsistency in Table 1 of RAI-TR-SBLOCA-PIRT-04 as noted in the question. [ ]a,c Table 1 in RAI-TR-SBLOCA-PIRT-04 is updated and provided on the following page with the changes highlighted to correct the noted inconsistencies. The order of the signals was also modified to correspond to the anticipated sequence. Table 2 of RAI-TR-SBLOCA-PIRT-04 was modified for consistency with Table 1 and to clarify the sequence of events.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1: Westinghouse SMR Signals and Actuations

a,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2: Sequence of Events for Westinghouse SMR DVI Line DEG Break

a,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-66
Revision: 0

Question:

The SBLOCA DVI line break scenario provided with the response to RAI-TR-SBLOCA-PIRT-04 [

]a,c,e

Westinghouse Response:

[

]a,c

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-67
Revision: 0

Question:

Several mDNBR plots were provided in the response to RAI-TR-SBLOCA-PIRT-35 but the minimum allowable DNBR is not shown on these plots. Please provide updated plots showing the safety limit DNBR and briefly discuss the basis of this safety limit. In addition, please identify the correlation used for the mDNBR plots and discuss the applicability of this correlation to the W-SMR fuel.

Westinghouse Response:

The [ ]^{a,c} correlation was used in developing the plots provided in response to RAI-TR-SBLOCA-PIRT-35. [

]^{a,c} The following pages contain the DNBR plots with the safety analysis limit DNBR of [ ]^{a,c} identified:

- Figure 67-1 – Feedwater Malfunction event
- Figure 67-2 – Pressurizer Spray Malfunction event
- Figure 67-3 – Main Steamline Break event
- Figure 67-4 – Recirculation Steamline Break event
- Figure 67-5 – Complete Loss of Flow event

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c

Figure 67-1: Feedwater Malfunction DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 67-2: PZR Spray Malfunction DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 67-3: Main Steamline Break DNBR vs. Time

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c

Figure 67-4: Recirculation Steamline Break DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 67-5: Complete Loss of Flow DNBR vs. Time

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-68
Revision: 0

Question:

The response to RAI TR SBLOCA PIRT-30 Part L considers a Recirculation Steam Line Break (RSLB) event. Please provide clarifications and additional information on the flow restrictor or nozzle (if any) upstream the break location on the steam generator side. Did the analysis assume choking on the steam generator side of the break?

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-69
Revision: 0

Question:

The last line of the first paragraph on page 1-3 states that [

]^{a,c}

Westinghouse Response:

In the current design, the [ ]^{a,c} Figures 1-1, 1-3 and 3-1 through 3-5 will be revised to reflect this arrangement.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P will be revised by the changes above. These include text on page 1-3, Figures 1-1, 1-3, and 3-1 through 3-5. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-70
Revision: 0

Question:

The second paragraph on page 1-3, Figures 1-1, 1-3, 1-5 and 1-6 calls the tanks connected to the lower ICPs as "top ICPs" or "ICP tanks". Based on recent information provided by Westinghouse it appears that these tanks are now called "Sump Injection Tanks" or SITs. Please confirm and, if necessary, make appropriate changes in the LTR for clarity. Please also update the description for component 'T' in Table 1-1 and the nomenclature list accordingly.

Westinghouse Response:

The two tanks that are elevated inside containment and provide the hydrostatic head to promote gravity injection are connected to [ ]^{a,c} large tanks of water in the bottom of the containment. [

]^{a,c} At the time the PIRT was completed, the lower tanks were referred to as "Lower ICP Tanks" and the upper tanks were referred to as "Upper ICP Tanks". This was confusing, so the name of the upper tanks was changed to "Sump Injection Tanks (SITs)", and the lower tanks were referred to as the "ICP Tanks". This updated nomenclature will be made to the PIRT when revised.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Changes to the nomenclature within WCAP-17573-P will be made in the next revision. These changes will be throughout the WCAP as needed including those indicated above. These changes will modify the "upper ICP tanks" to "sump injection tanks (SITs) and the "lower ICP tanks" to "ICP tanks". These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-71
Revision: 0

Question:

Section 1.2 of the LTR states (second line of the first paragraph on page 1-4) that "all of the safety components are passive and require no AC power or operator action to function." However, the plant description on pages 1-2 and 1-3 of the LTR does not specify the valve type for the CMT return (DVI) line and the ADS-1. Please provide information on these valve types and their performance during loss of AC to support the assertion that no AC power is required for the safety systems.

Westinghouse Response:

The valves on the Core Makeup Tank (CMT) discharge lines are [

]a,c

The ADS-1 valves are [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-72
Revision: 0

Question:

Table 1-2 provides elevations for various W-SMR components and penetrations but does not provide the reference for these elevations. Please provide an appropriate reference point.

Westinghouse Response:

In response to RAI-TR-SBLOCA-PIRT-73 these elevations have been updated. The reference point for the updated elevations is the inside surface of the bottom of the containment vessel, this defines the 0.0 ft elevation.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-73
Revision: 0

Question:

Please make changes, if necessary, to Tables 1-2 and 1-3 and Figure 1-2 based on the latest design information.

Westinghouse Response:

The changes to Tables 1-2 and 1-3 and Figure 1-2 are provided in response to RAI-TR-SBLOCA-PIRT-103.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 1-2 and 1-3 and Figure 1-2. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-74
Revision: 0

Question:

The scenario description during the blowdown phase as given in Table 2-1 states [ ]^{a,c} which appears to be contradicted by the event sequence for the DVI DEGB provided in response to RAI-TR-SBLOCA-PIRT-04 (see also RAI # 91). In addition, the description in Table 2-1 states [ ]^{a,c}. Based on the information provided by Westinghouse, the [ ]^{a,c}. In addition, it appears that these tanks are now referred to as SITs (see RAI # 70). Please address all of the cited inconsistencies in Table 2-1. Note that Section 3.2 has the same inconsistencies.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

WCAP-17573-P changes are needed for the above items. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-75
Revision: 0

Question:

The phase definitions and the variation of key parameters during each phase as shown in Figure 2-3 of the LTR appear to be inconsistent with the analysis results presented in response to RAI-TR-SBLOCA-PIRT-04. Similarly, the event descriptions in Figures 3-2 through 3-5 also appear to be inconsistent with the event timings provided in response to RAI-TR-SBLOCA-PIRT-04. Please address these inconsistencies.

Westinghouse Response:

Provided in the response to TR-SBLOCA-PIRT-74, Figure 2-3 will be revised such that the [ ]^{a,c} Figures 3-2 through 3-5 will also be revised to reflect this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P will be revised for the item above. WCAP-17573-P changes are needed for the above items. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-76
Revision: 0

Question:

The second paragraph on page 3-14 of the LTR states that [ ]^{a,c} which is inconsistent the information provided by Westinghouse that [ ]^{a,c}. In addition, the cited statement is also inconsistent with that made on page 3-13 of the LTR where it was mentioned that [ ]^{a,c} open (see RAI #74). Please address these inconsistencies.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P page 3-14 will be revised to indicate the proper signal. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

[1] The sump injection tanks are referred to as ICP tanks in WCAP-17573-P Revision 1.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-77
Revision: 0

Question:

The importance ranking for [

]^{a,c} Please explain and further justify the ranking and rationale for A.1.d in Table 3-3, especially during [ ]^{a,c}.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P will be revised based on the update to the A.1 phenomenon. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-78
Revision: 0

Question:

The phenomena of [

]a,c. Such behavior is believed to be highly design specific.
[

]a,c In light of this, please explain the rationale for even a 'Moderate' knowledge ranking. If analysis results such as those from CFD are available and were used in determining the ranking, please provide the same.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-79
Revision: 0

Question:

The PIRT in the LTR includes and ranks the phenomenon of [ ]a,c in the "CV" component (A.1.L in Table 3-3). No design information is available for such [ ]a,c. The model documented in response to RAI-TR-SBLOCA-PIRT-04 does not seem to credit such [ ]a,c as confirmed by the response to RAI-TR-SBLOCA-PIRT-16. Please explain the rationale for including the above mentioned phenomenon/component.

Westinghouse Response:

[ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P will be revised to remove A.1.L from Table 3-3. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-80
Revision: 0

Question:

The analysis results made available in response to RAI-TR-SBLOCA-PIRT-04 indicate that the reactor trip occurs (accounting for the delay) at the [ ]^{a,c}. The response to RAI-TR-SBLOCA-PIRT-21 also indicates this. In light of this, please explain the reason for not considering and ranking the phenomenon of fission power. In addition, since the reactor does not appear to be tripped [ ]^{a,c}, the rationale for the importance ranking (P13 in Table 3-4) for the "Decay Heat Generation – Heat Source" in the "Core Region" component (B.1.a in Table 3-3) does not appear to be applicable during that phase. Please clarify.

Westinghouse Response:

[

]^{a,c} Tables 3-3 and 3-4 will be revised to reflect these changes.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be changed to reflect the change to the end of Phase 1. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-81
Revision: 0

Question:

The importance ranking for [ ]^{a,c}. In fact, [ ]^{a,c} in the core region are given a 'Low' importance rank for all phases. Heat removal from the core is essential for accident mitigation. The rationale for the rankings (P14 in Table 3-4) states that these phenomena are [ ]^{a,c}. This logic appears to be backwards because the core [ ]^{a,c} unless the heat was adequately removed by one or more clad-to-coolant heat transfer mechanisms. Please elaborate on the rationale for these rankings.

Westinghouse Response:

The assessment provided in the questions above is correct. Table 3-3 will be revised so that B.3.a and B.3.b are ranked as [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P, Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-82
Revision: 0

Question:

The list of phenomena in Table 3-1 of the LTR includes [ ]^{a,c} of the reactor coolant. In addition, the same phenomenon is ranked as being of [ ]^{a,c} in the "Core region" component. The rationale for the importance ranking (P23 in Table 3-4) states that a [ ]^{a,c}. Please provide more details on the bases for the inclusion of the phenomenon and its ranking rationale such as the [ ]^{a,c}.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-1 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-83
Revision: 0

Question:

The importance ranking for ["]a,c. The corresponding rationale states that [

]a,c Please justify the ranking and rationale for phenomenon B.7.b in Table 3-3.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-84
Revision: 0

Question:

[ ]^{a,c} in the "Upper Plenum" component (C.1.a in Table 3-3) is assigned a [ ]^{a,c}. On the basis of the analysis results presented in response to RAI-TR-SBLOCA-PIRT-04, [ ]^{a,c}. Please explain how [ ]^{a,c} is likely to occur in the upper plenum during [ ]^{a,c} of the accident.

Westinghouse Response:

[

]^{a,c} Tables 3-3 and 3-4 will be revised to reflect this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-85
Revision: 0

Question:

[ ]^{a,c} in the "Upper Plenum" component (C.1.b in Table 3-3) is assigned a [ ]^{a,c}. The corresponding rationale (P109 in Table 3-4) states that [ ]^{a,c}. Both the breaks documented in the executive summary as representative of a SBLOCA scenario are [ ]^{a,c}. This also holds true for [ ]^{a,c} that is the basis for the PIRT in the LTR. It is likely that [ ]^{a,c} may occur in the upper plenum during [ ]^{a,c}. However, the rationale provided for the ranking for [ ]^{a,c} does not account for this possibility. Please address these inconsistencies.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-86
Revision: 0

Question:

The importance ranking for [ ]^{a,c} (C.4.d in Table 3-3) is [ ]^{a,c}. The corresponding rationale (P22 in Table 3-4) generically discusses the issue of [ ]^{a,c}. Please elaborate on the rationale for the [ ]^{a,c} for phenomenon C.4.d in Table 3-3.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-87
Revision: 0

Question:

The rationale for ranking [ ]^{a,c} in the "Hot Leg/Cone" component (D.2 in Table 3-3) discusses the impact of the phenomenon [ ]^{a,c}. The reviewer finds the likelihood of [ ]^{a,c} in a large diameter pipe (hot leg) to be minimal in [ ]^{a,c}. Please elaborate on the rationale and ranking for phenomenon D.2 in Table 3-3 especially in [ ]^{a,c} of the accident.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-88
Revision: 0

Question:

The knowledge ranking for [ ]^{a,c} in the "Pressurizer / Separation Plates" component (E.1 in Table 3-3) is [ ]^{a,c} while that for [ ]^{a,c} for the same component (E.5 in Table 3-3) is [ ]^{a,c} make testing or, at least, detailed CFD simulations necessary to understand the performance of the separation plates. Although the behavior of the fluid through the separation plates is being termed as [ ]^{a,c}, the lack of testing (or detailed CFD simulations) makes this claim unsubstantiated. Please justify the rationale for the knowledge ranking for phenomenon E.5 in Table 3-3.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-89
Revision: 0

Question:

The importance ranking for all the phenomena under [ ]^{a,c} in the "SG – Primary / Tube Side" (G.2.a-c in Table 3-3) is [ ]^{a,c}. The corresponding rationale (P47 in Table 3-4) states that a [

]^{a,c} Based on the above discussion, please explain the ranking, especially for [ ]^{a,c}, and the corresponding rationale for phenomena under G.2 in Table 3-3.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-90
Revision: 0

Question:

Please address the following questions regarding the phenomena under [ ]^{a,c} in the "SG – Secondary / Shell Side" component (H.1 in Table 3-3):

a. *The importance ranking for the [ ]^{a,c} phenomenon (H.1.a in Table 3-3) is [ ]^{a,c} In addition, the rankings for [ ]^{a,c} (H.1.a in Table 3-3) and [ ]^{a,c} (H.1.d in Table 3-3) are identical which also appears to be contradictory. Please comment.*

b. *The importance ranking for [ ]^{a,c} (H.1.b in Table 3-3) and [ ]^{a,c} (H.1.c in Table 3-3) is [ ]^{a,c}. The corresponding rationale (P48 in Table 3-3) does not provide any details. It is unclear how the contribution of these phenomena will be significant because the amount of energy transmitted via the hot leg wall to the secondary side and from the RV wall due to stored energy release is expected to be small as compared to the fission and decay power. Please explain the rationale behind the ranking for phenomena H.1.b and H.1.c in Table 3-3.*

Westinghouse Response:

a. Westinghouse agrees. Table 3-3 H.1.a will be removed..
b. [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-91
Revision: 1

Question:

The importance ranking for [$]^{a,c}$ (H.3.e in Table 3-3) and [$]^{a,c}$ (H.4 in Table 3-3) is [$]^{a,c}$. On the basis of the analysis results presented in response to RAI-TR-SBLOCA-PIRT-04 and the phase definitions, the [$]^{a,c}$. Please address this inconsistency.

Westinghouse Response:

[$]^{a,c}$ Tables 3-3 and 3-4 will be revised to reflect this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

NRC Additional Comments:

The changes due to RAI-TR-SBLOCA-PIRT-91 as shown in response to RAI-TR-SBLOCA-PIRT-103 simply alter the importance ranking for [

$]^{a,c}$

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Westinghouse Additional Response:

Westinghouse agrees with the reviewer. The original response was incomplete. Phenomena H.3e and H.4 should be ranked [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-92
Revision: 0

Question:

Please provide additional description for the rationale for the ranking for [ ]^{a,c} in the "SG – Secondary / Shell Side" component (H.3.a in Table 3-3). The rationale under P132 in Table 3-4 does not provide information about how [ ]^{a,c} impacts the FoMs for the PIRT. Note that [ ]^{a,c} has already been ranked separately.

Westinghouse Response:

[ ]^{a,c} Tables 3-3 and 3-4 will be revised to reflect this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-93
Revision: 0

Question:

The [ ]^{a,c} in conjunction with the SBLOCA is expected to have an appreciable impact on the FoMs. However, the [ ]^{a,c} is not included as a separate phenomenon in the PIRT developed by Westinghouse and documented in the LTR. None of the phenomena descriptors in Table 3-2 for the "RCP" component address the [ ]^{a,c}. Please explain the reason for the [ ]^{a,c}.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-94
Revision: 0

Question:

There appear to be inconsistencies in the importance rankings for [ ]^{a,c} in the "CMT" component (L.1.c in Table 3-3) and [ ]^{a,c} in the "PRHR HX – Tube Side (RCS)" component (M.1.c in Table 3-3). The rationale for L.1.c (P63 in Table 3-4) refers to [ ]^{a,c}. If L.1.c is indeed ranked based on [ ]^{a,c}, it is expected that the rankings for M.1.c should be the same as those for L.1.c. However, this is not the case for [ ]^{a,c}. Please comment and clarify the phenomena that are being considered in L.1.c and M.1.c.

Westinghouse Response:

[ ]^{a,c} Tables 3-3 and 3-4 will be revised to reflect this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised to reflect the change in rankings. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-95
Revision: 0

Question:

According to the event description for the DVI DEGB, the [ ]^{a,c}. The calculated ADS-1 and ADS-2 flow rates (provided as part of the response to RAI-TR-SBLOCA-PIRT-04) appear to [ ]^{a,c} Please confirm or clarify. If [ ]^{a,c} please make appropriate changes to the LTR, including items O.2 and O.3 in Table 3-3.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-96
Revision: 0

Question:

The PIRT in the LTR does not distinguish between the [ ]^{a,c}. The flow (choked or otherwise) from the [ ]^{a,c} is expected to have an impact on the FoMs for the PIRT. However, this phenomenon does not appear in the PIRT in the LTR. Please explain the reason for not considering the flow from the [ ]^{a,c} in the PIRT.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-97
Revision: 0

Question:

The PIRT in the LTR does not distinguish between the [ ]^{a,c}. Please confirm that the rankings for the phenomena in the [ ]^{a,c} component (S in Table 3-3) are equally applicable to the [ ]^{a,c}. If this is not the case, please clarify [ ]^{a,c} the ranking in Table 3-3 refers to and provide the corresponding rankings for the [ ]^{a,c}.

Westinghouse Response:

As identified in the response to RAI-TR-SBLOCA-PIRT-96, these phenomena are [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-98
Revision: 0

Question:

Please address the following questions regarding the phenomena under [ ]a,c in the "CMT Balance Line" component (S.1 in Table 3-3):

a. *Based on the phenomena definitions and the rationale provided for [ ]a,c (S.1.b in Table 3-3) and [ ]a,c (S.1.g), it appears that S.1.b accounts for S.1.g. The [ ]a,c will be a direct consequence of the [ ]a,c. Please explain the influence of the [ ]a,c that is being ranked in phenomena S.1.g and is not captured in S.1.b.*

b. *The rationale in the LTR (P121 in Table 3-4) for the importance rankings for [ ]a,c (S.1.c in Table 3-3) mentions the phases during the accident when [ ]a,c is present in the CMT. However, the reason for the rankings is missing. As a result, it is difficult to determine what exactly is being ranked and how S.1.c differs from S.1.b and S.1.g. Please expand on the rationale for the importance ranking for S.1.c in Table 3-3.*

c. *There appears to be an inconsistency in the importance rankings for [ ]a,c (S.1.b in Table 3-3) and [ ]a,c (S.1.c in Table 3-3) in [ ]a,c. It is unclear how [ ]a,c. Please address this inconsistency.*

Westinghouse Response:

a. [

]a,c

c. See item b. above, Table 3-3 will be revised.

Reference:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Tables 3-3 and 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-99
Revision: 0

Question:

The rationale for the importance ranking for the phenomenon [ ]a,c in the "ICP" component (T.1.e in Table 3-3) raises the possibility of [ ]a,c. It is presumed that this implies blockage of the piping connecting adjacent ICPs. Please address the following questions on the rankings for T.1.e:

a. [ ]a,c In addition, Westinghouse contends that [ ]a,c (see P21 in Table 3-4 and the response to RAI-TR-SBLOCA-PIRT-16). Therefore, please provide further discussion to support the expectation of [ ]a,c and the resulting 'High' importance ranking for phenomenon T.1.e.

b. The knowledge ranking for phenomenon T.1.e is given as 'High'. The corresponding rationale (S20 in Table 3-5) states that [ ]a,c In fact, the rationale in S33 in Table 3-5 states that such behavior is not well known. Please justify the knowledge ranking and corresponding rationale for phenomenon T.1.e.

Westinghouse Response:

[ ]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-100
Revision: 0

Question:

The importance ranking rationale described in P89 in Table 3-4 is not used anywhere in Table 3-3. Please confirm and if necessary, delete it from the LTR.

Westinghouse Response:

Westinghouse agrees that P89 is not used anywhere in Table 3-3. It will be removed from Table 3-4.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-4 will be revised. These changes are provided in the response to RAI-TR-SBLOCA-PIRT-103-P which contains a table of the changes and recommended mark-ups of WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-101
Revision: 0

Question:

[ ]^{a,c} are considered adequate for some of the phenomena with 'High' importance ranking and 'Moderate' knowledge ranking in Table 4-2 of the LTR. Examples include [ ]^{a,c}. In such cases, it is unclear how a particular assumed value can be justified as being bounding. As an example, it is not evident what value of the [ ]^{a,c} can be considered bounding to represent the [ ]^{a,c}. The obvious bounding value would be one that gives [ ]^{a,c}. It is unclear how any other value can be justified given that characterizing the [ ]^{a,c} requires corresponding experimental data. Please explain, preferably with an example.

Westinghouse Response:

[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-102
Revision: 0

Question:

Table 4-1 and Table 4-2 include specific testing recommendations that include references to a proposed integral effects test (IET) and a separate effects test (SET). As an example, Table 4-1 states [

]^{a,c} Please clarify the intent of providing the information in the testing rationale columns for these two tables. Please additionally clarify the scope of approval sought by the NRC with respect to these tables. The staff cannot reach conclusions regarding the acceptability of the proposed testing rationales in these tables insofar as they relate to the EMDAP without additional information, such as: (1) a detailed test plan, including experimental test matrix, (2) a detailed design description of the IET and SET, and (3) a scaling analysis of the IET and SET. If such approval is sought, please provide this information.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-103
Revision: 2

Question:

Please provide a table summarizing the changes to the WCAP-17573-P due to the responses to RAI-TR-SBLOCA-PIRT-69 through -102.

Westinghouse Response:

Table 103-1 provides a summary of the changes to WCAP-17573-P that were discussed in response to RAI-TR-SBLOCA-PIRT-69 through -102. Note that in addition to the changes identified in the responses to these RAIs, related pages were updated and included in Table 103-1 for consistency.

Revision 1:

Based on the revised response provided in RAI-TR-SBLOCA-PIRT-91, Revision 1, an additional change to WCAP-17573-P is required beyond those provided in Revision 0 of RAI-TR-SBLOCA-PIRT-103. Table 103-1 is updated for this change.

Revision 2:

Table 103-2 provides a summary of the changes to WCAP-17573-P that were discussed in response to RAI-W SMR Test Plan and Scaling-80 through -84.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

The changes described in Tables 103-1 and 103-2 are attached in the form of markups to WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-103
Revision: 3

Question:

RAI-TR-SBLOCA-PIRT-103 requests documentation of all the changes made to the LTR due to responses to other RAIs. The changes due to the responses to RAI-W SMR Test Plan and Scaling-79 and RAI-W SMR Test Plan and Scaling-84 do not appear to be completely reflected in the material provided in the updated version (Revision 2) of the response to RAI-TR-SBLOCA-PIRT-103.

a. The response to RAI-W SMR Test Plan and Scaling-79 (follow-on to RAI-TR-SBLOCA-PIRT-91) agrees to change the importance ranking for phenomena H.3.e and H.4 to [ ]^{a,c} The same is also mentioned in Table 103-1. However, Table 3-3 of the LTR in the most recent response to RAI-TR-SBLOCA-PIRT-103 does not show this change.

b. The response to RAI-W SMR Test Plan and Scaling-84 (follow-on to RAI-TR-SBLOCA-PIRT-88) agrees to change the importance ranking for phenomena E.1 to [ ]^{a,c} The same is also mentioned in Table 103-2. However, Table 3-3 of the LTR in the most recent response to RAI-TR-SBLOCA-PIRT-103 does not show this change

Westinghouse Response:

Westinghouse agrees that the changes to Table 3-3 of the LTR (WCAP-17573-P) described above are appropriate. Tables 103-1 and 103-2 from Revision 2 of RAI-TR-SBLOCA-PIRT-103 remain valid. Changes to Table 3-3 of WCAP-17573-P are attached in the form of markups.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

The changes described above are attached in the form of markups to WCAP-17573-P.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 103-1
Summary of Changes Made in Response to
RAI-TR-SBLOCA-PIRT-69 through -102

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

a,c,e

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

a,c,e

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c,e

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 103-2
Summary of Changes Made in Response to
RAI-W SMR Test Plan and Scaling-80 through -84

a,c,e

RAI Number	Summary of Change	Impacted Page Number(s) from WCAP-17573-P, Revision 1

LIST OF ACRONYMS

ADS	Automatic Depressurization System
ADS-1	ADS Stage One
ADS-2	ADS Stage Two
CCFL	Counter Current Flow Limitation
CHF	Critical Heat Flux
CMT	Core Makeup Tank
CRDM	Control Rod Drive Mechanism
CSAU	Code Scaling, Applicability, and Uncertainty
CV	Containment Vessel
DVI	Direct Vessel Injection
FoM	Figure of Merit
ICP	In-containment Pool
IET	Integral Effects Test
iPWR	Integral PWR
IRWST	In-containment Refueling Water Storage Tank
IVR	In-vessel Retention
LBLOCA	Large Break LOCA
LOCA	Loss-of-Coolant Accident
LTCC	Long-term Core Cooling
MFIV	Main Feed Isolation Valve
MSIV	Main Steam Isolation Valve
OCP	Outside Containment Pool
PCCWST	Passive Containment Cooling Water Storage Tank
PIRT	Phenomena Identification and Ranking Table
PLS	Plant Control System
PMS	Protection Monitoring System
PORV	Power Operated Relief Valve
PRHR	Passive Residual Heat Removal
RCCA	Rod Cluster Control Assembly
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RFA	Robust Fuel Assembly
RV	Reactor Vessel
SBLOCA	Small Break LOCA
SCV	Sump Coupling Valve
SDIV	Steam Drum Isolation Valve
SET	Separate Effects Test
SG	Steam Generator
SGDV	Steam Generator Depressurization Valve
SIT	Sump Injection Tank
SMR	Small Modular Reactor
SoK	State of Knowledge
UHS	Ultimate Heat Sink

a,c,e

Figure ES-1 Scenario Selection Process

Table ES-4 Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

a,c,e

Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

a,c,e

Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

a,c,e

Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

a,c,e

Table ES-4 (cont.) Westinghouse SMR SBLOCA PIRT Results Significant to Continued Experimental Data and Analytical Tool Development

a,c,e

[

]a,c,e

[

]a,c,e

The second means of removing heat is through the passive residual heat removal (PRHR) heat exchanger which is connected to the RCS, and is situated in the IRWST at an elevation above the reactor core. The PRHR heat exchanger is maintained at RCS pressure, and isolation valves at the outlet prevent flow during normal operation. In the event of an S-Signal, the isolation valves are opened, hot reactor coolant enters the PRHR heat exchanger from the RCS hot leg, and transfers heat to the IRWST. Cold water is returned to the RCS cold leg. The water in the IRWST is heated, reaches saturation, and generates steam. The steam is condensed on the containment. Then, heat is conducted through the wall and is removed by the PCS.

The **AP1000** plant uses nitrogen-charged accumulators to provide post-LOCA makeup water to the reactor. After the accumulators empty, the nitrogen expands into the RCS and accumulates in the high points including the reactor vessel head, steam generator tubes, and the PRHR tubes. After becoming filled with nitrogen, the PRHR heat exchanger becomes less effective and nearly all decay heat removal is through the ADS valves into containment. Accumulators are the primary defense for large break LOCAs. (There are no large break LOCAs in the Westinghouse SMR.)

1.2.4 Long-Term Core Makeup Water Supply

Westinghouse SMR

[

]a,c,e

AP1000 Plant

For the **AP1000** plant, the CMTs also provide makeup flow at all RCS pressures. After the ADS valves are actuated, the RCS pressure falls and the nitrogen-charged accumulators begin to inject. As the RCS pressure is equalized with the containment, gravity injection of the IRWST water starts when the pressure difference is less than the hydrostatic head in the IRWST.

Condensed steam from the containment fills the containment sump. As the sump level increases, valves are opened between the sump and the IRWST creating one source of water. The CMTs, accumulators, IRWST and sump all inject into the reactor vessel downcomer through two direct vessel injection (DVI) lines.

The IRWST injection in the **AP1000** plant is functionally similar to the ~~ICP tank~~ SIT gravity injection in the Westinghouse SMR. The sump injections for the two designs are also functionally similar.

Additional information regarding the PIRT panel and the qualifications of the panel members are provided in Appendix A.

Although not considered panel members, the project was supported by Westinghouse SMR experts. These individuals were Westinghouse engineers responsible for various areas of the Westinghouse SMR design. To insure transparency in the process, the role of the Westinghouse SMR experts was to address requests for information from the PIRT panel.

1.5 REPORT STRUCTURE

The PIRT methodology used for this SBLOCA application is described in Section 2. Section 2.1 focuses on the generalized PIRT process. Section 2.2 then expands the generalized process to those features common to the SBLOCA scenario addressed. Section 3 presents the results of the PIRT in several tables. The significant conclusions drawn from the results are given in Section 4.

Table 1-1 Westinghouse SMR Component Descriptions

a,c,e

Table 1-1 (cont.) Westinghouse SMR Component Descriptions

a,c,e

Table 1-1 (cont.) Westinghouse SMR Component Descriptions

a,c,e

a,c,e

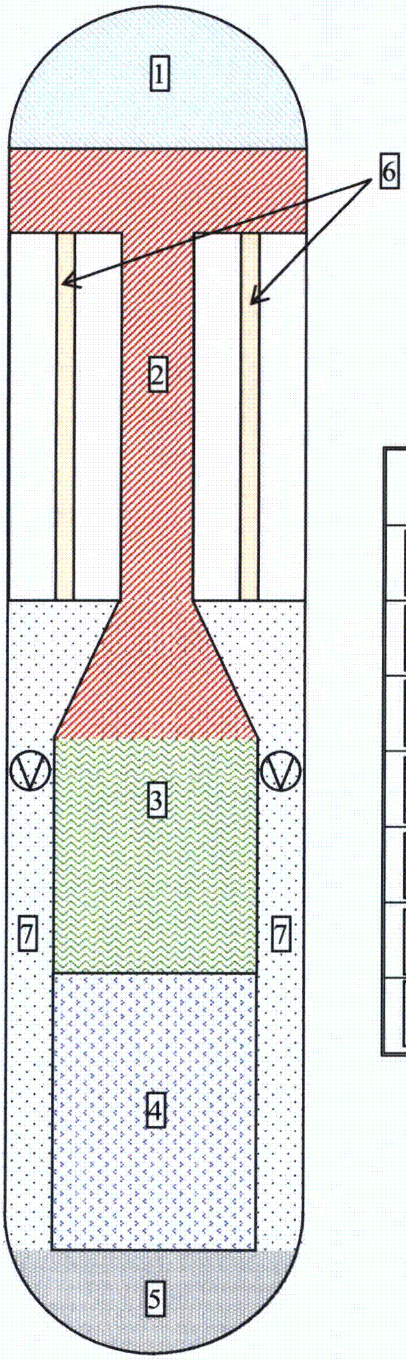
Table 1-2 Westinghouse SMR Important Dimensions

Table 1-3 Westinghouse SMR Normal Operating Conditions

a,c,e

a,c,e

Figure 1-1 Schematic of Safety Systems Design



Parameter		Value
1	Pressurizer Volume	
2	Hot Leg & Cone Volume	
3	Upper Plenum Volume	
4	Core Volume	
5	Lower Plenum Volume	
6	Steam Generator Primary Volume	
7	Downcomer Volume	

a,c,e

Figure 1-2 Reactor Vessel Regions

a,c,e

Figure 1-3 Illustrations of Westinghouse SMR ICP

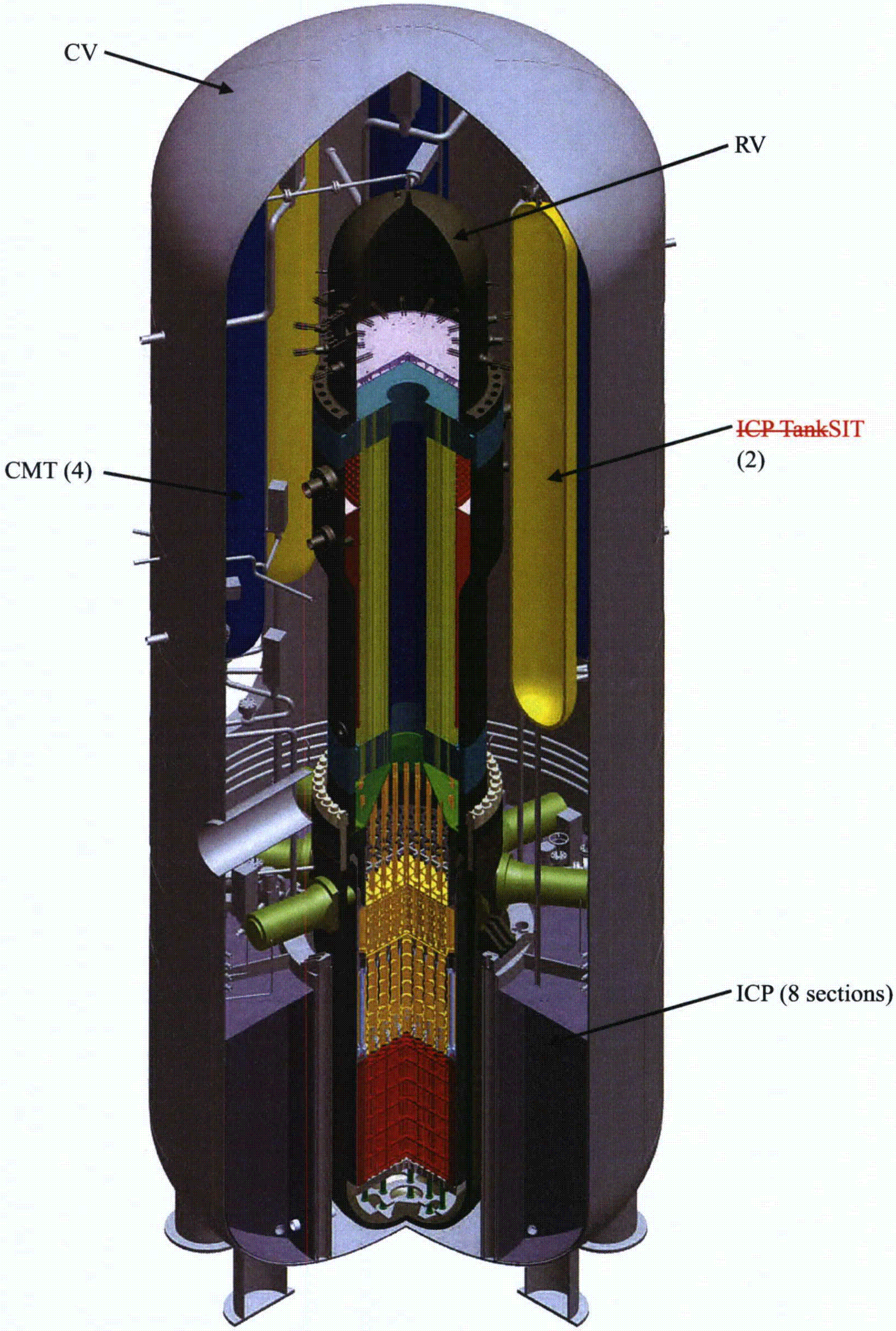


Figure 1-5 Illustration of Westinghouse SMR CV with Quarter Cutaway

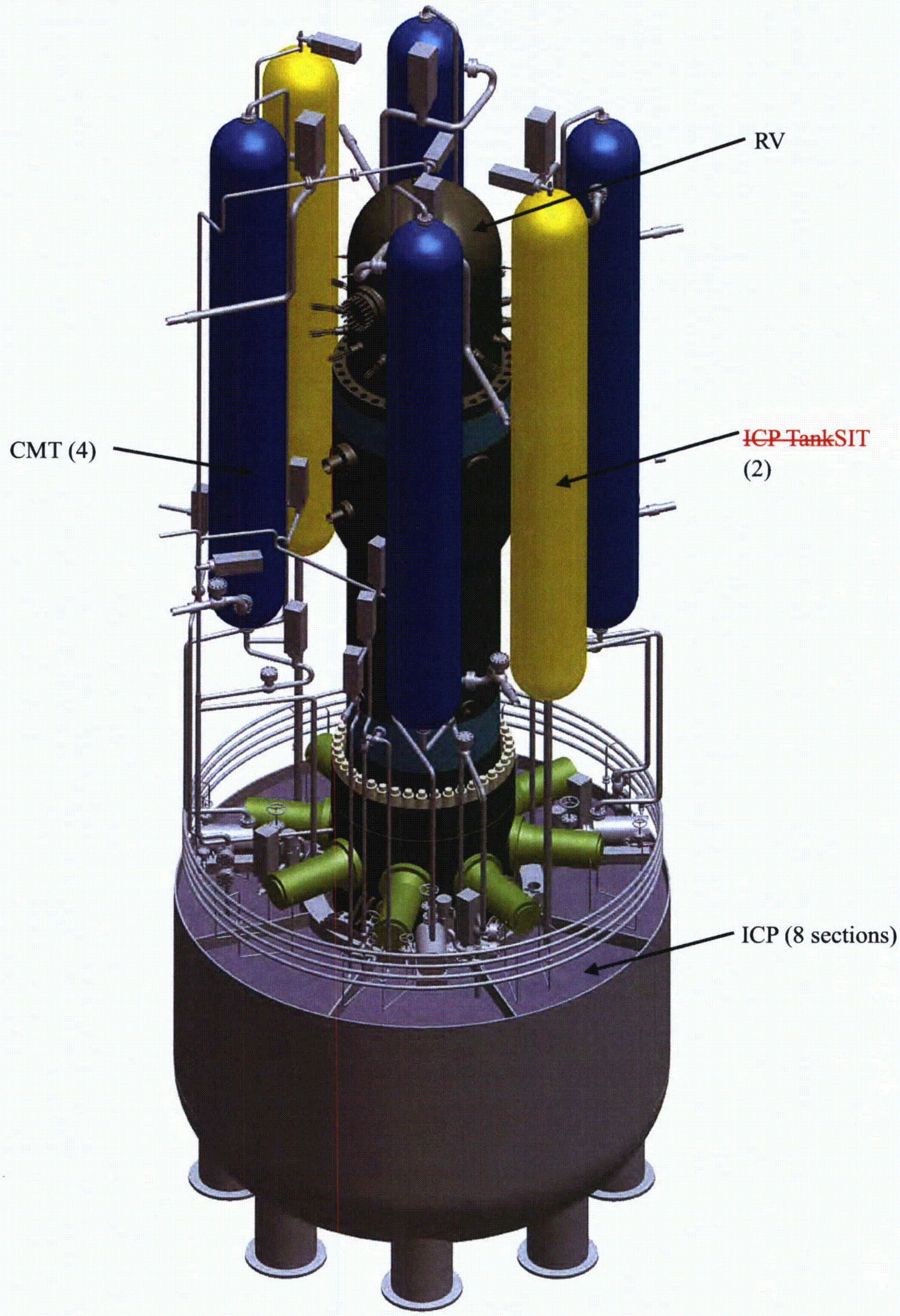


Figure 1-6 Illustration of Westinghouse SMR CV with Full Cutaway

2.2.4 System, Component and Scenario Specifications

A hierarchical system break down in subsystems and components was performed in order to complete the PIRT. For example, a reactor design can be partitioned into systems and components within those systems. As noted in the previous section, a sufficiently mature design database existed to partition the plant into systems and components that provided a logical framework for the subsequent plausible phenomena identification (see subsection 2.2.6). The systems and components are described in Table 1-1.

For reasons already given, this PIRT effort was directed to SBLOCAs. Postulated breaks that were considered by the PIRT panel include:

[

]a,c,e

Table 2-1 Westinghouse SMR SBLOCA Scenario Description

a,c,e

Table 2-1 (cont.) Westinghouse SMR SBLOCA Scenario Description

a,c,e

2.2.5 Figures of Merit

Figures of Merit are those criteria against which the relative importance of each "phenomenon" is judged. Successful figures of merit have distinct characteristics, and in particular they are (1) directly related to the issue(s) being addressed by a PIRT, (2) directly related to the phenomena being assessed for relative importance, (3) easily comprehended, (4) explicit, and (5) measurable. In this context, the design goals of the Westinghouse SMR design provide the basis for selection of suitable Figures of Merit. The design goals are to:

[

]a,c,e

Accordingly, the Figures of Merit appropriate to the SBLOCA PIRT are consistent throughout all four phases of the scenarios and are: the core coolant inventory as associated with successful removal of the initial stored energy and core decay heat, the containment pressure and successful heat removal to the environment, and the demonstration of long-term core coolability accounting for debris and chemical precipitation as indicated by a core exit quality less than one. Figure 2-3 shows the SBLOCA Figures of Merit from above as predicted from models as a function of time.

a,c,e

Figure 2-3 SBLOCA Figures of Merit

2.2.6 Phenomena Identification

In the PIRT process, phenomena are broadly defined. Plausible phenomena are those physical behaviors and/or processes that may have some influence in reactor plant's response. It is important to clearly characterize the plausible phenomena before a PIRT panel considers what safety importance (ranking) a phenomenon may have in influencing the plant response. That is, the panel first considers all possible physical behaviors and/or processes that may occur before evaluating if each phenomenon has real

3 SBLOCA SCENARIO PIRT RESULTS

3.1 INTRODUCTION

The general scenario including system and component descriptions and phase details were described in Sections 1 and 2, respectively. A list of plausible phenomena is provided in Table 3-1. As might be expected, the plausible phenomena are cast in terms of the component partitioning already described. Descriptions of the phenomena are also provided in Table 3-2. Additional information relative to the expected scenario progression is given in the following section.

Table 3-1 Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-1 Plausible Phenomena (cont.)

a,c,e

Component	Phenomena	Code

Table 3-1 (cont.) Plausible Phenomena

a,c,e

Table 3-2 Plausible Phenomena Descriptions

a,c,e

Table 3-2 (cont.) Plausible Phenomena Descriptions

a,c,e

Table 3-2 (cont.) Plausible Phenomena Descriptions

a,c,e

3.2 EXPECTED SCENARIO PROGRESSION

[

]a,c,e

[

]a,c,e

3.3 RANKING RESULTS

The complete body of ranking results for the DVI break is provided in Tables 3-3, 3-4, and 3-5. Table 3-3 shows the phenomena safety rank for each phase and the state of knowledge rank. Also, listed in this table are rationale codes for each safety rank (denoted as PX) and state of knowledge rank (denoted as SX). These codes correspond to the descriptions given for every safety rank rationale and state of knowledge rank rationale in Tables 3-4 and 3-5, respectively.

a,c,e

Figure 3-1 Westinghouse SMR During Normal Operation

a,c,e

Figure 3-2 Westinghouse SMR During a SBLOCA Blowdown Phase (Phase 1)

a,c,e

Figure 3-3 Westinghouse SMR during a SBLOCA CMT Natural Circulation and Draining Phase (Phase 2)

a,c,e

Figure 3-4 Westinghouse SMR during a SBLOCA ADS Phase (Phase 3)

a,c,e

Figure 3-5 Westinghouse SMR During a SBLOCA Long-term Core Cooling Phase (Phase 4)

Table 3-3 Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) **Phenomena Importance**

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-3 (cont.) Phenomena Importance

a,c,e

Table 3-4 Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-4 (cont.) Safety Ranking Rationales

a,c,e

Table 3-5 (cont.) State of Knowledge Ranking Rationales

a,c,e

Table 4-1 (cont.) High Safety and Low State of Knowledge Ranking Phenomena Recommendations

a,c,e

4.3.2 Recommendations to Support Phenomena with High Safety and Moderate State of Knowledge Ranking

Table 4-2 lists all phenomena that received a high safety ranking in at least one phase of a SBLOCA scenario and also a moderate SoK rank. The table describes the recommendations that may be considered to increase the SoK. In some cases, the information can be developed using tests while in other cases, a bounding approach in the computer simulation can be used.

Table 4-2 High Safety and Moderate State of Knowledge Ranking Phenomena Recommendations

a,c,e

APPENDIX B
AP600 PLANT PROGRAM TEST SUMMARIES

The following provides a summary of each **AP600** plant test including their purpose, a description of the facility, and a discussion of the test matrix/results.

B.1 PASSIVE CORE COOLING SYSTEM (PXS) TEST SUMMARIES

The following tests were performed for the PXS:

- Departure from Nucleate Boiling (DNB) test (subsection B.1.1)
- Passive Residual Heat Removal Heat Exchanger (PRHR HX) test (subsection B.1.2)
- Automatic Depressurization System (ADS) test , phase A (subsection B.1.3)
- ADS test, phase B (subsection B.1.4)
- Core Makeup Test (CMT) test (subsection B.1.5)
- Low-pressure, integral systems test, OSU (subsection B.1.6)
- Low-pressure, integral systems test, OSU-NRC (subsection B1.7)
- High-pressure, integral systems test, SPES-2 (subsection B.1.8)
- High-pressure, integral systems test, ROSA-**AP600** (subsection B.1.9)

B.1.1 DNB Tests

General Purpose/Description

While low-flow DNB tests have been performed successfully on other fuel assembly geometries, data accumulated over several years of testing on the current Westinghouse fuel designs have concentrated on the higher flow range associated with operating conditions of conventional, higher-power density cores. The purpose of these tests was to determine the critical heat flux (~~CFI~~CHF) performance of the **AP600** plant fuel assembly design, particularly at low-flow conditions. In addition, the effect on CHF of the intermediate flow mixer (IFM) grids at low-flow conditions was measured.

The test objective was to gather CHF data on typical and thimble cell **AP600** plant bundle geometry covering the range of fluid conditions anticipated during **AP600** plant DNB-related ANS Condition I and II transients. The conditions cover the following ranges:

Pressure:	1500 to 2400 psia
Mass velocity:	0.5 to 3.5 x 10^6 lbm/hr-ft^2
Inlet temperature:	380° to 620°F

Also, a typical cell test where the **AP600** plant bundle has the IFM grids replaced by simple support grids (SSGs) was run to assess the effect of the IFMs at low-flow conditions.

To perform a series of low-flow tests, two test bundles were constructed. The test bundles consisted of a small 5 by 5 array of rods, which are electrically heated and well-instrumented with thermocouples. The components for the test bundles were shipped to the test site, Columbia University, and assembled just prior to testing.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-104
Revision: 0

Question:

Based on the discussion during the audit of October 24, 2013, [ ]a,c in the DVI line break simulation provided in response to RAI-TR-SBLOCA-PIRT-04. Table 2 provided in response to that RAI shows a delay of [ ]a,c for the activation of the "S" signal. Please update the cited table with correct information.

Westinghouse Response:

Note that Table 1, as opposed to Table 2, of RAI-TR-SBLOCA-PIRT-04 contains the "S" signal delay referred to in this RAI. Subsequent to the issuance of RAI-TR-SBLOCA-PIRT-04, Table 1 was revised in response to RAI-TR-SBLOCA-PIRT-65. A revised Table 1, which incorporates the changes made for both RAIs is attached.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1: Westinghouse SMR Signals and Actuations

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-105
Revision: 0

Question:

Please provide the elevations over which the [ ]a,c are calculated in the DVI line break scenario.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-106
Revision: 0

Question:

Please clarify if any discharge coefficient was used in the simulation of the DEGB of the DVI line as documented in the response to RAI-TR-SBLOCA-PIRT-04. If yes, please provide the location of the break and the associated value.

Westinghouse Response:

For the DVI line DEGB simulation presented in RAI-TR-SBLOCA-PIRT-04, the discharge coefficient at the break was set to [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-107
Revision: 0

Question:

The total ICP surface area provided in Table 2 of the response to RAI-TR-SBLOCA-PIRT-01 appears to be much lower than the surface area for [ ]^{a,c} ICPs in one group calculated based on the ICP geometry. Please clarify how many ICPs are included in the provided surface area. Please also clarify the surfaces of the ICP that the surface area provided includes (e.g. all the side walls, inside curved surface, outside curved surface etc.).

Westinghouse Response:

The ICP surface area provided in Table 2 of the response to RAI-TR-SBLOCA-PIRT-01 is for [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-108
Revision: 0

Question:

Please provide drawings SMR-FA01-V2-001 and SMR-FS01-V2-101 made available during the audit in electronic format.

Westinghouse Response:

Drawing SMR-FA01-V2-001 and SMR-FA01-V2-101 are provided electronically on a CD. Please note this CD contains proprietary information and has been marked as such. (NOTE: SMR-**FS**01-V2-101 is assumed to be SMR-**FA**01-V2-101) based on discussion with the NRC.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-109
Revision: 0

Question:

Please provide detailed design information for the secondary side of the PRHR heat exchanger located in the UHS tank (e.g., type of heat exchanger, number of tubes, tube inner and outer diameter, total and active lengths, elevations of inlet and exit piping, size of inlet and exit piping, header dimensions and volumes etc.).

Westinghouse Response:

[

[1] Because design of this component is not final, it is likely that the tube material will change.

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-110
Revision: 0

Question:

Please provide the diameter and elevation of the sump injection valves.

Westinghouse Response:

The inside diameter of the sump injection valves is [ ]^{a,c} The elevation of the centerline of the valves is [ ]^{a,c} above the bottom outside of the reactor vessel.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-111
Revision: 0

Question:

Please provide the opening criterion (pressure difference) for all the check valves in the ECCS including those located on [ ]^{a,c}.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-112
Revision: 0

Question:

Please provide the elevations of ADS-1 and ADS-2 discharge locations inside the containment. Please also specify the datum for the elevations.

Westinghouse Response:

[ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-113
Revision: 0

Question:

Please provide the size and centerline elevation from a specified datum of the connections between the [ ]a,c that form a group.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-114
Revision: 0

Question:

Please provide the detailed pump homologous curves that were used in the W-SMR SBLOCA analyses. Please also provide the curves in tabular format.

Westinghouse Response:

[

]a,c

Table 1. The Four Segments of Pump Homologous Curves

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[ ] a,c

Figure 1. Single-Phase Homologous Head Curves

[ ] a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[ ] a,c

Figure 2. Two-Phase Homologous Head Curves

[ ] a,c

[ ] a,c

Figure 3. Single-Phase Homologous Torque Curves

[ ] a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[ ]a,c

Figure 4. Two-Phase Homologous Torque Curves

[ ]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 2. Multipliers used for a transition from single- to two-phase conditions

a,c

[ ]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-115
Revision: 0

Question:

Please provide the material specifications and properties (thermal conductivity, roughness, wall thickness, heat capacity, etc) for all components with significant area in contact with the RCS fluid. This includes not only all fuel rods, pipes/tubes, vessel, and tanks, but also all major structures in the RPV and steam drum. There may be situations where a wall thickness is not appropriate (i.e., dryers) or not available (i.e., RCP metal mass). In these situations, please provide the total metal volume or mass and the total heat transfer surface area.

Westinghouse Response:

[

]^{a,c}

Table 115-1
Internal Structure Components mass or volume and heat transfer surface areas properties

Internal Structure Components	Material Weight (lbs)	Material Volume (in^3)	Surface Area (in^2)	Number	Material

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-116
Revision: 0

Question:

Please provide the following information about the CMT:

a. *Elevation of the top of the CMT downcomer from the secondary surface of the lower tube sheet. Alternately, the elevation of the secondary surface of the CMT lower tube sheet and the height of the downcomer (including the gap at the bottom) is also fine*
b. *Please provide the design cooling capacity of Passive Residual Heat Removal system (PRHR) in CMT*
c. *Please provide vertical and horizontal line lengths from CMT secondary side to UHS heat exchanger*
d. *Please provide loss coefficients used for CMT/PRHR component including those in the CMT balance line, on the primary and secondary side of the PRHR and the CMT return line*
e. *Please provide the elevation of various sections (wherever the orientation changes) of the CMT balance line and the CMT return line*
f. *Please provide detailed elevation information, preferably with a diagram, for various sections of the CMT/PRHR heat exchanger including the top of the upper head, the top and bottom of the upper tube sheet, the top and bottom elevation of the separation between the feedwater and steam outlet plenum, the top and bottom of the lower tube sheet and the bottom of the lower head*
g. *Please provide the diameter of the CMT tube bundle and wrapper*
h. *Please provide the material of construction for the CMT including the PRHR heat exchanger components within the CMT*
i. *Please provide boron concentration in the primary reactor system BOL, MOL, and EOL, and the primary side of the CMT during normal operation*

Westinghouse Response:

The core makeup tank (CMT) and boron concentration details requested are as follows:
[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

[1] INCONEL is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

a,c

Figure 116-1
CMT Piping Layout

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 116-1
Resistance of Each Flow Path

a,c

Table 116-2
CMT Elevations

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-117
Revision: 0

Question:

Please provide the following information about the UHS and the heat exchanger in the UHS:

a. *Please provide the volume, inner diameter, wall thickness and shape of inlet and outlet head of UHS heat exchanger*
b. *Please provide the connection elevation for the hot and cold leg nozzle on the UHS heat exchanger from the inside bottom of UHS*
c. *Please provide the distance between inside bottom of UHS tank and bottom of the UHS heat exchanger*

Please provide the geometry, opening criterion, form loss and elevation information for the line connecting each ultimate heat sink tank to the outer containment pool

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-118
Revision: 0

Question:

Please provide form losses in the SIT/ICP piping including those for the sump screen and trash rack.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-119
Revision: 0

Question:

Please provide geometrical information including the width and depth at various heights for the in-containment pool tanks. Preferably please provide engineering drawing(s) that includes such information.

Westinghouse Response:

Geometrical information related to the in-containment pool tanks is shown on Figure 119-1 (top view) and Figure 119-2 (side view).

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 119-1
In-containment Pool Tank (Top View)

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 119-2
In-containment Pool Tank (Side View)

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-120
Revision: 0

Question:

Please provide details, with diagrams, of the geometry of the pressurizer plate and path of fluid flow through the plate.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 120-1

Pressurizer Surge Plate Details

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 120-2

Pressurizer Surge Plate Flow Path

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 120-3

Lower Pressurizer Surge Plate 3-D Rendition

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-121
Revision: 0

Question:

Please provide representative flow areas, path lengths and form loss values (or pressure drop) for fluid flow through the pressurizer surge plate assembly. If the design is being finalized, please provide the values used in the safety analysis performed by Westinghouse with the understanding that the final values will be provided upon design completion.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 121-1

Pressurizer Surge Plate Pressure Drop as a Function of Flowrate

a,c

Flowrate (gpm)	Pressure Drop (psi)	
	Insurge	Outsurge

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-122
Revision: 0

Question:

Please provide the ID and OD for all piping that is part of the ECCS including the secondary side of the PRHR loop. In cases where the final values have not been determined please provide representative pipe schedules for high and low pressure piping to be used in conjunction with the nominal sizes. If representative schedules are provided please specify what should be considered as high and low pressure.

Westinghouse Response:

Figure 122-1 on the following page provides a simplified sketch of the Westinghouse SMR Passive Residual Heat Removal (PRHR) Loop that includes both primary and secondary side components and piping. The piping schedules and associated outside diameters (OD) and inside diameters (ID) for the primary and secondary piping segments are also included in Figure 122-1 for clarity. [
]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 122-1: Simplified depiction of SMR Passive Residual Heat Removal (PRHR) Loop. Piping schedule and the associated Outside Diameters (OD) and Inside Diameters (ID) for the primary and secondary side piping segments are shown where indicated.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-123
Revision: 0

Question:

Please provide drawing SMR-RXS-V1-001 that was made available during the audit in electronic format.

Westinghouse Response:

Drawing SMR-RXS-V1-001 is provided electronically on a CD. Please note this CD contains proprietary information and has been marked as such.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-124
Revision: 0
Question:

Please provide additional information including the mass, surface area, flow area, number and hydraulic diameter of holes/flow passages for the "heavy reflector" in the region between the core barrel and the core baffle/shroud. If the final design is unavailable, please provide representative values that can be used in confirmatory model development with the understanding that the final values will be provided upon design completion.

Westinghouse Response:

The additional details above regarding the Westinghouse SMR reflector design were added. See Appendices 167-1 and 167-2 to RAI response RAI-TR-SBLOCA-PIRT-167. [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-125
Revision: 0

Question:

Please provide the following details:

a. *Mass and surface area of the support structure in the reactor vessel lower plenum*
b. *The mass of each control rod guide tube*
c. *The mass of a rodlet in each different type of control rod assembly*
d. *The mass of the lower core support plate*
e. *The mass of the absorber Ag-In-Cd in the core*

Westinghouse Response:

[

]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 125-1: Schematic diagrams of core support structure in reactor vessel lower plenum. The core support structure consists of a [ ]^{a,c} as shown.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Figure 125-2 - Schematic diagrams of SMR Upper Internals and Control Rod Drive Mechanism (CRDM). The image at right shows the layout of the [ ]a,c control rod guide tubes that house either "black" or "gray" control rods.

a,c

Figure 125-3: Schematic diagram of SMR Rod Control Cluster Assembly (RCCA)

a,c

Figure 125-4: Schematic diagram of SMR Gray Rod Cluster Assembly (GRCA)

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-126
Revision: 0

Question:

Please provide the form loss coefficients on the secondary side of the steam generator including the recirculation lines. Please also provide the line lengths and orientation for the recirculation lines.

Westinghouse Response:

Loss coefficients for one of the two near identical steam lines, from the steam generator to the steam drum can be found in Table 1. Loss coefficients for the recirculation line from the steam drum to the steam generator can be found in table 2. The loss coefficients in the lines, steam generator (SG) and steam drum (SD) are based on the following conditions:

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Table 1
Loss Coefficients for steam line from the steam generator to the steam drum

a,c

[ ]

Table 2
Loss Coefficients for recirculation lines from the steam drum to the steam generator

a,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-127
Revision: 0

Question:

Please provide the core decay heat at the Beginning-, Middle- and End-of-Cycle for the equilibrium core.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-128
Revision: 0

Question:

Please provide the radial power distribution in the core and the axial power shape for the equilibrium core at the Beginning-, Middle- and End-of-Cycle.

Westinghouse Response:

The radial power distributions at all burnup steps (CA-Power edits) for the Westinghouse SMR Cycle 1 and EQ24 cycle are provided in ASCII files 1.a and 2.a (smr-cy1-BU-power-peaking-update.txt and smr-eq24-BU-power-peaking-update.txt, respectively). These files are provided as part of RAI response RAI-TR-SBLOCA-PIRT-167. These files also include the axial power shape at each burnup step which can be found in the AM-General edits.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-129
Revision: 0

Question:

Please provide drawing SMR-MV50-V1-001 that was made available during the audit in electronic format. In addition, please provide the following information:

a. *The geometric dimensions and the shape of containment lower head.*
b. *The distance of containment vessel outside bottom to the floor of outer containment pool (OCP)*
c. *The total mass, surface area, and approximate distribution for following heat sinks in the containment:*
    i. *CMT/PXS support structure (please provide design and elevation of all circular platforms inside the containment)*
    ii. *Ladders and floor panels*
d. *The mass of following heat sinks:*
    i. *Containment wall*
    ii. *SIT or upper ICP wall*
    iii. *Lower ICP wall.*

Westinghouse Response:

Drawing SMR-MV50-V1-001 is provided electronically on a CD. Please note this CD contains proprietary information and has been marked as such. The additional information requested is as follows:

[

]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

a,c

Figure 129-1

Elevations of Floor Platforms

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-130
Revision: 0

Question:

Please clarify whether the following components are insulated., If they are insulated please provide the type of insulation, its thickness and thermal properties of the insulation material.

a. *Reactor vessel cylindrical wall*
b. *Reactor vessel lower head*
c. *Recirculation steam and feedwater lines between steam generator and steam drum*
d. *CMT, SIT, and ICP tanks.*

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-131
Revision: 0

Question:

If there is any geometrical structure designed on the outer surface of the reactor vessel lower head to enhance the lower head cooling, please provide the detailed design and material of construction of this structure.

Westinghouse Response:

[ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-132
Revision: 0

Question:

If there are any structures around the RPV lower head (other than the lower ICP tanks) that are expected to affect the natural circulation of water around the lower head, please provide more details of such structures.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-133
Revision: 0

Question:

Please provide details regarding the operation of the pressurizer heaters including the number of heater banks, the power of each bank, and appropriate setpoints.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-134
Revision: 0

Question:

Please provide details regarding the operation of the pressurizer sprays including the flow capacity and setpoints.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-135
Revision: 0

Question:

Please provide the volume of the [ ]^{a,c} connected to the PRHR secondary side.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-136
Revision: 0

Question:

Please provide the mass of the mid-span grid.

Westinghouse Response:

This information was added to Table 5 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 on per grid basis.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-137
Revision: 0

Question:

Please provide the mass and material composition of the plenum spring.

Westinghouse Response:

The material composition and mass of the plenum spring has been provided in Table 15 of Appendix 167-1 and Table 16 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-138
Revision: 0

Question:

In the fuel information audited on August 13, 2013, please clarify the following for Figure 1:

a. It is not clear what the fuel shuffling sequence is from this figure for the equilibrium cycle. For example, does the labeling indicate the location of the assembly in the previous cycle, if so, how do these indices relate to the assembly locations?

b. Further, please clarify if the figure indicates the rotation of fuel assemblies between cycles.

Westinghouse Response:

a. A note has been added to Figure 1 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 which describes the shuffling scheme for the equilibrium core. Further clarification was added to the text of the Appendix as well.

b. The rotations are provided in Figure 1 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 for each assembly in quarter core geometry. A description of the rotations has also been added as Figure 1.a in Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 which clarifies the rotation of fuel assemblies assumed in the Westinghouse design.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-139
Revision: 0

Question:

Please provide the clearance between the fuel and the shroud plate.

Westinghouse Response:

The clearance between the fuel and the shroud plate is modeled as the hot fuel assembly to assembly gap of approximately [ ]a,c A note has been included in radial reflector portion of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 to address this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-140
Revision: 0

Question:

For the ASCII files providing the nodal exposure data, please provide a description of column headings and the units of the values reported.

Westinghouse Response:

The nodal exposure ASCII files are represented as Files #1.b -1.d and Files #2.b -2.d. Titles for these files are provided below:

1.b smr-cy1-boc-nodal-exposure.txt
1.c smr-cy1-moc-nodal-exposure.txt
1.d smr-cy1-eoc-nodal-exposure.txt
2.b smr-eq24-boc-nodal-exposure.txt
2.c smr-eq24-moc-nodal-exposure.txt
2.d smr-eq24-eoc-nodal-exposure.txt

The ASCII files are provided electronically on a CD as part of RAI-TR-SBLOCA-PIRT-167 response.

Cksums for the files have been provided in the reports (Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167). A detailed explanation of the column heading descriptions and units has been added to the sections of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 which present the data contained in these ASCII files.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-141
Revision: 0

Question:

In the fuel information audited on August 13, 2013, the fraction of heat generated in the fuel was provided. Please clarify if the remaining heat is deposited directly to coolant. Further, if the energy is deposited to the coolant, how it is apportioned between the bypass flow and active (i.e. flowing over the fuel) flow?

Westinghouse Response:

[ ]^{a,c} A note has been added. See Table 4 found in Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-142
Revision: 0

Question:

Please clarify if the RCC length corresponds to the length of the absorber material in the RCCA.

Westinghouse Response:

Yes, [ ]^{a,c} is the length of absorber material. A note has been added. See Table 7 in Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-143
Revision: 0

Question:

Please provide the position of the rod relative to BAF when the rod is in either the fully withdrawn or fully inserted position.

Westinghouse Response:

This information is provided in the Control Rod Information section of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-144
Revision: 0

Question:

Please provide the composition of [ ]^{a,c} assumed in the analysis.

Westinghouse Response:

The composition of [ ]^{a,c} utilized in the Westinghouse SMR design have been included in Table 18 of Appendix 167-1 and Table 19 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-145
Revision: 0

Question:

Please provide the nominal composition of alloys assumed in the PARAGON calculations.

Westinghouse Response:

The nominal composition of all the alloys utilized in the Westinghouse SMR design have been included in Table 18 of Appendix 167-1 and Table 19 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-146
Revision: 0

Question:

In the PARAGON output, please provide clarification of the output file information. In particular, please clarify column headings and units.

Westinghouse Response:

A detailed description of the column headings, including units, has been added to the beginning of Table 9 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 which contain the PARAGON data output. Column headings have also been inserted within the tables which provide the appropriate column units.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-147
Revision: 0

Question:

Please provide the stack density for the fuel accounting for theoretical density and dishing.

Westinghouse Response:

Fuel stack densities were added to the Basic Fuel Information sections of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. Values for fuel with and without [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-148
Revision: 0

Question:

In the PARAGON data audited on August 13, 2013, please clarify why the equilibrium cycle PARAGON data does not include information for 0 burnup.

Westinghouse Response:

Equilibrium cycle burned fuel PARAGON data is based upon restarts from the previous cycle and therefore does not contain information from earlier burnup steps. A note was added to Table 9 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 to address this statement.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-149
Revision: 0

Question:

In the nodal exposure files, please clarify the units for the reference time and burnup.

Westinghouse Response:

Complete descriptions of all data in the ASCII files including associated units was provided in the associated Lattice and Nodal Information sections of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-150
Revision: 0

Question:

Please provide details of the top and bottom reflector necessary to generate cross-section data (e.g. volume fractions of metal, water, etc.).

Westinghouse Response:

The top and bottom reflector properties are described in the axial reflector section of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. Specific volume fractions are provided in Table 17 of Appendix 167-1 and Table 18 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-151
Revision: 0

Question:

Please confirm that natural boron is treated as being [ ]^{a,c} atomic percent (as opposed to weight percent) in the analysis.

Westinghouse Response:

Yes, the natural boron is treated as [ ]^{a,c} atomic percent.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-152
Revision: 0

Question:

Some PARAGON data audited on August 13, 2013, indicates that [ ]a,c Please clarify what results are adjusted. Please confirm that the K-Infinity includes [ ]a,c

Westinghouse Response:

Yes, the [ ]a,c A note about this is provided in Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-153
Revision: 0

Question:

Please confirm the definition of boron ppm, for example, as mass of natural boron equivalent divided by mass of coolant.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-154
Revision: 0

Question:

Please confirm for the initial and equilibrium cores that the enrichment in the blanket zone is always [ ]^{a,c}.

Westinghouse Response:

[

]^{a,c} A note is included in Figure #2 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 for the EQ24 cycle to confirm this.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-155
Revision: 0

Question:

For a typical W-SMR fuel lattice, please provide pin power distribution as a function of exposure in electronic format. Please further provide the assumed thermal-hydraulic conditions (e.g. moderator density, temperature, and boron concentration).

Westinghouse Response:

Detailed pin power distribution data can be found in the ASCII File #2.e (smr-495-wo-fuel-lattice-pin-power.txt) of RAI response RAI-TR-SBLOCA-PIRT-167 for a typical Westinghouse SMR lattice. A description of this file is provided in the Lattice Pin Power Distribution section of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-156
Revision: 0

Question:

Please provide the heights (i.e. axial lengths) of the top and bottom axial reflectors.

Westinghouse Response:

The top and bottom reflector properties are described in the Axial Reflector section of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-157
Revision: 0

Question:

Please provide (in electronic format) the distribution of nodal exposure (burnup) for various points in cycle (e.g. BOC, MOC, and EOC) for the first and equilibrium cycle. Please additionally provide typical exposure average values for fuel temperature, moderator temperature, and boron concentration.

Westinghouse Response:

This information is described in the Lattice and Nodal Information section of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. Nodal detail is also provided in ASCII files represented as Files #1.b -1.d and Files #2.b -2.d. Titles for these files are provided below:

1.b smr-cy1-boc-nodal-exposure.txt
1.c smr-cy1-moc-nodal-exposure.txt
1.d smr-cy1-eoc-nodal-exposure.txt
2.b smr-eq24-boc-nodal-exposure.txt
2.c smr-eq24-moc-nodal-exposure.txt
2.d smr-eq24-eoc-nodal-exposure.txt

The ASCII files are provided electronically on a CD as part of RAI-TR-SBLOCA-PIRT-167 response.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-158
Revision: 0

Question:

Please supplement calculated bank worths by providing the worth of the individual banks inserted.

Westinghouse Response:

Individual bank worth tables were added to Tables 11 through 13 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-159
Revision: 0

Question:

For the black and gray RCCAs, please provide the density of the absorber material.

Westinghouse Response:

The density of the absorber material is now provided in Table 7 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-160
Revision: 0

Question:

It appears based on the fuel information audited on August 13, 2013, that [ ]a,c are present in the core. Please provide material composition and density (as assumed in the current analysis) for both alloys.

Westinghouse Response:

The material composition and density for all alloys used in the Westinghouse SMR design including [ ]a,c have been included in Table 18 of Appendix 167-1 and Table 19 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. [ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-161
Revision: 0

Question:

Please provide average axial and radial power distributions that are representative of the equilibrium fuel cycle (e.g. BOC/MOC/EOC radially averaged axial shape, and axially averaged assembly powers for a quarter core).

Westinghouse Response:

Axial and radial power distributions for all modeled burnups have been provided for the Westinghouse SMR EQ24 cycle in File# 2.a (smr-eq24-BU-power-peaking-update.txt) of RAI response RAI-TR-SBLOCA-PIRT-167.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-162
Revision: 0

Question:

Please provide sufficient detail regarding the design of the radial reflector to perform cross-section calculations. As an example, please provide the material composition of the steel in the reflector and the volume fraction of the reflector occupied by steel.

Westinghouse Response:

The radial reflector is discussed in some detail in Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. In those documents the key dimensions and materials are discussed. The heavy reflector design material is [ ]^{a,c} Material properties of all alloys utilized in the Westinghouse SMR design are presented in Table 18 of Appendix 167-1 and Table 19 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-163
Revision: 0

Question:

In response to audit log question D11i, please clarify what version of PAD was used for the RETRAN tuning.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-164 (Response Revision 1)
Revision: 1

Question:

Please describe how fuel thermal conductivity degradation is taken into account in the analysis?

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

NRC Additional Comments:

The response did not provide sufficient information for staff evaluation. Please supply more information on how the process is modeled in the code, not just the code name and its version.

Westinghouse Additional Response:

The process described in Attachment 3 to Enclosure 3 of Westinghouse transmittal DCP_NRC_003214 is also being used for the Westinghouse SMR. This enclosure can be obtained via NRC Accession Number ML12167A250.

Reference:

ML12167A250, "10 CFR 50.46 Thirty (30) Day Report for the AP1000 Standard Plant Design," 6/13/2012.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-165
Revision: 0

Question:

Please provide the following clarification details regarding the gap properties described in audit log question D11i:

a. *What value of gap conductance would be considered representative?*
b. *What values were assumed in the non-LOCA transient analyses provided to the NRC in RAI responses?*
c. *Were the values reported in audit log question D11i applied uniformly throughout the entire core in the analyses?*

Westinghouse Response:

The following provide the additional clarifications requested regarding the fuel rod gap conductance properties described in audit log question D11i.
[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-166
Revision: 0

Question:

The response to audit log question D11i states that the values of the gap conductance are conservative. Please clarify, with respect to what limits or regulatory criteria are the values conservative? For example, is the larger value conservative with respect to DNBR while the other is conservative relative to RCS pressure?

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-167
Revision: 0

Question:

It is the intention of the staff to perform core design calculations to support the initiating conditions required for confirmatory accident and transient analysis. For this reason we will need to be able to replicate certain calculations performed by Westinghouse and to know that these calculations are reasonably representative of what will be submitted in support of design certification. Please provide fuel assembly nuclear design information in electronic format for the staff to perform confirmatory calculations including:

a. *A description of all lattices in the reference core design including dimensions, enrichments, densities, and burnable absorber loadings*
b. *A description of the axial arrangements, volume fractions, and general dimensions used for all grids*
c. *Complete material composition description of all fuel assembly materials (structural material, spacers, cladding, fuel, control rods) including percentages of all isotopes*
d. *A description of the control rod cluster designs appropriate for performing lattice calculations, including materials and geometry*
e. *A description of the fuel assembly arrangement used to perform depletion calculations to the equilibrium cycle including shuffle patterns and control rod positions used*
f. *A tabulation of the boron rundown results from each cycle of depletion including the equilibrium cycle*
g. *For BOC-1 provide the individual control rod bank worths (in pcm) and the axially averaged full core power distribution by assembly at HFP, ARO, no Xenon conditions*
h. *For the equilibrium cycle provide the individual control rod bank worths at BOC and EOC and the axially averaged power and burnup by assembly for each depletion step.*

Westinghouse Response:

a. All lattice information for the Westinghouse SMR Cycle 1 and Equilibrium 24 (EQ24) month fuel cycle designs are attached to this RAI response. The Cycle 1 data is designated as Appendix 167-1 and the EQ24 data is designated as Appendix 167-2.

   Additionally the Word files for Appendix 167-1 and Appendix 167-2 are provided electronically on a CD. The ASCII files identified in the Appendices 167-1 and 167-2 are also provided on the CD. The list of Word files and ASCII files are provided below:

   1. Cy1-Nuclear-Design_NRC-Questions_update.docx
      a. smr-cy1-BU-power-peaking-update.txt
      b. smr-cy1-boc-nodal-exposure.txt
      c. smr-cy1-moc-nodal-exposure.txt
      d. smr-cy1-eoc-nodal-exposure.txt

   2. EQ24-Nuclear-Design_NRC-Questions_update.docx
      a. smr-eq24-BU-power-peaking-update.txt
      b. smr-eq24-boc-nodal-exposure.txt

   c. smr-eq24-moc-nodal-exposure.txt
   d. smr-eq24-eoc-nodal-exposure.txt
   e. smr-495-wo-fuel-lattice-pin-power.txt

   Please note this CD contains proprietary information and has been marked as such.

b. The grid information within the active fuel is provided in Appendix 167-1 and Appendix 167-2 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
c. Material compositions of all core materials are provided in Appendix 167-1 and Appendix 167-2 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
d. All RCCA information is contained within Appendix 167-1 and Appendix 167-2 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
e. All fuel assembly arrangement information is contained within Appendix 167-1 and Appendix 167-2 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
f. All boron letdown information is contained within Appendix 167-1 and Appendix 167-2 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
g. A table of individual back worths calculated at BOC (0 MWD/MTU) HFP, no xenon conditions was added as Table 14 of Appendix 167-1. A quarter core axially averaged assembly wise power distribution for these same conditions is provided in Figure 13. The Westinghouse SMR Cycle 1 core is quarter core symmetric.
h. The BOC and EOC EQ24 individual bank worths at HFP, Equilibrium conditions are provided in Table 14 and Table 15 of Appendix 167-2.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

Appendix 167-1: Westinghouse SMR Cycle 1 Data

Core and Cycle Overview

The Westinghouse Small Modular Reactor (SMR) Cycle 1 Loading Pattern (LP) is shown in Figure 1. The fuel rod axial features for all rod types in the Cycle 1 model are shown in Figure 2. [

]^{a,c}

Grids dimensions are specified in Table 5. [

]^{a,c}

An all rods out (ARO) critical boron concentration vs. cycle exposure curve is provided as Figure 9. A summary of the Westinghouse SMR Cycle 1 depletion featuring various core average parameters of interest is provided in Table 1. [

]^{a,c}

An ASCII file detailing Westinghouse SMR Cycle 1 assembly-wise burnup, average power, $F_{\Delta H}$, and F_Q as well as core average axial power shape at each burnup step listed in Table 1 has been provided. The specific file description and information is seen below. Note in the AM-General edit that moderator densities provided are in units of gm/cc, and fluxes are in units of n/cm^2/sec and the fluence is in units of n/cm^2.

Description	Filename	Cksum	File Size (bytes)
Axial power shape, assembly burnup, power, and peaking information	smr-cy1-BU-power-peaking-rev1.txt	59776486	344764

The neutronics design dimensions needed for cross-section generation are provided in Tables 2-7. The mass of uranium for each fuel type is provided in Table 8.

Basic Fuel Information

The cladding and pellet dimensions as well as pellet characteristics are provided in Table 2 and basic fuel assembly information is provided in Table 3. [

]a,c

Radial Reflector Information

[

]a,c

Axial Reflector Information

[

]a,c

Control Rod Information

The RCCA pattern for Westinghouse SMR is provided in Figure 8. [

]a,c

Lattice and Nodal Information

Cross-section k-inf and other properties are provided in Table 9 for the various Westinghouse SMR Cycle 1 lattice types as described in Figures 3-7.

Various nodal properties for the Westinghouse SMR Cycle 1 core are provided in separate ASCII files for BOC, MOC, and EOC. The nodes are specified in coordinates of (I,J,K). To relate these coordinates to specific Westinghouse SMR core position, please refer to Figures 10 and 11. The provided values are defined as the following:

[

]a,c

The specific file descriptions are provided below:

Description	Filename	Cksum	File Size (bytes)
Cycle 1 BOC (116 MWD/MTU)	smr-cy1-boc-nodal-exposure.txt	1685526544	349604
Cycle 1 MOC (9448 MWD/MTU)	smr-cy1-moc-nodal-exposure.txt	989040499	349604
Cycle 1 EOC (19620 MWD/MTU)	smr-cy1-eoc-nodal-exposure.txt	3143614334	349604

[

]^{a,c}

Material Compositions

Material compositions for all alloys utilized in the neutronic modeling of the Westinghouse SMR are provided in Table 18. The data provided includes the material density, material atomic weight, and material composition. The material composition includes all isotopes with their related atom fraction and associated number density. [

]^{a,c}

Table 1: Westinghouse SMR Cycle 1 Depletion Information

a,c

Table 2: Westinghouse SMR Fuel Rod Design Parameters of Interest

a,c

Table 3: Westinghouse SMR Assembly Design Parameters of Interest

a,c

Table 4: Westinghouse SMR Core Parameters of Interest

a,c

Table 5: Westinghouse SMR Grid and Sleeve Parameters of Interest

a,c

Table 6: Westinghouse SMR Instrumentation Thimble Parameters of Interest

a,c

Table 7: Westinghouse SMR RCCA Parameters of Interest

a,c

Table 8: Westinghouse SMR Cycle 1 Mass of Uranium per Fuel Type

a,c

Table 9: K-inf vs. Exposure for Multiple Westinghouse SMR Cycle 1 Assembly Types

The tables below show k-inf as a function of exposure for various Westinghouse SMR fuel lattice types. The specific regions can be related to the Westinghouse SMR Cycle 1 core via Figures 3 through 7. [

]a,c

The data and units are defined as the following:

[

]a,c

a,c

a,c

[ ]

a,c

[redacted]

Page 167-1-12

a,c

Page 167-1-13

[ ]a,c

a,c

Page 167-1-15

a,c

a,c

[ ]

Page 167-1-17

Table 10: Westinghouse SMR Control Rod Bank Overlap Scheme

a,c

[ ]

Table 11: Westinghouse SMR Cycle 1 BOC (116 MWD/MTU) HZP, no xenon Rod Worths

a,c

[ ]

Table 12: Westinghouse SMR Cycle 1 MOC (9447 MWD/MTU) HZP, no xenon Rod Worths

a,c

[ ]

Table 13: Westinghouse SMR Cycle 1 EOC (19620 MWD/MTU) HZP, no xenon Rod Worths a,c

[ ]

Table 14: Westinghouse SMR Cycle 1 BOC (0 MWD/MTU) HFP, no xenon Rod Worths

[ ] a,c

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Table 15: Westinghouse SMR Plenum and Spring Data

[ ] a,c

Table 16: Westinghouse SMR Cycle 1 PBU Average Burnup Data

[ ] a,c

[ ] a,c

a,c

Table 17: Westinghouse SMR Axial Reflector Properties

a,c

Table 18: Material Composition of Alloys Utilized in the Westinghouse SMR Nuclear Design

a,c

Table 18 (cont.): Material Composition of Alloys Utilized in the Westinghouse SMR Nuclear Design

a,c

Figure 1: Westinghouse SMR Cycle 1 Quarter Core Loading Pattern

a,c

Figure 2: Westinghouse SMR Cycle 1 Fuel Axial Design

a,c

Figure 3: Westinghouse SMR Cycle 1 Radial Assembly Pattern for Regions A, B, and C No IFBA

a,c

Figure 4: Westinghouse SMR Cycle 1 Region D 2x 100 IFBA Pattern

a,c

Figure 5: Westinghouse SMR Cycle 1 Region D 2x 140 IFBA Pattern

[ ]a,c

Figure 6: Westinghouse SMR Cycle 1 Region D Blanket Region

a,c

Figure 7: Westinghouse SMR Cycle 1 Region D Cutback Region

a,c

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Figure 8: Westinghouse SMR RCCA Pattern

[ ]a,c

Figure 9: Westinghouse SMR Cycle 1 All Rods Out Critical Boron Concentration vs. Cycle Exposure

a,c

Figure 10: Westinghouse SMR Location of Radial Nodes

[ ]a,c

Figure 11: Westinghouse SMR Location and size of Axial Nodes

[ ]a,c

Figure 12: Westinghouse SMR Rod Insertion Limits

a,c

Figure 13: Westinghouse SMR Cycle 1 Assembly PBU Makeup and Locations

a,c

Appendix 167-2: Westinghouse SMR 24 Month Equilibrium Cycle Data

Core and Cycle Overview

The Westinghouse Small Modular Reactor (SMR) 24 month equilibrium cycle (EQ24) Loading Pattern (LP) is shown in Figure 1. [

]^{a,c}

The fuel rod axial features for all rod types in the EQ24 model are shown in Figure 2. [

]^{a,c}

Grids dimensions are specified in Table 5. [

]^{a,c}

An all rods out (ARO) critical boron concentration vs. cycle exposure curve is provided as Figure 7. A summary of the Westinghouse SMR EQ24 depletion featuring various core average parameters of interest is provided in Table 1. [

]^{a,c}

An ASCII file detailing Westinghouse SMR EQ24 assembly-wise burnup, average power, $F_{\Delta H}$, and F_Q as well as core average axial power shape at each burnup step listed in Table 1 has been provided. The specific file description and information is seen below. Note in the AM-General edit that moderator densities provided are in units of gm/cc, the fluxes are in units of n/cm^2/sec and the fluence is in units of n/cm^2.

Description	Filename	Cksum	File Size (bytes)
Axial power shape, assembly burnup, power, and peaking information	smr-eq24-BU-power-peaking-update.txt	2998123675	313331

The neutronics design dimensions needed for cross-section generation are provided in Tables 2-7. The mass of uranium for each fuel type is provided in Table 8.

Basic Fuel Information

The cladding and pellet dimensions as well as pellet characteristics are provided in Table 2 and basic fuel assembly information is provided in Table 3. [

]^{a,c}

Radial Reflector Information

[

]a,c

Axial Reflector Information

[

]a,c

Control Rod Information

The RCCA pattern for Westinghouse SMR is provided in Figure 6. [

]a,c

Lattice and Nodal Information

Cross-section k-inf and other properties are provided in Table 9 for the various Westinghouse SMR lattice types as described in Figures 3-5.

Various nodal properties for the Westinghouse SMR EQ24 core are provided in separate ASCII files for BOC, MOC, and EOC. The nodes are specified in coordinates of (I,J,K). To relate these coordinates to specific Westinghouse SMR core position, please see Figures 8 and 9. The provided values in these ASCII files are defined as the following:

[

]^{a,c}

The specific file descriptions are provided below:

Description	Filename	Cksum	File Size (bytes)
EQ24 BOC (116 MWD/MTU)	smr-eq24-boc-nodal-exposure.txt	3921464417	349604
EQ24 MOC (10172 MWD/MTU)	smr-eq24-moc-nodal-exposure.txt	522405999	349604
EQ24 EOC (20344 MWD/MTU)	smr-eq24-eoc-nodal-exposure.txt	504717194	349604

[

]^{a,c}

Lattice Pin Power Distributions

Pin power distribution as a function of exposure for a typical Westinghouse SMR lattice is also provided. [

]^{a,c}

The pin power distribution data for the lattice can be found in the following file:

Description	Filename	Cksum	File Size (bytes)
Pin Power Distribution as a function of exposure for a 4.95 w/o fuel lattice	smr-495-wo-fuel-lattice-pin-power.txt	983265855	55162

Material Compositions

Material compositions for all alloys utilized in the neutronic modeling of the Westinghouse SMR are provided in Table 19. The data provided includes the material density, material atomic weight, and material composition. The material composition includes all isotopes with their related atom fraction and associated number density. [
]^{a,c}

Table 1: Westinghouse SMR EQ24 Depletion Information

a,c

[ ]

Table 2: Westinghouse SMR Fuel Rod Design Parameters of Interest

a,c

Table 3: Westinghouse SMR Assembly Design Parameters of Interest

a,c

Table 4: Westinghouse SMR Core Parameters of Interest

a,c

Table 5: Westinghouse SMR Grid and Sleeve Parameters of Interest

a,c

Table 6: Westinghouse SMR Instrumentation Thimble Parameters of Interest

a,c

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Table 7: Westinghouse SMR RCCA Parameters of Interest

a,c

a,c

Page 167-2-10

Table 9: K-inf vs. Exposure for Multiple Westinghouse SMR EQ24 Assembly Types

The tables below show k-inf as a function of exposure for various Westinghouse SMR fuel lattice types. The specific regions can be related to the Westinghouse SMR EQ24 core via Figures 3 through 5. Note that the PARAGON data for regions B, X, and Y do not start with 0 MWD/MTU. This is because this fuel is burned and restarts are performed from the previous cycle for the cross-section generation. Note also that the cross-sections for the regions that contain IFBA have a note that states: `NOTE - CONTRIBUTION FOR B10 BURNABLE ABSORBERS HAVE BEEN REMOVED FROM THE MACROSCOPIC TABLE.` This is because the lattice code generates macroscopic cross-sections that are feedback free, e.g. do not contain the effects of soluble boron, boron-based integral fuel burnable absorbers (IFBA), xenon, or samarium. These feedback effects are calculated explicitly and applied in our ANC code.

The data and units are defined as the following:

[

]a,c

a,c

a,c

a,c

[ ]

Page 167-2-14

a,c

a,c

a,c

[ ]a,c

Page 167-2-18

a,c

a,c

Page 167-2-20

a,c

Page 167-2-21

a,c

[ ]

Page 167-2-22

a,c

Table 10: Westinghouse SMR Control Rod Bank Overlap Scheme

a,c

[ ]

Table 11: Westinghouse SMR EQ24 BOC (116 MWD/MTU) HZP, no xenon Rod Worths

a,c

[ ]

Table 12: Westinghouse SMR EQ24 MOC (10172 MWD/MTU) HZP, no xenon Rod Worths

a,c

[ ]

Table 13: Westinghouse SMR EQ24 EOC (20344 MWD/MTU) HZP, no xenon Rod Worths a,c

Table 14: Westinghouse SMR EQ24 BOC (116 MWD/MTU) HFP, Equilibrium Xenon Rod Worths

a,c

Table 15: Westinghouse SMR EQ24 EOC (20344 MWD/MTU) HFP, Equilibrium Xenon Rod Worths

a,c

Table 16: Westinghouse SMR Plenum and Spring Data

[ ]a,c

Table 17: Westinghouse SMR PBU Average Burnup Data

[ ]a,c

a,c

a,c

Table 18: Westinghouse SMR Axial Reflector Properties

a,c

Table 19: Material Composition of Alloys Utilized in the Westinghouse SMR Nuclear Design

a,c

Table 19 (cont.): Material Composition of Alloys Utilized in the Westinghouse SMR Nuclear Design

a,c

Figure 1: Westinghouse SMR EQ24 Quarter Core Loading Pattern

a,c

Figure 1.a: Rotations for Quarter Core Cyclic Geometry

a,c

[ ]

Figure 2: Westinghouse SMR EQ24 Fuel Axial Design

a,c

Figure 3: Westinghouse SMR EQ24 Radial Assembly Pattern for Region B and Regions X, Y, and Z, No IFBA

a,c

Figure 4: Westinghouse SMR EQ24 Regions X, Y, and Z 2x 80 IFBA Pattern

a,c

Figure 5: Westinghouse SMR EQ24 Regions X, Y, and Z 2x 128 IFBA Pattern

a,c

Figure 6: Westinghouse SMR RCCA Pattern

a,c

Figure 7: Westinghouse SMR EQ24 All Rods Out Critical Boron Concentration vs. Cycle Exposure

a,c

Figure 8: Westinghouse SMR Location of Radial Nodes

[ ] a,c

Figure 9: Westinghouse SMR Location and size of Axial Nodes

a,c

Figure 10: Westinghouse SMR Rod Insertion Limits

a,c

Figure 11: Westinghouse SMR EQ24 Assembly PBU Makeup and Locations

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-168
Revision: 0

Question:

Please provide the following design information for the staff to perform confirmatory calculations including:

a. The expected control rod insertion limits at HFP
b. The control rod bank overlap scheme expected to be used
c. Please describe the implementation of the MSHIM search capability in ANC for achieving black/grey control rod positions that satisfy core reactivity and axial offset conditions.

Westinghouse Response:

a. Control rod insertion limits were provided in Figure 12 of Appendix 167-1 and Figure 10 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.
b. This data is provided in Table 10 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.
c. MSHIM™[1] strategy search capability has been implemented in ANC for [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

[1] MSHIM is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-169
Revision: 0

Question:

Please provide the fuel thermal-mechanical design and analysis information for the staff to perform confirmatory thermo-mechanical calculations by providing a description of each unique fuel rod type in each fuel assembly design, including:

a. *Cladding dimensions*
b. *Pellet dimensions*
c. *Heights of axial segments with differing pellet loadings*
d. *Plenum dimensions*
e. *The initial gas gap pressure*
f. *A description of the power history assumptions used to derive parameters for subsequent transient analyses (e.g. the assumed linear heat generation rate history assumed for the average fuel rod in determining gap conductance in downstream transient evaluations and the axial power shape).*

Westinghouse Response:

a. The cladding dimensions are provided in Table 2 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
b. The pellet dimensions are provided in Table 2 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
c. The axial segment heights are provided in Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167 for the Westinghouse SMR Cycle 1 and EQ24 designs respectively.
d. Plenum dimensions are provided in Table 15 of Appendix 167-1 and Table 16 of Appendix 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167.
e. The initial gas gap pressure is provided in Table 2 of Appendices 167-1 and 167-2 of RAI response RAI-TR-SBLOCA-PIRT-167. It is [
   ]a,c
f. [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR-SBLOCA-PIRT-170
Revision: 0

Question:

In response to RAI-TR-SBLOCA-PIRT-67, Westinghouse provided mDNBR plots for several events. In Figure 67-5 for the Complete Loss-of-Flow (CLOF) event, the mDNBR decreases after the pumps trip. The minimum value reached during the event appears to be very close to the mDNBR limit. Please provide this minimum value and justify the acceptance of this event in terms of DNBR.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-1
Revision: 0

Question:

Containment phenomenon such as [ ]a,c are highly dependent on the containment design and layout of the internal structures. The condensation on the containment shell and on the passive heat sinks in the presence of non-condensable gases involves multi-dimensional phenomena. The Westinghouse Small Modular Reactor (W-SMR) containment is noticeably different in its size, construction and the containment internals as compared to other PWR containments including AP600/AP1000. In addition, thermal-hydraulically, the containment is tightly coupled to the Reactor Coolant System (RCS), again unlike other PWRs. Based on the responses to RAI-TR-SBLOCA-PIRT-04 and RAI-TR-SBLOCA-PIRT-30, the containment pressure during design basis events can vary from [ ]a,c in contrast to the design pressure for AP1000 which is approximately 0.5 MPa. The conditions on the outside of the containment shell in the W-SMR also differ from those for AP1000 (i.e., a pool of water as compared to a falling and evaporating water film). Therefore, the available test data from AP600/AP1000 testing program cannot necessarily be considered to be applicable to W-SMR accident conditions [

]a,c

Note that the knowledge ranking for containment phenomena has also, for similar reasons, been questioned separately in RAI-TR-SBLOCA-PIRT-78. Please provide justifications for [ ]a,c The response should include delineation of specific design differences with AP600/AP1000, and substantiation of the basis for applicability of the specific AP600/AP1000 test data that is considered to be applicable to the W-SMR design.

Westinghouse Response:

[

]a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-2
Revision: 0

Question:

The proposed Integral Effects Test (IET) facility design for the containment appears to be [

]a,c As discussed in RAI #1 above, multi-dimensional effects are considered to be important in the prediction of containment response behavior under transient and accident conditions in W-SMR. It is questionable whether the containment characterization in the proposed IET facility will adequately capture the conditions that are expected in the prototype. Furthermore, an incorrect representation of the containment response will also affect the RCS behavior for the tested scenario. Please provide the rationale for the proposed containment modeling in the IET facility addressing the aforementioned concerns.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-3
Revision: 0

Question:

SETs have not been proposed for investigating the potential for debris- and chemical precipitate-induced blockage in the reactor core. [

]^{a,c} Furthermore, if it is intended to use the existing debris related test data for W-SMR, please address the following:

a. [

]^{a,c}

b. WCAP-17573-P states that the knowledge level for blockage due to chemical precipitates is [

]^{a,c} Please provide justification for not proposing SETs for W-SMR conditions and explain how the impact of debris- and chemical precipitate-induced blockage in the reactor core will be captured in the evaluation model.

Westinghouse Response:

[

]^{a,c}

[1] AP1000 is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-4
Revision: 0

Question:

SETs have not been proposed for the pressurizer separator plates. The unique design of the pressurizer separator plates and the [

]a,c The IET design information (Addendum 1 to WCAP-17712-P) states that the plates in the IET will be scaled [

]a,c Please explain/justify the absence of plans for tests applicable to the W-SMR pressurizer separator plates.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-5
Revision: 0

Question:

SETs have not been proposed to determine the applicability of the existing DNBR correlations to the W-SMR conditions and fuel assembly geometry. The responses to previous RAIs (e.g., RAI-TR-SBLOCA-PIRT-67) indicate that Westinghouse currently intends to use its [

]a,c

Westinghouse Response:

Justification that the use of the [ ]a,c is appropriate for the design basis accident conditions analyzed, including limiting events such as complete loss of flow, will be provided in the Westinghouse SMR design certification application.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-6
Revision: 0

Question:

Please confirm that all the proposed tests in the IET matrix (Table 7-1 in Addendum 1 to WCAP-17712-P) will be performed to be representative of the behavior expected in the prototype. As an example, for the DVI line break, [

]a,c

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-7
Revision: 0

Question:

Please explain the rationale for not including design basis transients, especially those that are expected to be limiting, in the test matrix for the IETs presented in Table 7-1 of Addendum 1 to WCAP-17712-P. Examples include recirculation feedwater line break, and the recirculation steam line break [ ]a,c

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-8
Revision: 0

Question:

The IET facility test matrix (Table 7-1 in Addendum 1 to WCAP-17712-P) does not include [

]a,c The matrix for the DVI line break does not appear to address this issue. Please elaborate.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-9
Revision: 0

Question:

The four ADS-2 lines are designed to open in a [

]a,c will be effectively captured using only a sector of the upper plenum as is currently proposed for the test facility. Please elaborate.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-10
Revision: 0

Question:

One of the reasons for the proposed SETs is to determine [

]a,c. Please provide information on the criterion (or criteria) for determining the optimal combination of the [ ]a,c, and its basis.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-11
Revision: 0

Question:

There appears to be a typographical error in Section 1.10.1 of Addendum 2 to WCAP-17712-P. The "Wright-Reyes paper (Reference 24)" is referred to in that section. The reference number, based on the list in Section 2, should be 25 instead of 24. In addition, the authors in the citation are Wright and Schulz. Please confirm and correct the LTR, if appropriate.

Westinghouse Response:

It is confirmed that Section 1.10.1 of Addendum 2 to WCAP-17712-P should read "Wright – Schultz paper (Reference 25)".

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Addendum 2 to WCAP-17712-P will be updated to reflect this change.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-12
Revision: 0

Question:

Please explain the term [ ]^{a,c} in Section 1.12 of Addendum 2 to WCAP-17712-P. Furthermore, please explain how these will be factored into the test matrix (i.e., what will be the value of other test parameters at the "reserved" conditions?), and the expected results that will be achieved in terms of increasing the knowledge levels of the relevant phenomena.

Westinghouse Response:

As mentioned in response to RAI-W SMR Test Plan and Scaling-10, [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-13
Revision: 0

Question:

The results shown in Figures 1-7 through 1-14 are used to determine the range of superficial gas and liquid velocities. Please provide information on the scenario from which the cited figures have been obtained. Furthermore, please provide the justification for considering the selected scenario as being representative for determining the ranges.

Westinghouse Response:

The scenario from which the cited figures have been obtained is a [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-14
Revision: 0

Question:

Figures 1-20 and 1-21 cited in Section A.1.2 of Addendum 2 to WCAP-17712-P do not exist. Please confirm and correct the LTR as appropriate.

Westinghouse Response:

Figure A-6 and A-7 are the applicable referenced figures which correspond to the erroneously cited Figures 1-20 and 1-21 respectively. Figures A-6 and A-7 can be found in Section A.1.2 on page A-5 of Addendum 2 to WCAP-17712-P.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Addendum 2 to WCAP-17712-P will be updated to reflect this change.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-15
Revision: 0

Question:

Based on the test matrix in Tables A-3 and A-4 of Addendum 2 to WCAP-17712-P, the ADS-2 tests appear to be planned with [

]a,c expected in the core and upper plenum during ADS-2 operation.

Westinghouse Response:

[

]a,c

a,c

Figure 1: Superficial liquid velocities in ADS-2 nozzle venturi.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-16
Revision: 0

Question:

Please address the following questions on the representation of the CMTs (via the balance line) in the ADS-2 test facility (Addendum 2 to WCAP-17712-P):

a. It is unclear from the description of the test and the test matrix how the flow splitting between the CMTs and ADS-2 will be investigated experimentally.

b. Please explain what CMT balance line boundary conditions will be imposed during the tests and how this will be achieved. The test matrix presented in Tables A-3 and A-4 of Addendum 2 to WCAP-17712-P does not include any boundary conditions related to the CMT balance line. Please explain the reason for not including the impact of CMT conditions in the test matrix.

c. The results shown in Figures 1-11 through 1-14 that are used to determine the range of conditions for the CMTs are believed to be based on computer code calculations. For each phase through the CMT balance line [

]^{a,c} is expected to be influenced by natural circulation through the CMTs and condensation in the PRHR heat exchanger housed in the CMTs. The accuracy of the code predictions will affect the boundary conditions considered for the tests. Please explain whether the code has been benchmarked against any available natural circulation and tube condensation data test data for the prediction of these phenomena.

d. Please explain how the conditions imposed on the CMT balance line will be confirmed to be representative of the actual CMT behavior. Improper or non-representative CMT boundary conditions may skew the experimental results, especially related to flow splitting.

Westinghouse Response:

[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]^{a,c}

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

[

]a,c

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-17
Revision: 0

Question:

Referring to Section A.1.3 of Addendum 2 to WCAP-17712-P, please explain what section of the reactor is considered to be part of the "upper plenum" and what constitutes the "upper head".

Westinghouse Response:

Both Tables A-1 and A-2 are applicable to the upper plenum. Both the support column region and the CRDM region are within the upper plenum. To differentiate the two regions however the author designated the region with the CRDMs as the "upper head". Therefore Table A-1 considers the parameters in the region of the support columns in the upper plenum and Table A-2 considers the parameters in the region of the CRDM in the upper plenum, but designated as the "upper head".

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Addendum 2 to WCAP-17712-P will be updated in the future to designate the different regions instead of designating the CRDM as the "upper head".

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-18
Revision: 0

Question:

The caption for Figure A-7 in Appendix A to Addendum 2 to WCAP-17712-P appears to be incorrect. Please confirm and if appropriate, correct the LTR. Similarly, please check the caption of the section heading for references.

Westinghouse Response:

The caption for Figure A-7 in Appendix A to Addendum 2 to WCAP-17712-P should be:
[ ]a,b,c

The referenced Figures 1-20 and 1-21 in Section A.1.2 of Appendix A to Addendum 2 to WCAP-17712-P should be Figures A-6 and A-7.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Addendum 1 to WCAP-17712-P will be updated to reflect these changes.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-19
Revision: 0

Question:

The [

]^{a,c} have not been used.

a. Please confirm this understanding.

b. If the understanding is correct, please explain how the [ ]^{a,c} in Table A-3 were selected based on the [ ]^{a,c}.

c. Please compare the [ ]^{a,c} selected in Table A-3 of Addendum 2 to WCAP-17712-P for the test matrix against the values at which [ ]^{a,c} are expected to occur

Westinghouse Response:
[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-20
Revision: 0

Question:

According to Section A.1.3 of Addendum 2 to WCAP-17712-P, the [

]a,c Please clarify. If the [
]a,c is selected as the boundary condition, please clarify the method to determine the flow through the spargers.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-21
Revision: 0

Question:

Table A-6 of Addendum 2 to WCAP-17712-P states that sensitivities to [ ]^{a,c}. Previous discussions in Appendix A to Addendum 2 to WCAP-17712-P lead one to believe that the [ ]^{a,c}.

Please clarify.

Westinghouse Response:

The Staff's understanding is correct. [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-22
Revision: 0

Question:

Table A-6 of Addendum 2 to WCAP-17712-P provides qualitative information about the proposed sensitivities. Please confirm that it is Westinghouse's intention to include in the Addendum 2 to WCAP-17712-P, when available, a detailed discussion, including justification, of the final sensitivity cases selected and a full factorial test matrix, similar to the one in Table A-4, for the sensitivity cases.

Westinghouse Response:

[

]a,c

Westinghouse will communicate the test matrix along with sufficient technical justification to the Staff.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-23
Revision: 0

Question:

Table ES-4 of WCAP-17573-P identifies the [

]^{a,c} to separate effects testing.

a. In Addendum 1 to WCAP-17712-P, there is no equivalent indication of what phenomena will be evaluated and if all [ ]^{a,c} assigned to IETs will be assessed by tests listed in the matrix established for the IETs. Please propose a revision to the Addendum 1 to WCAP-17712-P introduction that indicates the phenomena to be evaluated.

b. The test matrices and test descriptions in both Addenda 1 and 2 of WCAP-17712-P do not indicate which tests in each matrix will be used to assess the individual phenomena assigned to IETs and SETs. Please propose a revision to the test matrices in Addenda 1 and 2 of WCAP-17712-P that relates the planned test to the specific phenomenon.

Westinghouse Response:

[

]^{a,b,c}

[

]^{a,b,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

PRA Revision:

None.

Technical Report (TR) Revision:

Update Addenda 1 and 2 of WCAP-17712-P with a statement that indicates that all the identified phenomena that will be tested in the IET and SET.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-24
Revision: 0

Question:

Table ES-1 of WCAP-17712-P lists [ ]^{a,c}. The same table also states that additional details about this phenomenon that can be studied using the SETs. Table 1-1 of Addendum 2 to WCAP-17712-P does not include this phenomenon and there is no discussion of how the SET plan and test matrix will provide information on this phenomenon.

Please explain.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-25
Revision: 0

Question:

Since the SET section described in Addendum 2 to WCAP-17712-P is [ ]^{a,c} may not be well reproduced. When the CMT balance line is in operation, the entrainment and counter current flow process may occur in radial location which is outside of the [ ]^{a,c}

Westinghouse Response:

As noted in response to RAI-W SMR Test Plan and Scaling-16 [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-26
Revision: 0

Question:

The SET facility design pressure is [

]a,c Does the pressure operating range of the test facility cover the splitting of ADS-2 flow and CMT balance line flow in the early stage of ADS-2 operation?

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-27
Revision: 0

Question:

According to the SET plan described in Addendum 2 to WCAP-17712-P, the working fluid is an [ ]^{a,c}. The entrainment and countercurrent flow limiting processes are related to surface tension and interfacial drag. Please justify the applicable operating range of the correlations in lieu of fluid properties and test operating conditions.

Westinghouse Response:

The correlations in references 1 and 2 are presented in [

]^{a,c}

See also the response to RAI-W SMR Test Plan and Scaling-30.

Reference:

[

]^{a,c}

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-28
Revision: 0

Question:

In Section 1.12.1 of Addendum 2 to WCAP-17712-P, please show the superficial liquid velocity for the ADS-2 line.

Westinghouse Response:

Superficial liquid velocity as a function of transient time for the ADS-2 line is shown below:

a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-29
Revision: 0

Question:

In Section 1.13 TEST PROCEDURE of Addendum 2 to WCAP-17712-P, the [

]a,c may result in distortion that is difficult to quantify. Please justify this approach.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-30
Revision: 0

Question:

In Section A.1.2 Entrainment Scaling of Addendum 2 to WCAP-17712-P, please explain why the test facility [ ]a,c separately in order to measure all three regimes?

Westinghouse Response:

The purpose of Section A.1.2 is to [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-31
Revision: 0

Question:

In Table A-4 of Addendum 2 to WCAP-17712-P, please explain the purpose of varying [ ]a,c.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-32
Revision: 0

Question:

Appendix A-F (SPES-4 Scaling Basis) of Addendum 1 to WCAP-17712-P is incomplete and several errors were identified in the document. Some important components do not have scaling information. In addition, the report does not address the scaling of some important phase-specific local phenomena. The missing information and errors are identified with RAIs #33 through #58 below. The scaling methodology proposed in earlier Westinghouse presentation slides was [ ]a,c. Please provide a complete top-down and bottom-up scaling analysis justifying the similarity between the prototype and the scaled model.

Westinghouse Response:

[ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-33
Revision: 0

Question:

The quality of Addendum 1 to WCAP-17712-P and the accuracy of calculations documented in this addendum need to be improved. Please address the following issues:

a. The reviewer identified use of different values for the same scaling ratio in the document, [ ]a,c This inconsistency results in design inaccuracy. Please use consistent values for scaling ratios.

b. Please include complete information for both SPES-4 and W-SMR for comparisons. An example for missing information is the downcomer, which has design value table but no W-SMR values.

c. Different nomenclatures are used for scaling factor, e.g. F and SF. Please use consistent nomenclature.

d. Please correct the unit of the Outer Containment Pool (OCP) water level on page 67 of Addendum 1 to WCAP-17712-P.

e. Please show the prototype and model design values for each component in one table for side-by-side comparison.

Westinghouse Response:

a. A scaling ratio of [ ]a,c was consistently applied throughout the report. [ ]a,c was also applied in cases where other scaling factors such as [ ]a,c were reported. These will be made consistent.

b. The SMR parameters for the downcomer is:

a,c

[ ]

c. The consistent nomenclature for the scaling factor should have been F.

d. The Outer Containment Pool (OCP) water level on page A-67 should have been [ ]a,c.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

e. The prototype and model design values for each component in one table for side-by-side comparison were presented in Appendix B of Addendum 1 to WCAP-17712-P.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Addendum 1 to WCAP-17712-P will be updated to reflect these changes.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-34
Revision: 0

Question:

Please address the scaling of stored energy in the reactor vessel components, such as the core. For a fast transient, the fuel stored energy plays an important role.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-35
Revision: 0

Question:

The single phase and two-phase loop flow resistance in the RPV loop and, in particular, in the core region and SG tubes were not considered. Please address this finding.

Westinghouse Response:

WCAP-17712-P was written to provide [

]^{a,c}

Refer also to the response to RAI-W SMR Test Plan and Scaling-59 which describes the planned separate methodology report related to the scaling of the test facilities and its relationship to the scaling formulation in the addenda to WCAP-17712-P.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-36
Revision: 0

Question:

The [ ]^{a,c} used in Addendum 1 to WCAP-17712-P lacks [ ]^{a,c} Please describe the compensating actions planned to address these distortions.

Westinghouse Response:

Westinghouse plans to perform a [[1]]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-37
Revision: 0

Question:

SPES-4 was modified from SPES-2 which was developed for AP-600 testing. Please justify the modifications made to SPES-2, [ ]a,c, and sufficiency for W-SMR testing based on the design differences.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-38
Revision: 0

Question:

Please include core bypass scaling in Table A-7 and A-8 of Addendum 1 to WCAP-17712-P.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

"Core Bypass Volume" will be removed from Table A-6 of WCAP-17712-P, Addendum 1

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-39
Revision: 0

Question:

In section A.2.7 of Addendum 1 to WCAP-17712-P, the [ ]a,c is not well presented. The scaling calculation is not shown. The [ ]a,c do not appear to be in agreement with the flow paths shown in Figures A13, A14, and A16. On page A21, please provide the description for parameters used in the equation.

Westinghouse Response:

The separation plates in the Westinghouse SMR pressurizer [

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Section A.2.7 of Addendum 1 to WCAP-17712-P will be revised.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-40
Revision: 0

Question:

In section A.2.8 of Addendum 1 to WCAP-17712-P please verify and correct as necessary the [ ]^{a,c} scaling equation set and numbers. Please check and correct inconsistencies, such as: the constant value of [ ]^{a,c} in the first equation does not match the numbers shown in Table A-20 for L1, L2 and L3 pipe ID. Also, a scaling factor should appear in V5 and V6 terms.

Westinghouse Response:

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Section A.2.8 of Addendum 1 to WCAP-17712-P will be updated to reflect these changes.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-41
Revision: 0

Question:

In section A.2.9 of Addendum 1 to WCAP-17712-P, the RCP scaling is not shown. Will the RCP scaling include the portion of the flow path from SG primary tube outlet to RCP input? As mentioned on Page 31, please also provide the pump curve and the design connecting the downcomer and the SGPSS.

Westinghouse Response:

a,b,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

[ ] a,b,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Provide the detailed connection design connecting the downcomer and the SGPSS after detail design of the SPES 4.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: W SMR Test Plan and Scaling-42
Revision: 0

Question:

The PRHR heat transfer area distortion (difference between ideal and actual) shown on Table A-23 and discussed on Page A-34 of Addendum 1 to WCAP-17712-P was evaluated as [ ]^{a,c}. Please elaborate on ways to compensate for this distortion in the design. Also, since there are only [ ]^{a,c} (as shown on Figure A-21), the heat transfer flow boundary condition outside of the tube is changed from the prototype. Please address any distortion due to this tube pattern difference.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-43
Revision: 0

Question:

The geometry data in Table A-24 of Addendum 1 to WCAP-17712-P should be for the W-SMR's and not SPES-4. Please verify and correct, as necessary.

Westinghouse Response:

Table A-24 of Addendum 1 to WCAP-17712-P is applicable to the Westinghouse SMR CMT geometric data and not to SPES -4.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Update Table A-24 of Addendum 1 to WCAP-17712-P with the above correction.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-44
Revision: 0

Question:

In Table A-25 of Addendum 1 to WCAP-17712-P, the SPES-4 [ ]^{a,c} were not scaled according to the scaling ratio. Please verify and correct, as necessary.

Westinghouse Response:

Please find the following updated scaling values for Table A-25 of Addendum 1 to WCAP-17712-P:

[ ]^{a,b,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Update Table A-25 of Addendum 1 to WCAP-17712-P with the above correction.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-45
Revision: 0

Question:

In section A.2.11 of Addendum 1 to WCAP-17712-P, the scaling factor appears to be in the wrong part of the equations. Sign and subscripts are wrong in some places. Please verify and correct the equations, as necessary, and re-verify the SPES-4 geometry data.

Westinghouse Response:

Westinghouse agrees that portions of the equations presented in section A.2.11 of Addendum 1 were incorrect. The following equations will replace those presented on page A-38 of Addendum 1 of WCAP-17712-P.

[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

The equations provided on pages A-37 and A-38 of WCAP-17712-P, Addendum 1, Revision 0 will be revised as described herein.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-46
Revision: 0

Question:

A constant factor of [ ]^{a,c} is applied to the horizontal length of CMT balance line (and other flow components) to obtain the total flow length in Addendum 1 to WCAP-17712-P. Please justify the use of this factor.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-47
Revision: 0

Question:

In Table A-29 of Addendum 1 to WCAP-17712-P, the pipe ID [ ]^{a,c} does not match the ID derived from the equation [ ]^{a,c}. Please verify and correct, as necessary.

Westinghouse Response:

The test facility direct vessel injection line pipe inside diameter of [ ]^{a,c} provided in Table A-29 of WCAP-177712-P, Addendum 1, Revision 0 has been confirmed to be accurate using the appropriate equation. The value listed in the equation is incorrect and will be updated accordingly.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

The equation provided on Page A-40 of WCAP-177712-P, Addendum 1, Revision 0 will be revised as described above.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-48
Revision: 0

Question:

In section A.2.13 of Addendum 1 to WCAP-17712-P, the scaling of the Sump Injection Line is incomplete. Please review and correct, as necessary.

Westinghouse Response:

The following update in Section A.2.13 of Addendum 1 to WCAP-17712-P:

[ ]a,b,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Update section A.2.13 of Addendum 1 to WCAP-17712-P with the above correction.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-49
Revision: 0

Question:

In Table A-35 of Addendum 1 to WCAP-17712-P, the pipe ID [ ]^{a,c} does not match the ID derived from the equation [ ]^{a,c}. Please verify and correct, as necessary.

Westinghouse Response:

Westinghouse agrees the test facility ICP injection line pipe inside diameter should be [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Table A-35 of WCAP-17712, Addendum 1 will be revised to reflect the correct pipe inside diameter.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-50
Revision: 0

Question:

The scaling of the [ ]^{a,b,c} is considered in detail in Addendum 1 to WCAP-17712-P but the scaling of the [ ]^{a,b,c} is not provided. Please provide the missing scaling information including any minor losses.

Westinghouse Response:

a,b,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,b,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Update section A.2.16 of Addendum 1 to WCAP-17712-P to include the above [ ]a,b,c line scaling.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-51
Revision: 0

Question:

According to the Westinghouse SBLOCA analysis for the W-SMR, the SG isolation valve will close around [
]^{a,c} The heat transfer from the primary to the secondary side plays an important role in determining the primary side energy. The primary side volume and flow area are considered in Addendum 1 to WCAP-17712-P but it is not clear how the heat transfer from primary side to the secondary side is scaled. Please provide details on SG heat transfer scaling and quantify the scaling distortions.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-52
Revision: 0

Question:

The [ ]^{a,c} of the SBLOCA event for the W-SMR. The containment scaling [ ]^{a,c} were not considered either. The analysis also considered the [ ]^{a,c} as heat sinks by adding additional mass in the [ ]^{a,c} Please include more factors, such as the geometry of the component, in the analysis.

Westinghouse Response:

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-53
Revision: 0

Question:

On page A-54 of Addendum 1 to WCAP-17712-P, please clarify the symbols of the dome surface area equation.

Westinghouse Response:

In this equation, "a" equals "b" which equals the radius of the containment. "c" is the height of the dome above the top of the cylindrical wall. "p" is a constant that is recommended to be [ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-54
Revision: 0

Question:

In Table A-47 of Addendum 1 to WCAP-17712-P, please clarify the rows and columns data of the W-SMR flood up volume versus elevation.

Westinghouse Response:

Below is a revised Table A-47 that includes column descriptions. The rows represent vertical sections of the containment vessel (CV).

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Table A-47 of WCAP-17712-P, Addendum 1 will be updated as shown in the response provided.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-55
Revision: 0

Question:

In section A.2.21 of Addendum 1 to WCAP-17712-P, please provide the CMT secondary side cooling system scaling.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-56
Revision: 0

Question:

In Table C-2 of Addendum 1 to WCAP-17712-P, the W-SMR volume conversion from SI units to English units is not correct. Also, the volume for SPES-4 is not correct. Please review and correct as necessary.

Westinghouse Response:

The volumes provided in Table C-2 of WCAP-17712-P, Addendum 1 will be updated to those shown below.

a,c

[ ]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Table C-2 of WCAP-17712-P, Addendum 1 will be updated as shown in the response provided.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-57
Revision: 0

Question:

In Table D-1 of Addendum 1 to WCAP-17712-P, the reactor coolant flow for SPES-4 is not correct. Please double check and correct value.

Westinghouse Response:

The value associated with the reactor coolant flow for SPES-4 in US customary units was updated to reflect a consistent use of the scaling factor as described in the response to RAI-W SMR Test Plan and Scaling-33. The reactor coolant flow in metric units was updated to reflect the proper conversion between the units. The table below provides the revised values.

a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Table D-1 of WCAP-17712-P, Addendum 1 will be updated as shown in the response provided.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-58
Revision: 0

Question:

On page F-1 of Addendum 1 to WCAP-17712-P, please clarify the symbols used in the [ ]a,c

Westinghouse Response:

The terms of the [ ]a,c provided on Page F-1 of WCAP-17712-P, Addendum 1 are as follows:

[ ]a,b,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-59
Revision: 0

Question:

Westinghouse has indicated that a separate methodology topical report related to the scaling of the test facilities will be submitted. A brief description of the content of the planned topical report, its relationship to the scaling formulation in the addenda to WCAP-17712-P, and information about the expected submission schedule would be beneficial to the on-going pre-application review by NRC.

Westinghouse Response:

A topical report describing the scaling of SMR test facilities will be submitted to NRC [

]a,c,e

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-60
Revision: 0

Question:

Please provide diameter of air operated valves on the top of SITs.

Westinghouse Response:

The air-operated valves on top of the sump injection tanks (SIT) are [
]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-61
Revision: 0

Question:

Please provide the valve sizes (size of the most restrictive section) and the form losses for check valve and ADS valve in an ADS-1 line.

Westinghouse Response:

[

]a,b,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-62
Revision: 0

Question:

Please provide form loss in an ADS-2 valve.

Westinghouse Response:

The form loss coefficient for the ADS-2 valves is currently modeled to be [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-63
Revision: 0

Question:

Please provide wall thickness for CMT and SIT shell.

Westinghouse Response:

The wall thickness of the core makeup tank (CMT) varies anywhere from [ ]a,c as indicated in Figure 63-1 below.

The wall thickness of the sump injection tank (SIT) is planned to be [ ]a,c

[ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-64
Revision: 0

Question:

Please confirm that the BAT is open to the atmosphere.

Westinghouse Response:

The boric acid storage tank (BAST) resides outside containment and is designed for an operating pressure of [ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-65
Revision: 0

Question:

Please confirm that the free volume in the region between upper core plate and upper support plate excluding the free volume inside the guide tubes is [ ]a,c

Westinghouse Response:

The free volume in the region between the upper core plate and upper support plate, excluding both the guide tubes and support columns, is [ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-66
Revision: 0

Question:

Please confirm that the height of the cylindrical section in the pressurizer [ ]^{a,c} is relative to the top of the pressurizer surge plate.

Westinghouse Response:

The height of the cylindrical section in the pressurizer (taken from the top of the pressurizer surge plate to the bottom of the hemispherical upper head) is [ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-67
Revision: 0

Question:

Please confirm that the volume of pressurizer surge plate of [ ]^{a,c} is the free volume (i.e., the volume occupied by water).

Westinghouse Response:

The pressurizer baffle region has a designed flow region of [ ]^{a,c} The height of the pressurizer baffles are [ ]^{a,c}, resulting in a total flow volume of [ ]^{a,c} for the pressurizer surge plate. See Figure 67-1 for more information.

[ ]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-68
Revision: 0

Question:

The upper head of the RPV appears to be a portion of a hemisphere. Please provide the height of the upper head of the RPV/pressurizer.

Westinghouse Response:

The upper head of the pressurizer is a [ ]a,c, as shown in Figure 68-1 below.

a,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-69
Revision: 0

Question:

Please provide form loss coefficient for the steam generator depressurization valves (SGDVs)

Westinghouse Response:

[

] a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-70
Revision: 0

Question:

Please provide material of construction for the RPV wall.

Westinghouse Response:

The Reactor Pressure Vessel (RPV) is planned to be fabricated from [
]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-71
Revision: 0

Question:

Please provide inner diameter of the guide tubes between upper core plate and upper support plate.

Westinghouse Response:

The guide tubes between the upper core plate and upper support plate have dimensions as shown in Figure 71-1 below. Each of the [ ]^{a,c} is designed in the shape of a [ ]^{a,c}

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-72
Revision: 0

Question:

Please confirm that the support columns between upper core plate and upper support plate are solid rods; if not, please provide the inner diameter.

Westinghouse Response:

The support columns between the upper core plate and upper support plate are designed as shown in Figure 72-1 below. The support columns consist of a [

]a,c

a,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-73
Revision: 0

Question:

Please confirm that the control rod drive mechanisms (CRDMs) between upper core plate and upper support plate are solid structure; if not, please provide the inner diameter.

Westinghouse Response:

For the purpose of most core internal fluid analysis, the control rod drive mechanisms (CRDMs) between upper core plate and upper support plate [

]^{a,b,c}

For the purpose of heat transfer between CRDM and Reactor Coolant System (RCS) fluid, the current available thermal properties are defined in RAI-TR-SBLOCA-PIRT-115-P.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-74
Revision: 0

Question:

Please provide the material for the pressurizer separator plates.

Westinghouse Response:

The material for the pressurizer separator plates is [ ][a,c]

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-75
Revision: 0

Question:

Please provide height of the cylindrical wall of the steam drum.

Westinghouse Response:
The steam drum is currently planned to be comprised of the following sections as shown in Figure 75-1 below: [

]a,c

a,c

[ ]

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-76
Revision: 0

Question:

Please provide the geometry information for the upper and lower heads of the steam drum.

Westinghouse Response:

The geometry information for the upper and lower heads of the steam drum can be found the diagram below.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

a,b,c

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-77
Revision: 0

Question:

Please discuss the comparisons performed to validate Westinghouse's current neutronics methods against measurements from facilities that used shorter active core heights and reflectors of the type envisioned for W-SMR.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-78
Revision: 0

Question:

Please confirm the materials to be used for fabrication of the steam drum cylindrical wall and upper/lower elliptical heads.

Westinghouse Response:

The upper elliptical head, shell barrels (cylindrical wall), and lower elliptical head of the steam drum are planned to be fabricated from [ ]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-79
Revision: 0

Question:

Follow-up to RAI-TR-SBLOCA-PIRT-91: The changes due to RAI-TR-SBLOCA-PIRT-91 as shown in response to RAI-TR-SBLOCA-PIRT-103 simply alter the importance ranking for [

]^{a,c}

Westinghouse Response:

SMR_NRC_000034, "SMR Response to Request for Addition Information (SBLOCA PIRT)," February 14, 2014 contains Revision 1 to RAI-TR-SBLOCA-PIRT-91 which addresses this question.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-80
Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-75: According to the response to RAI-TR-SBLOCA-PIRT-74, Westinghouse has agreed that the [ ]^{a,c}.

Similarly, the response to RAI-TR-SBLOCA-PIRT-74 also states that there is [ ]^{a,c}. However, the updated version of Figure 3-2 shown in response to RAI-TR-SBLOCA-PIRT-103 does not appear to capture these changes. Figure 3-2 shown in response to RAI-TR-SBLOCA-PIRT-103 continues to states that the SDGVs [ ]^{a,c}." Please make appropriate changes to Figures 3-2 and 3-3.

Westinghouse Response:

Figure 3-2 and 3-3 of WCAP-17573 are modified as follows: [

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573 will be revised as described in the response. The changes are provided in a revision to the response provided for RAI-TR-SBLOCA-PIRT-103.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-81
Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-78: The response cites [

]a,c

Westinghouse Response:

[

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-82
Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-89: The response to the original RAI provided justification for the importance ranking which is acceptable. However, the rationale for the corresponding importance ranking still states that a [
]a,c." It is not clear how the [
]a,c. The rationale is expected to incorporate the justification provided in response to the RAI. Please clarify the rationale and/or make appropriate changes.

Westinghouse Response:
[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573 will be revised as described in the response. The changes are provided in a revision to the response provided for RAI-TR-SBLOCA-PIRT-103.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-83
Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-99: Even though the response to the original RAI is acceptable, the definition for the [ ]a,c phenomenon (D37 in Table 3-2 of the LTR) is unclear and does not contain the clarification provided in response to part (a) of the RAI. It is recommended that the definition be updated to clarify the phenomenon T.1.e to improve the LTR and facilitate review.

Westinghouse Response:

[

]a,c

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573 will be revised as described in the response. The changes are provided in a revision to the response provided for RAI-TR-SBLOCA-PIRT-103.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-84
Revision: 0

Question:

Follow-up to RAI-TR-SBLOCA-PIRT-88: The original RAI only questioned the knowledge ranking form phenomenon E.1 in Table 3-3. The response to the original RAI agreed to change the knowledge ranking to [ ]^{a,c}. However, the response to the original RAI also changed, without justification, the importance ranking for the phenomena to [ ]^{a,c} as seen in the response to RAI-TR-SBLOCA-PIRT-103. The importance ranking was never questioned in the original RAI. Furthermore, detailed justification for decreasing the importance ranking is necessary. Please explain the reason for changing the importance ranking for phenomenon E.1.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

WCAP-17573-P Table 3-3 will be updated to change the importance for E.1 from “L” to “M”.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-85
Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-164: The response did not provide sufficient information for staff evaluation. Please supply more information on how the process is modeled in the code, not just the code name and its version.

Westinghouse Response:

SMR_NRC_000034, "SMR Response to Request for Addition Information (SBLOCA PIRT)," February 14, 2014 contains Revision 1 to RAI-TR-SBLOCA-PIRT-164 which addresses this question.

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-86
Revision: 0

Question:

Follow-on to RAI-TR SBLOCA PIRT-118: Please provide the form loss coefficients in the sump injection line and sump coupling valve.

Westinghouse Response:

[

]^{a,c}

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

RAI Response Number: RAI-W SMR Test Plan and Scaling-87

Revision: 0

Question:

Follow-up to RAI-TR SBLOCA PIRT-132: The information provided on structures surrounding the RPV cylindrical wall and lower head is inadequate to visualize or understand the natural circulation flow that can occur around the lower head. Please provide a schematic drawing of [

]^{a,c}.

Furthermore, please explain the role of [

]^{a,c}.

Westinghouse Response:

[

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WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

]a,c

WESTINGHOUSE SMR REVIEW

Response to Request For Additional Information (RAI)

a,c

Figure 1: Components of the Reactor Vessel Insulation System

a,c

Figure 2: In-Vessel Retention Cooling Flow Path

WESTINGHOUSE SMR REVIEW
Response to Request For Additional Information (RAI)

Reference:

None.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

None.