Westinghouse

Westinghouse Small Modular Reactor

Small Break LOCA Phenomena Identification & Ranking Table (PIRT) Presentation

PROJ0797

NRC Headquarters
June 2012

WAAP-7951-NP

Outline

- Meeting Objectives
- Westinghouse SMR Plant
  - Plant Overview
  - Comparison of Westinghouse SMR and **AP1000®** Plant
  - Safety Systems Overview
  - Sample of Safety Analysis Results
- Small Break LOCA PIRT *(from WCAP-17573)*
  - EMDAP (RG 1.203) Methodology
  - PIRT Team
  - PIRT Process
  - PIRT Table 3.3 Overview

Outline (cont.)

- PIRT Analysis & Conclusions
  - Phenomena with High Importance Ranking
  - Analysis
  - Conclusions
- Westinghouse SMR Test Plan
- Path Forward

Westinghouse SMR Meeting Objectives

Ed Cummins, Vice President & Chief Technologist

New Plant Technologies

Objectives

- Familiarize NRC staff with the Westinghouse SMR plant and safety system functional design
- Review Westinghouse SMR small break LOCA scenarios to determine limiting accident sequences
- Review the Westinghouse SMR small break LOCA Phenomena Identification & Ranking Table (PIRT) process that was completed to determine highly important phenomena
- Present conclusions of the PIRT and conceptual design of future tests

Westinghouse SMR Plant Overview

Ed Cummins, Vice President & Chief Technologist
New Plant Technologies

SMR Design Considerations

- **Passive safety systems are conceptually similar to the AP1000® plant**
  - High head injection from core makeup tanks (x4)
  - Ultimately, transition to sump recirculation
    - 2 elevated in-containment pool (ICP) tanks and lower ICP reservoirs
  - Decay heat removal by closed cycle natural circulation of heat exchanger in core makeup tanks
- **3 Methods of Decay Heat Removal**
  - Steam generator with gravity feed from steam drum (80 minutes)
  - Core makeup tank closed cooling system transfers decay heat to UHS tank outside of containment
  - RCS feed & bleed with containment cooled by water

SMR Design Considerations

- Core Power Density less than AP1000® plant
- 8 integral RCPs provide flow for power operation
- Severe Accident mitigated by In-vessel Retention
- Hydrogen release mitigated by containment vacuum (no Oxygen)

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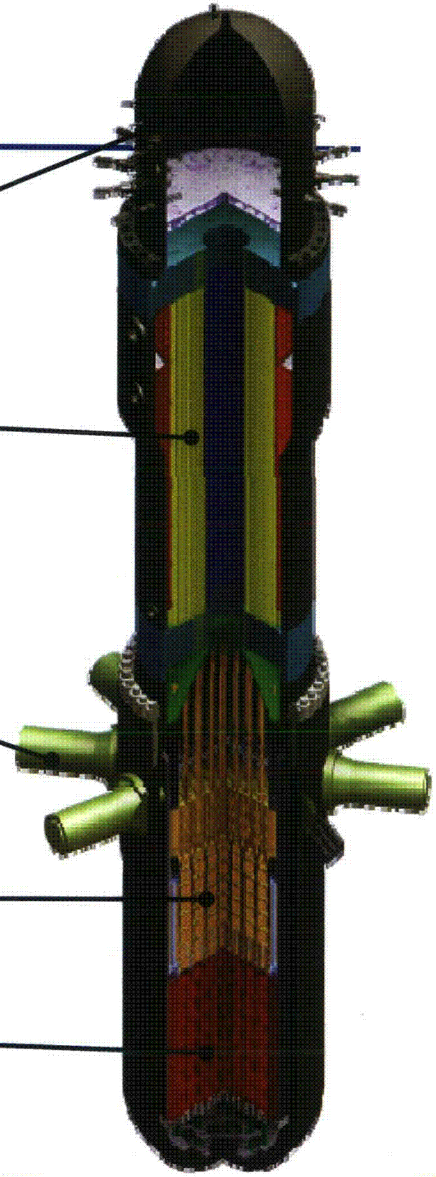
What It Is...

- An integral PWR
- Innovative packaging of proven components
- The highest levels of safety with fewer accident scenarios
- Industry-proven equipment designs
- Compact reactor coolant system and containment
- An engineered solution for today's clean energy challenges

...Simplicity in Design



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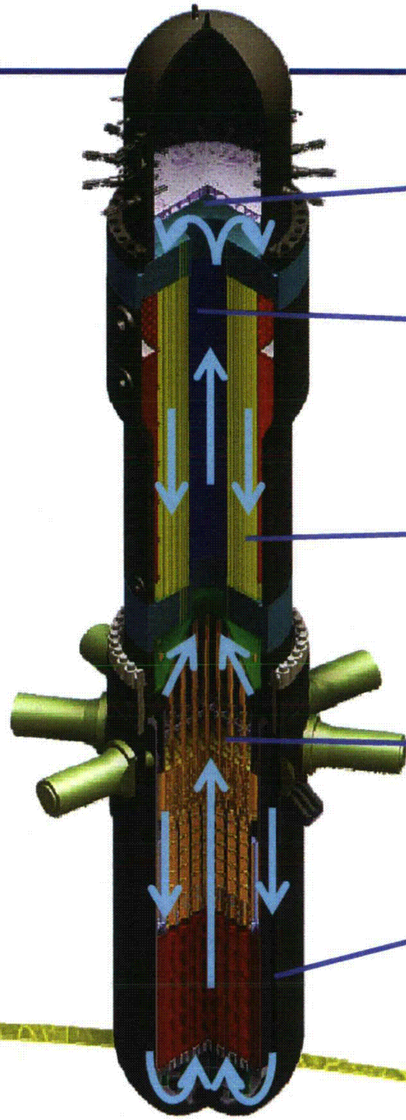
Coolant Flow Path

- Core
- Upper Plenum (Reactor Vessel Internals)
- Hot Leg
- Pressurizer
- Steam Generator
- Cold Leg
- Reactor Coolant Pumps
- Downcomer
- Lower Plenum



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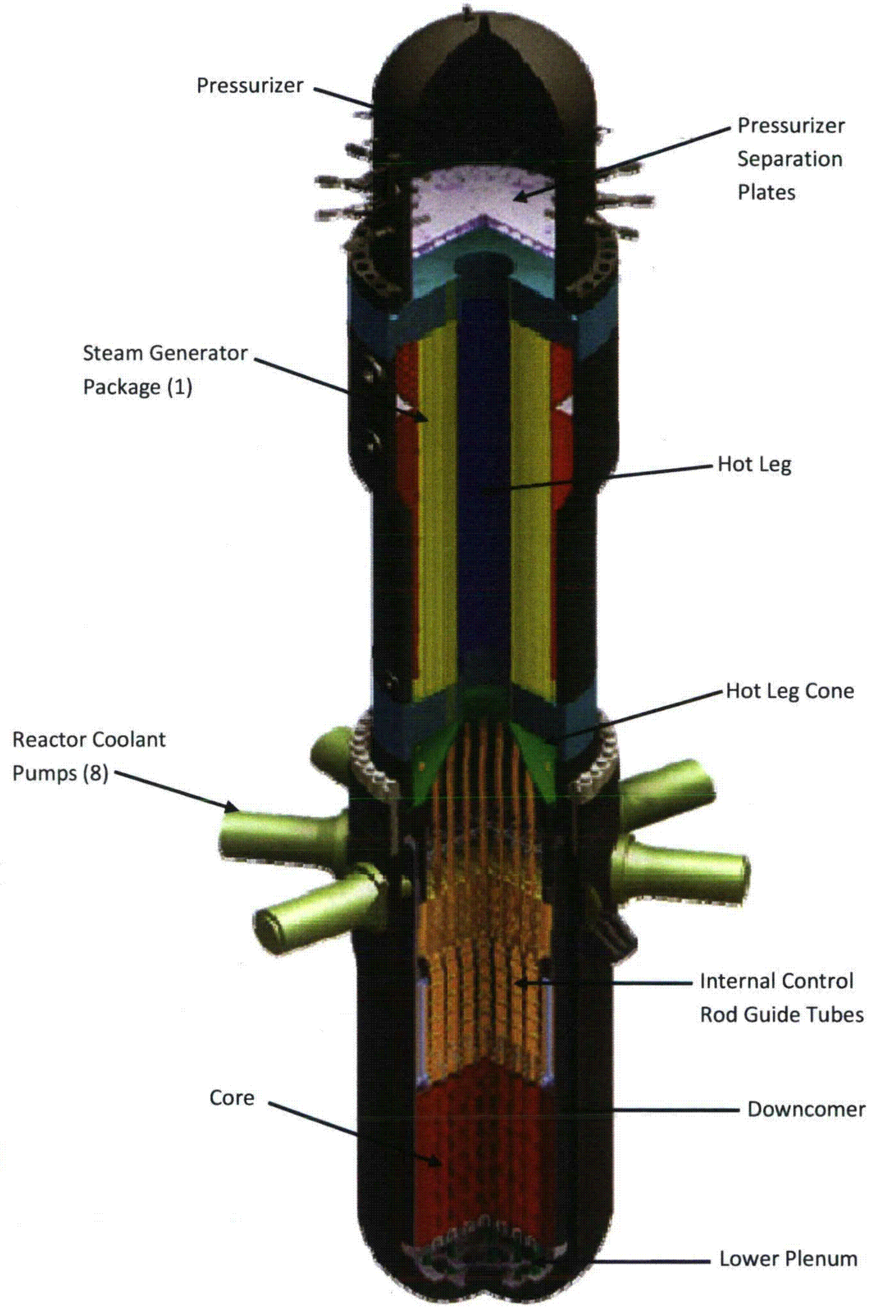

(PIRT Figure 1-4)

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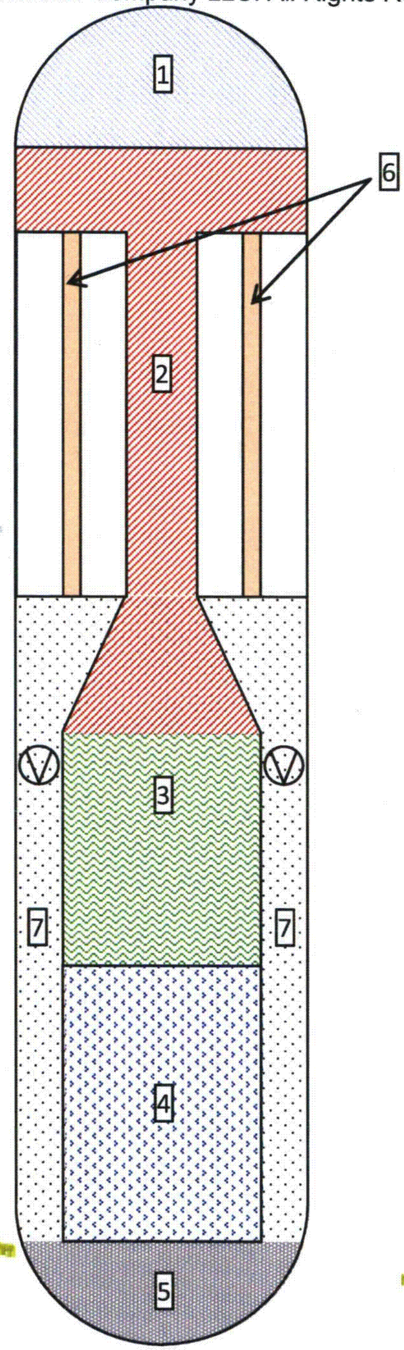
Reactor Vessel Regions
(PIRT Figure 1-2)

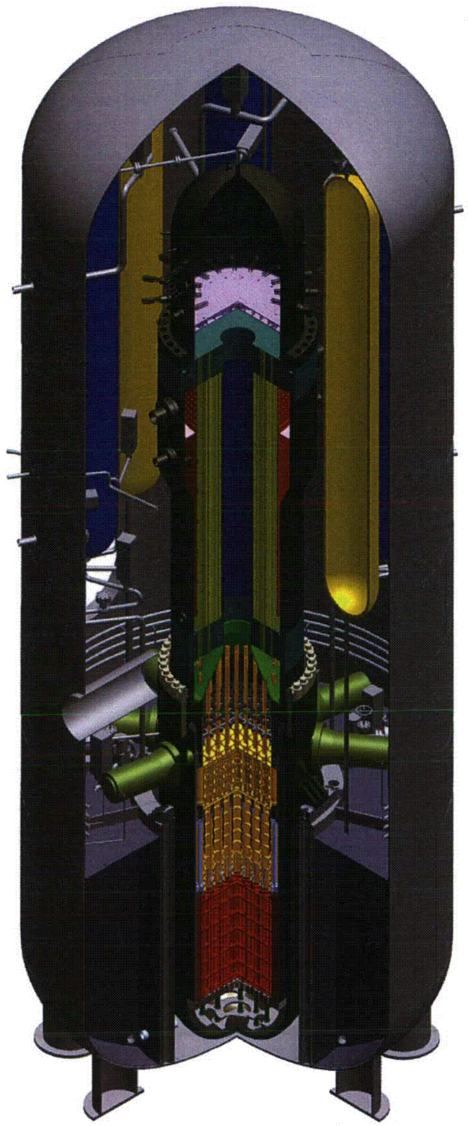
Parameter		Value
1	Pressurizer Volume	
2	Hot Leg & Cone Volume	
3	Upper Plenum Volume	
4	Core Volume	
5	Lower Plenum Volume	
6	Steam Generator Primary Volume	
7	Downcomer Volume	

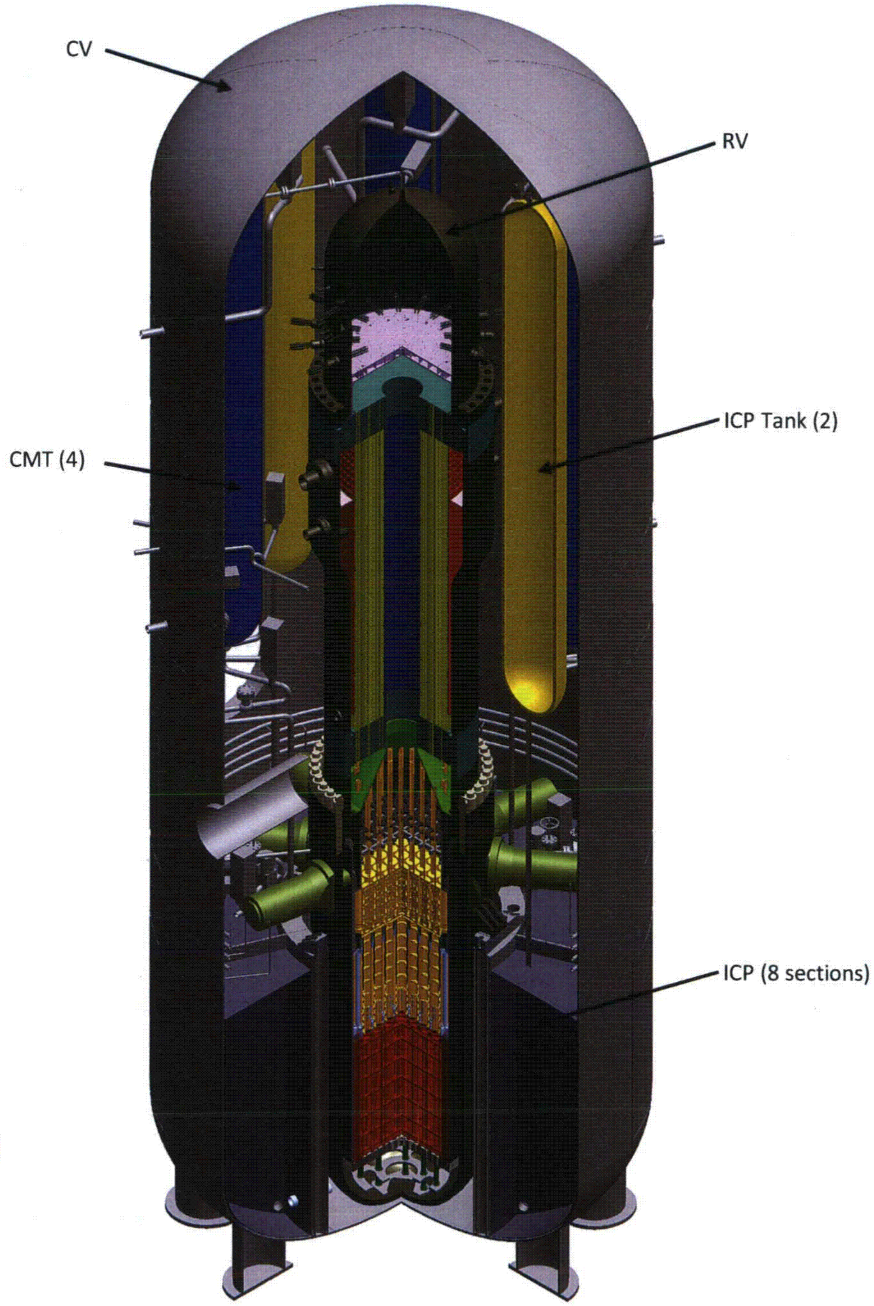
a,c,e



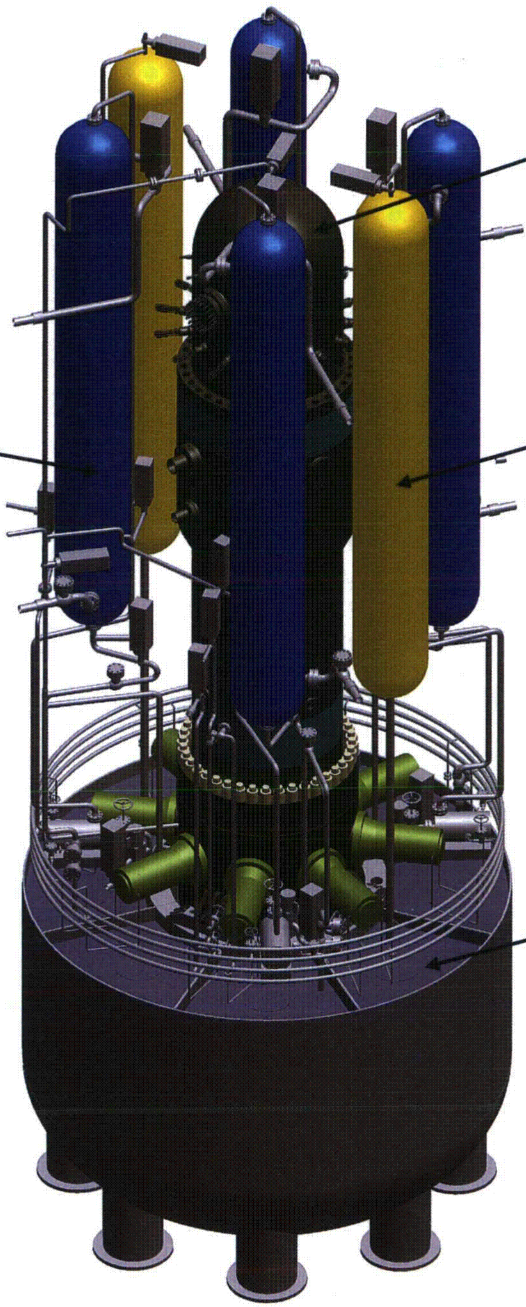
Containment Vessel

- **Compact, high-pressure containment**
- **Sized for ease of modular construction**
- **In-vessel retention strategy for severe accidents is accomplished by flooding lower containment vessel**
  - Derivative of **AP1000®** plant design
- **Initially at a vacuum [ ][a,c,e]**
- **Design pressure – [ ][a,c,e]**





(PIRT Figure 1-5)



(PIRT Figure 1-6)

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Fuel Overview

- **Core Size**
  - Diameter Directly Related to Reactor Vessel Diameter
    - [ ]a,c,e Assemblies, Room for a Heavy Reflector
  - Height Influences Length of Control Rods, Drives and Internals
    - [ ]a,c,e of Reactor Vessel Height Needed for Every Foot of Core
    - [ ]a,c,e Active Length

Core Shuffling Enhances Fuel Economics

- **Feed region size selected to balance fuel economics and fuel performance**

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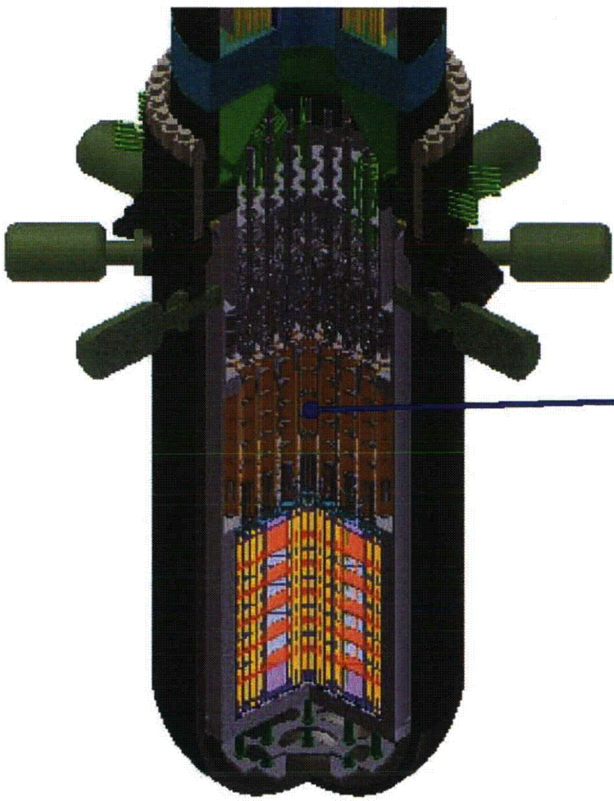
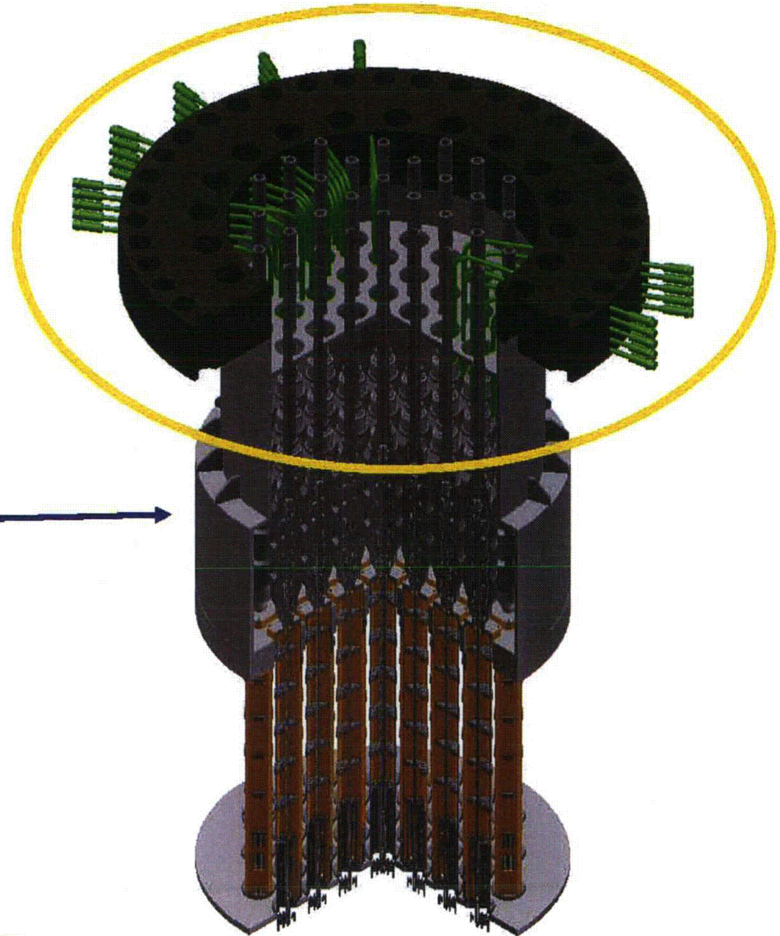
Upper Internals Assembly - Penetrations





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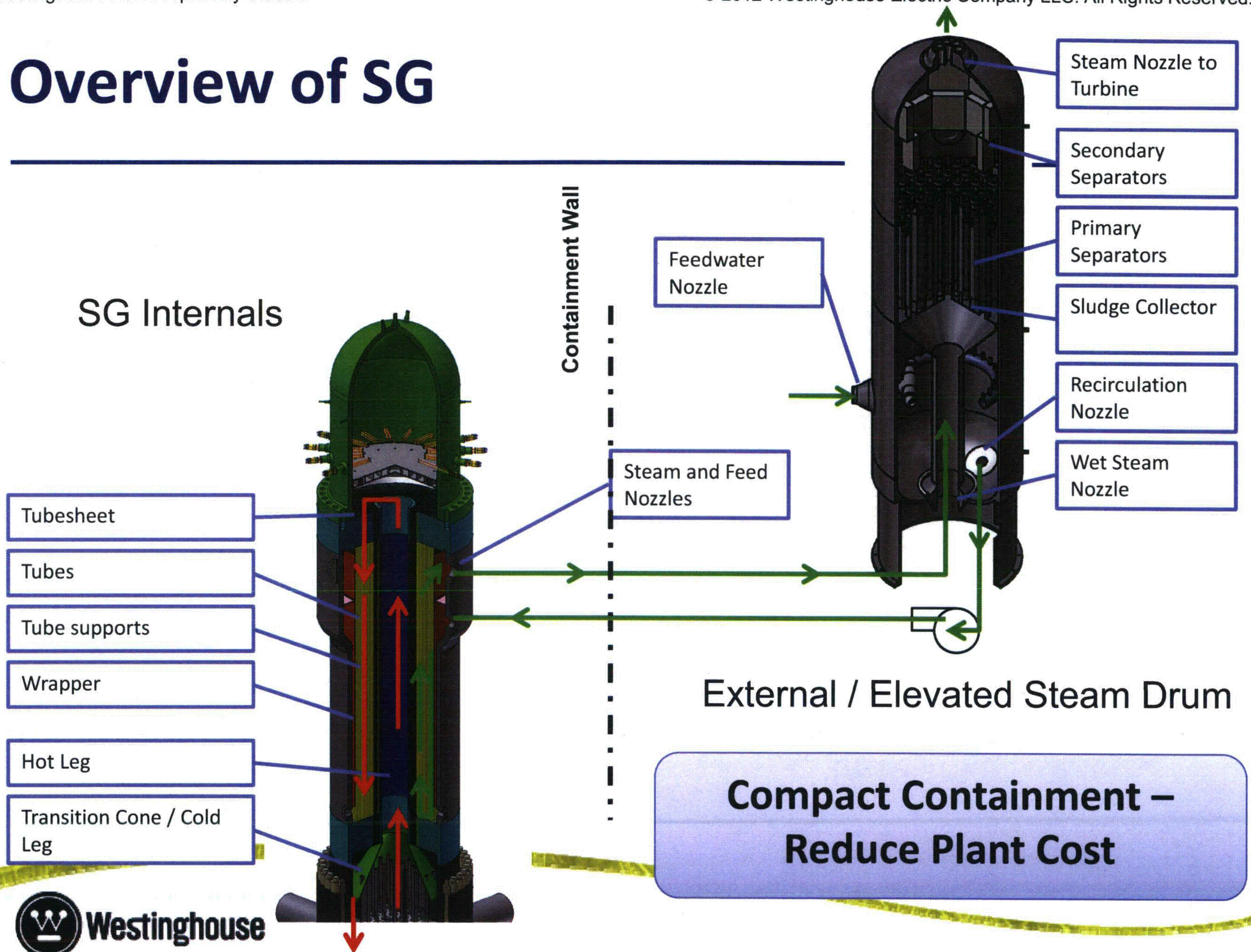
Overview of SG



Compact Containment – Reduce Plant Cost

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Westinghouse SMR
Safety Systems Overview

Ed Cummins, Vice President & Chief Technologist
New Plant Technologies

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Westinghouse SMR Passive Safety

- Passive safety systems are based on the AP1000® plant passive safety systems
- Eliminate Large Break LOCA and Control Rod Ejection
- Largest RCS connection is [ ][a,c,e] – no intermediate or large break LOCAs
- Accumulator not needed for rapid injection for large breaks
- PRHR and CMT Functions combined in 4 CMTs
- 2 stages of ADS with each having timed acutation of 4 valves
- Sump Injection through ICP Tanks
- Containment Vessel cooled by submerging in water pool vented to atmosphere

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a,c,e

(PIRT Figure 1-1)

Approach to Small Break LOCA Mitigation *(PIRT Section 1.3)*

Design Features:

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Comparison of Systems and Components to Mitigate Small Break LOCA for AP1000® Plant and Westinghouse SMR

Safety Function	AP1000 Plant	Westinghouse SMR
Short-term reactivity control	Control rods	
Long-term reactivity control	Boration by CMTs (2)	
Coolant flow during operation	4 Reactor Coolant Pumps (RCPs)	
Coolant Flow during SBLOCA	Safety trip of RCPs, natural circulation to Steam Generator and PRHR	
Decay heat removal	PRHR HX (1) which removes heat from the reactor coolant system (RCS) to the in-containment refueling water storage tank (IRWST).	
High-head injection	CMTs (2) provide core makeup at any RCS pressure until empty. Accumulators provide intermediate injection	
Long-term makeup water supply	IRWST (1) with transition to sump recirculation	

a,c,e

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Comparison of Systems and Components to Mitigate Small Break LOCA for AP1000® Plant and Westinghouse SMR (cont.)

Safety Function	AP1000 Plant	Westinghouse SMR
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.	

a,c,e

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Safety Overview

- **Integral design**
  - Vertical arrangement -> safe transition to natural circulation and inherently places RCS water directly above core
  - Larger water volume to thermal power ratio than operating PWRs and **AP1000®** plant.
  - No large bore piping -> reduced postulated loss of coolant accident flow area
  - SBLOCA mitigation functionally similar to **AP1000®** plant
  - Final state: RCS depressurized, injection from sump, containment heat transfer to OCP

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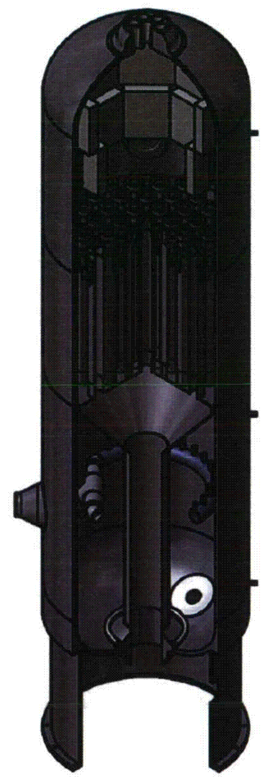
Safety Overview

- **Internal CRDMs**
  - Eliminates Rapid Ejection of a Control Rod
- **Pump-Driven RCS Flow at Power**
  - Large, predictable thermal margin of safety
- **External Steam Drum**
  - Water Level Control
  - Extended Response to Level Transients



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Safety Overview

- **Reactor Control (functionally similar to AP1000® plant)**
  - Rod Cluster Control Rods
    - Unlatch, Fall under **Gravity**
  - Diverse shutdown
    - Core Makeup Tanks **Gravity-Inject** Highly Borated Water

- **RCS Pressure Boundary Maintained by self-actuating, spring-loaded pressurizer safety valves**

a,c,e

(PIRT Figure 1-1)

Safety Systems Overview

a,c,e

Residual Heat Removal Paths:

- **Steam Generator System (SGS)**
  - **Steam Drum** with large inventory
    - **Natural circulation** cooling of SG Tubes
    - Start-up Recirculation Pump maintains inventory
    - [ ][a,c,e] of decay heat removal with no A/C power

Safety Systems Overview

a,c,e

Residual Heat Removal Paths:

- **Steam Generator System (SGS) (cont.)**
  - Steam drum is isolated in SBLOCA scenarios by **Steam Drum Isolation Valves (SDIV)**
  - Steam Generator depressurization by actuation of **SG Depressurization Valves (SGDVs)**

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Safety Systems Overview

a,c,e

Residual Heat Removal Paths:

- **Passive Core Cooling System (PXS)**
  - Four Straight Tube **Passive Residual Heat Removal (PRHR) Heat Exchangers** located in Core Makeup Tanks
    - Promotes RCS natural circulation
  - **Ultimate Heat Sink (UHS) Tanks** cools PRHR loops via natural circulation
    - Heat bypasses containment
    - UHS inventory sized for 7 days between 2 tanks

Safety Systems Overview

a,c,e

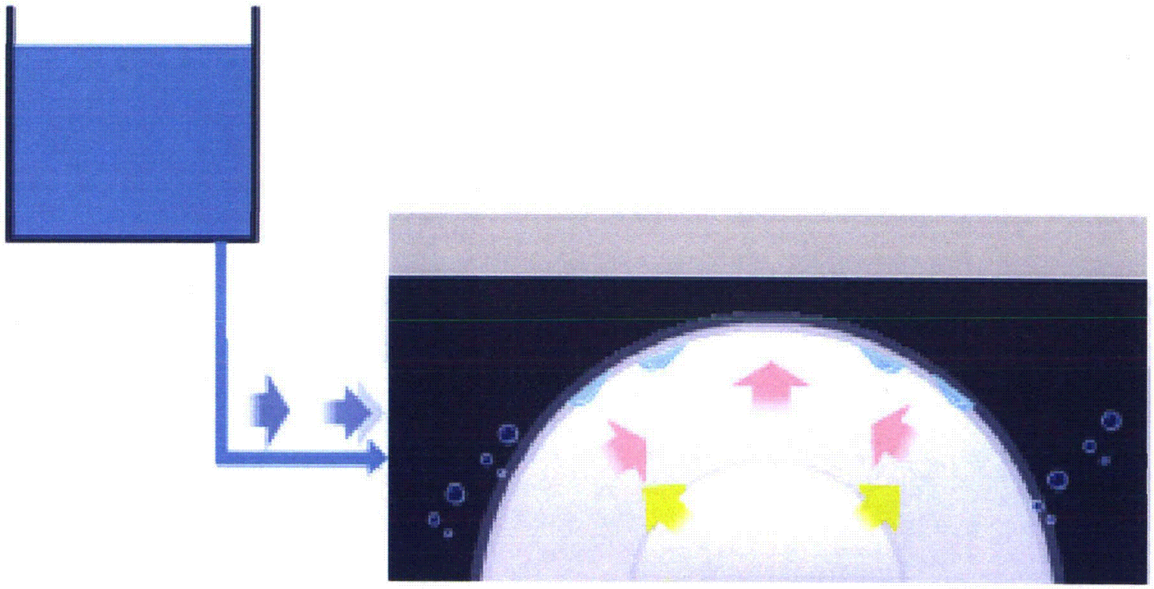
Residual Heat Removal Paths:

- **Containment Shell & Outside Containment Pool (OCP)**
  - Containment Vessel (CV) fully submerged in OCP
  - Pool water directly cools the shell of the CV
  - Steam condenses and cools core via Sump Injection
  - **UHS Tanks** refills OCP

Safety Systems Overview

Residual Heat Removal Paths:

- Containment Shell & Outside Containment Pool (OCP) (cont.)



Safety Systems Overview

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RCS Inventory Addition

- Four **Core Makeup Tanks (CMT)**
  - Filled with borated makeup water
  - **Gravity-injection** at RCS pressure through four **Direct Vessel Injection (DVI) Lines**
  - Natural circulation from upper plenum to CMTs through **CMT Balance Lines**
  - **CMTs** continue to condense steam and return water to core via DVI line

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Safety Systems Overview

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RCS Inventory Addition (cont.)

- Two **In-containment Pool (ICP)**
  - Two ICPs made up of 4 interconnected sections each
  - Two **elevated ICP tanks**
  - **Gravity-inject** when RCS pressure slightly greater than CV pressure through two **Sump Injection Lines**

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Safety Systems Overview

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RCS Inventory Addition (cont.)

- **Long-term Core Cooling (LTCC)**
  - Recirculation flow driven by **Sump** head
  - **Sump Coupling Valves (SCVs)** connect sump to ICPs
  - **Sump Screens** in ICPs

a,c,e

(PIRT Figure 1-3)

Safety Systems Overview

a,c,e

Automatic Depressurization System (ADS)

- **4 ADS Stage One (ADS-1) Valves**
  - Connected to top of each CMT
  - Staggered opening
  - Reduce RV to near CV Pressure
- **4 ADS Stage Two (ADS-2) Valves**
  - Directly Connected to RV
  - Equalize RV and CV Pressures for Long-term Core Cooling

Safety Systems Overview

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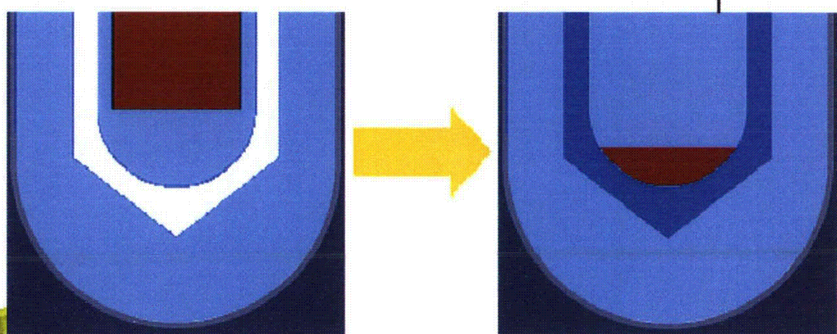
- **In-Vessel Retention for Severe Accidents**
  - IVR Squib Valves open to inject ICP tanks into Sump
  - Flood region surrounding reactor vessel
    - Prevents RV melting
    - Core remains in RV



Westinghouse SMR
Sample of Safety Analysis Results

Dr. Cesare Frepoli, Fellow Engineer
Core Engineering

DVI Line Double Ended Guillotine Break [ ]a,c,e

a,c,e

[ ]

DVI Line Double Ended Guillotine Break [ ]a,c,e

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DVI Line Double Ended Guillotine Break [ ]a,c,e

a,c,e

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DVI Line Double Ended Guillotine Break [ ]a,c,e

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DVI Line Double Ended Guillotine Break [ ]a,c,e

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DVI Line Double Ended Guillotine Break [ ]a,c,e

a,c,e

DVI Line Double Ended Guillotine Break [ ]a,c,e

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Westinghouse SMR
EMDAP (RG 1.203) Methodology

Dr. Cesare Frepoli, Fellow Engineer

Core Engineering

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EMDAP (CSAU) (RG 1.203) Methodologies

- Overview of Regulatory Guide 1.203
- Phenomena Identification and Ranking Table (PIRT)
- Code Scaling, Applicability, and Uncertainty (CSAU) Methodology
- Code assessment process and best practices

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Regulatory Guide 1.203 and SRP NUREG-0800

- Regulatory Guide 1.203 - Evaluation Model Development and Assessment Process (EMDAP)
  - New guidance was released in Dec. 2005.
  - Expand on the same principles that were applied in CSAU (RG 1.157).
  - Describes the "Evaluation Model Development and Assessment Process (EMDAP)"
  - The process is applicable to any transient and accident analysis method (not limited to LOCA)

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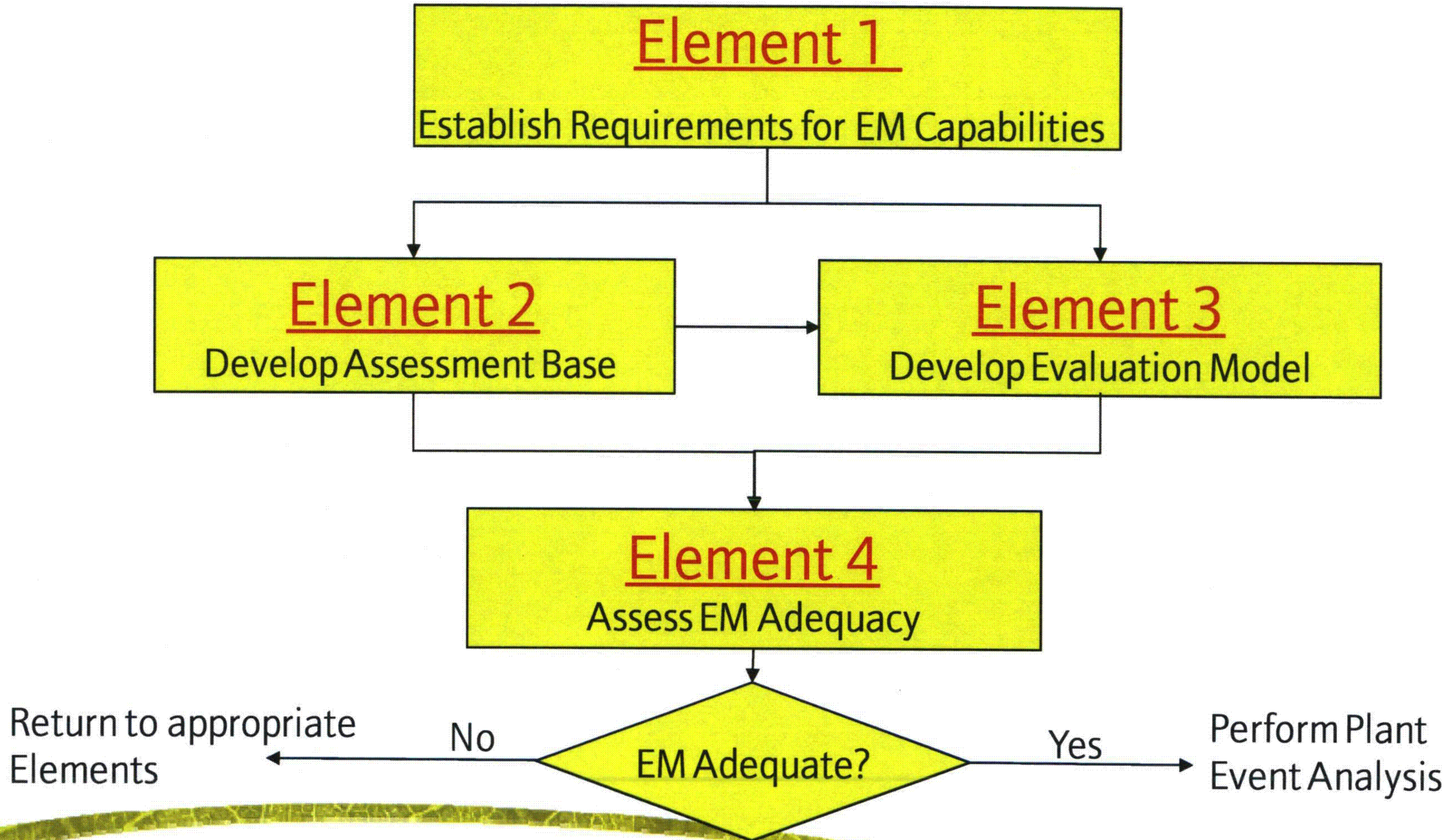
Regulatory Guide 1.203 - EMDAP



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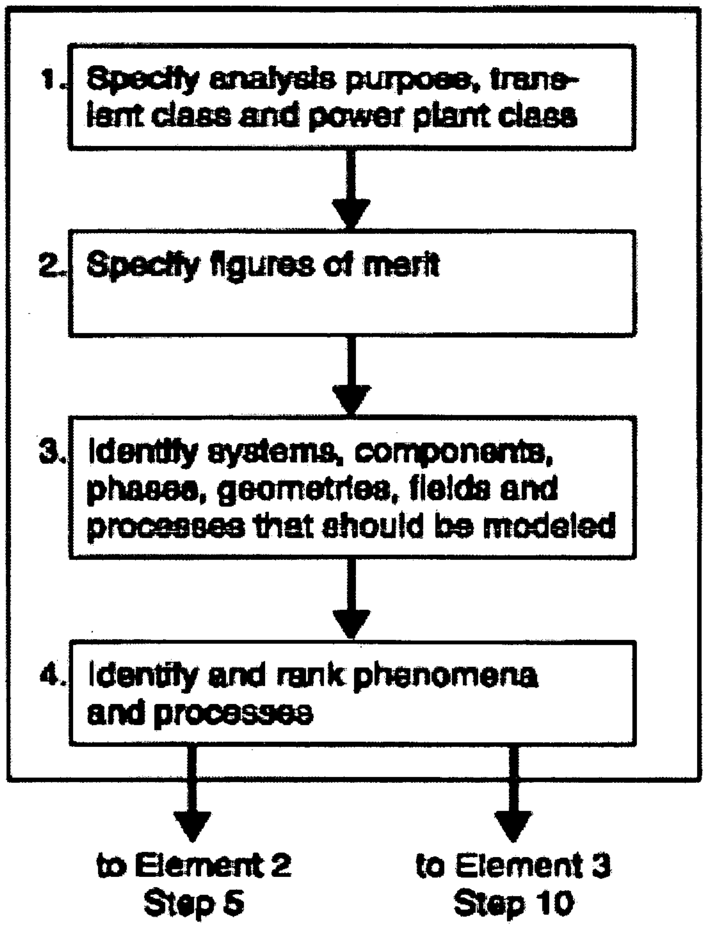
Regulatory Guide 1.203 - EMDAP



Element 1
Establish Requirements for Evaluation Model Capability

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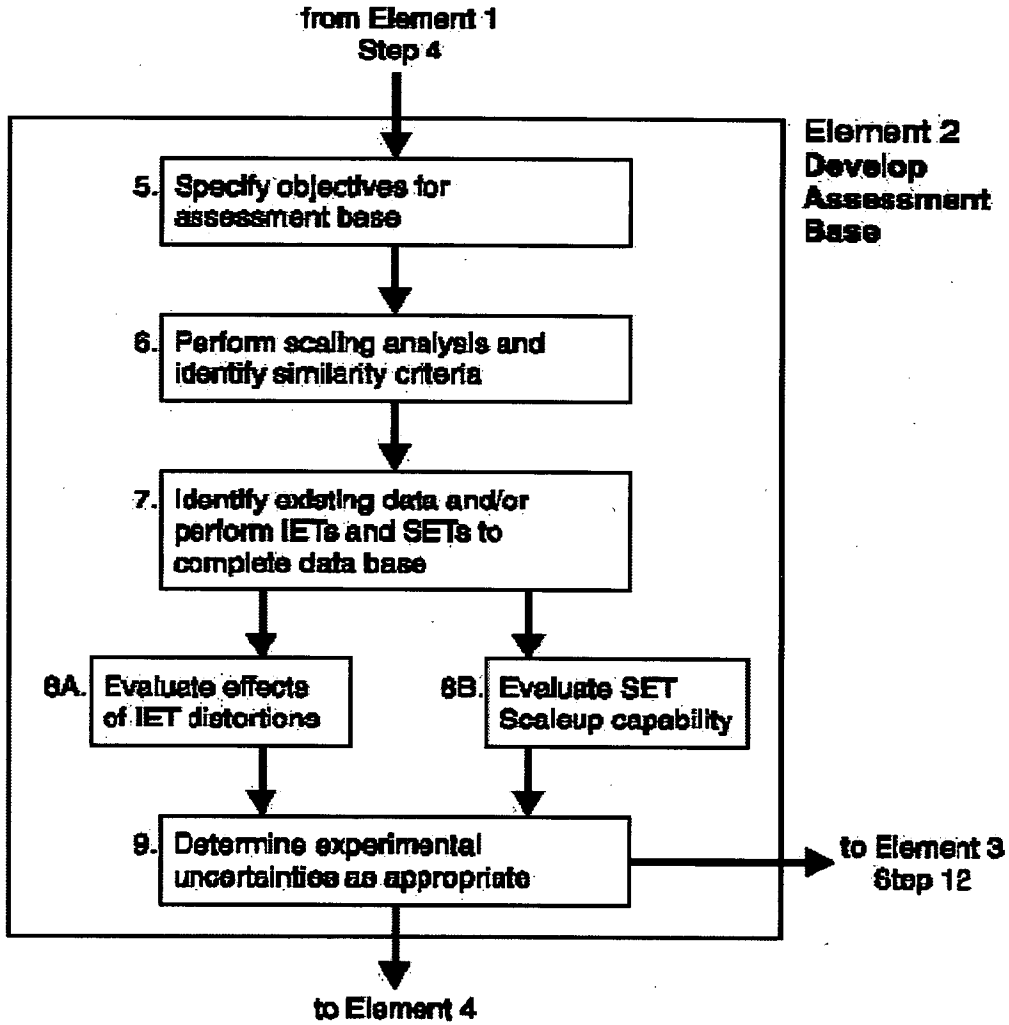
Regulatory Guide 1.203 - EMDAP



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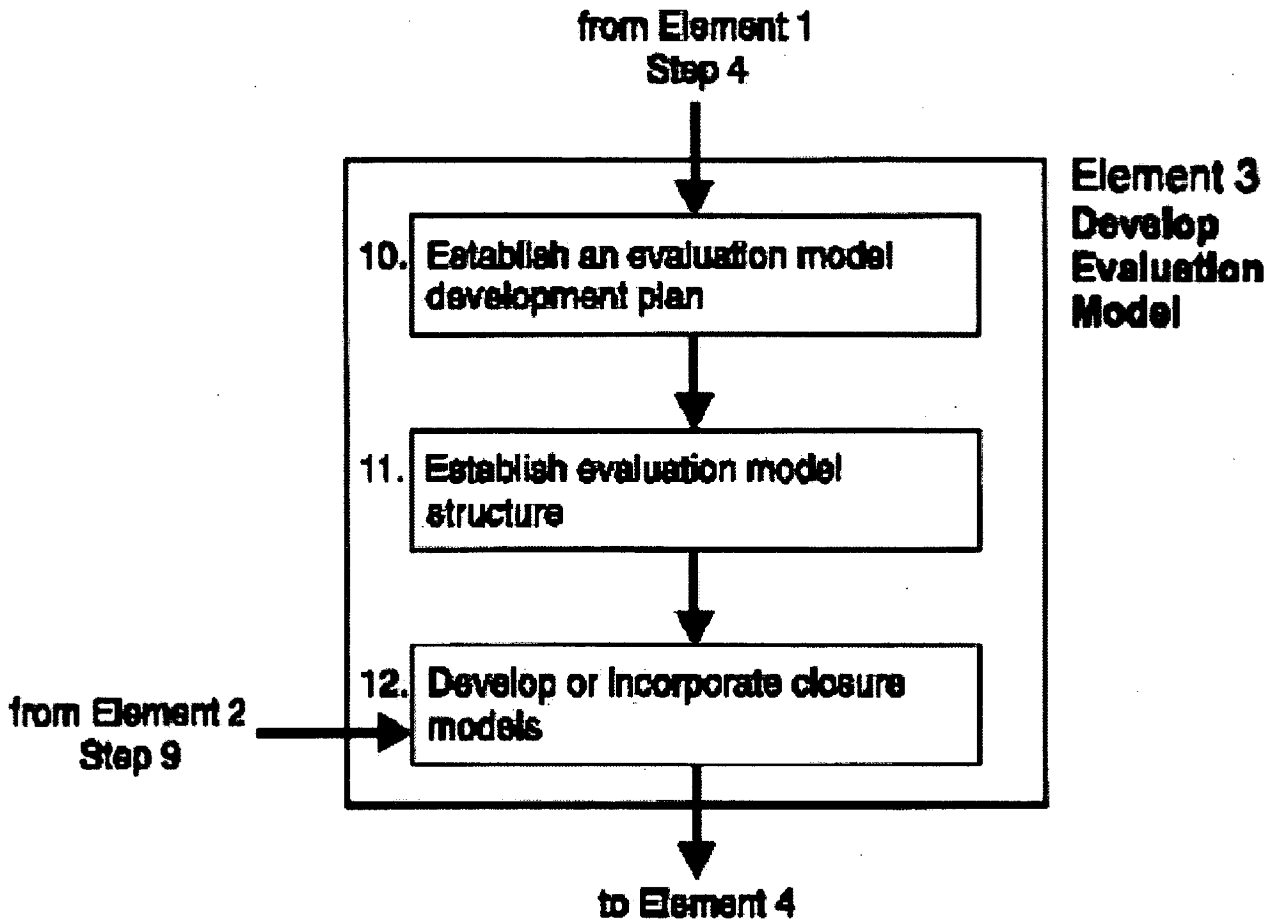
Regulatory Guide 1.203 - EMDAP



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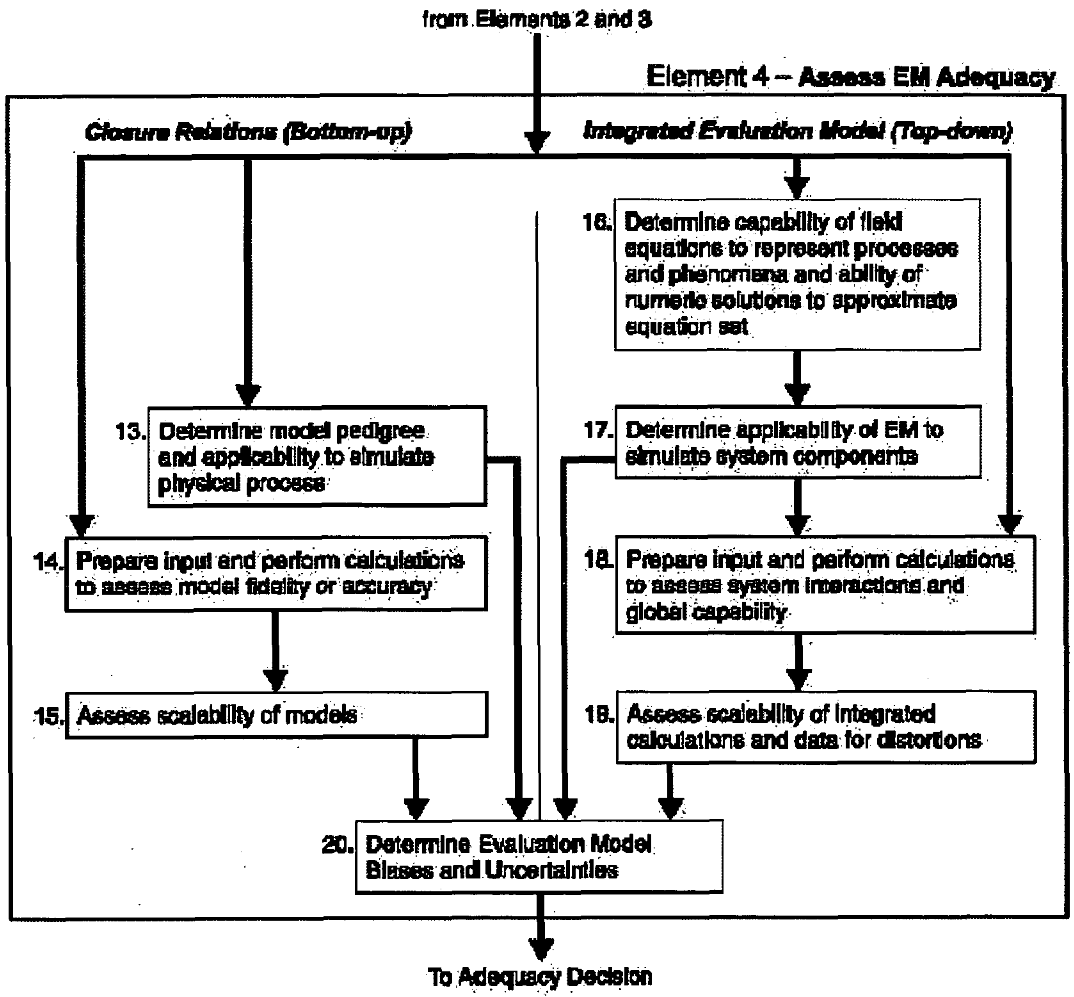
Regulatory Guide 1.203 - EMDAP



Westinghouse SMR
Small Break LOCA PIRT Process

Ramsey Arnold, Engineer
Research & Technology

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

PIRT Development

- → Design
  - → Representative Scenarios
    - → Important Phenomena

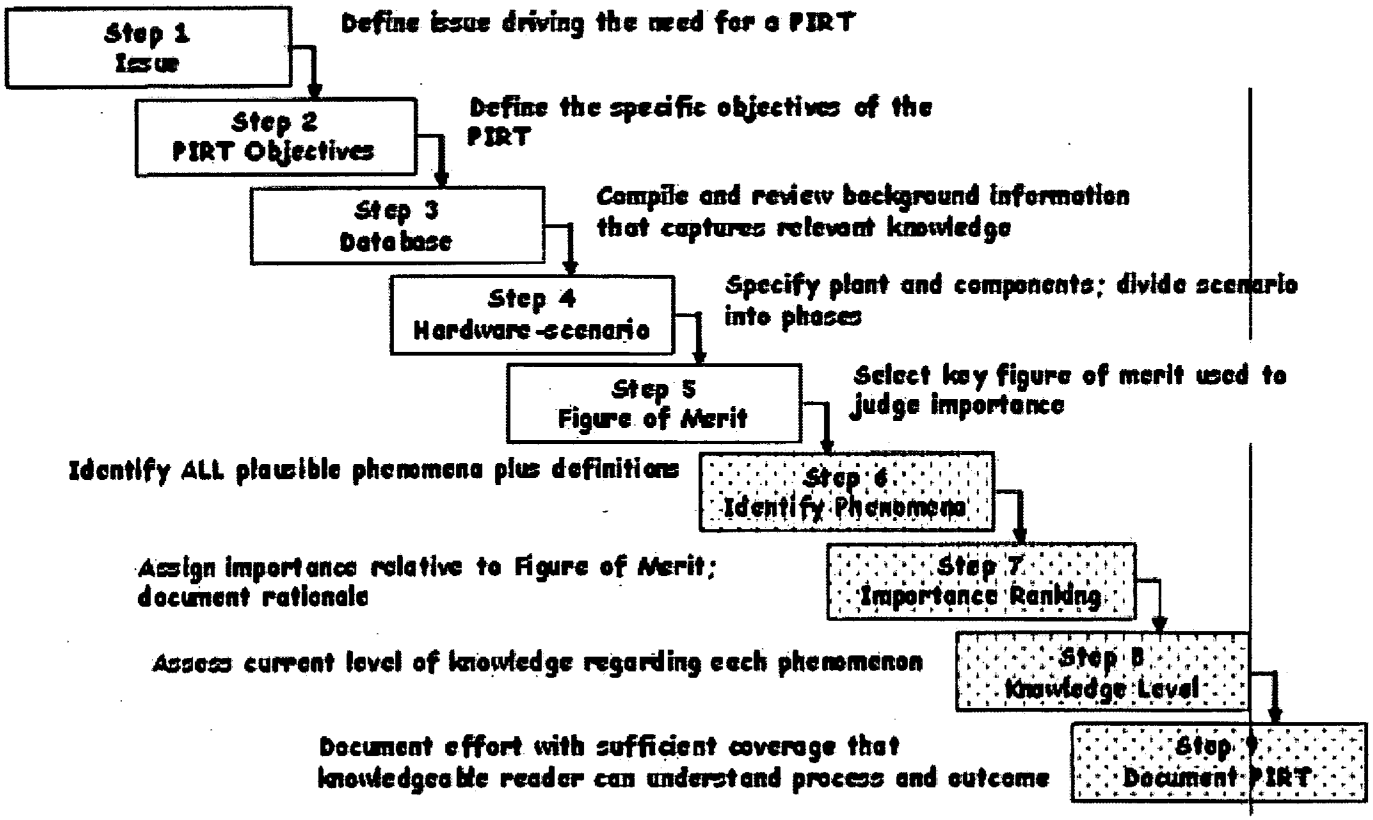
PIRT Application

- → Important Data and Models
  - → Available Data and Models
    - → Gaps in Available Data and Models

Use of the PIRT

- Phenomena Identification and Ranking Table considered a critical element of CSAU-based methodologies
  - Focus prioritization of code assessment
  - Facilitate decisions on physical model and methodology development
- PIRT concept has evolved
  - Recent works have factored in "State of Knowledge" (SoK)
  - Numerical importance rankings replaced by "High/Moderate/Low"

Nine-Step PIRT Process *(PIRT Figure 2-2)*



PIRT 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

PIRT Development Process

- Nuclear power plant broken down into relevant regions (e.g., core, upper plenum, hot leg)
- Scenario broken down into relevant time periods [

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- Identify Figures of Merit (FoMs)
- Potentially important phenomena/processes identified for each time period and region
- Experts perform Importance ranking, State of Knowledge (SoK) ranking, and document basis for consensus

PIRT Panel Organization – Internal Members

<u>Westinghouse Experts</u>

- Bill Brown
- Ed Carlin
- Larry Conway
- Jason Douglass
- Cesare Frepoli
- Rick Ofstun
- Jim Scobel
- Frank Vereb

<u>SMR Team</u>

- Rick Wright*
- Ramsey Arnold*
- Ed Cummins*
- Matt Smith*

**these people supported the PIRT Panel as needed with relevant details about the Westinghouse SMR design*

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PIRT Panel Organization – External Members

- **Jacopo Buongiorno**
  - Nuclear Engineering Ph.D., MIT, 2000; Nuclear Engineering B.S., Polytechnic of Milan, 1996
  - 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).

PIRT Panel Organization – External Members

- **Masahiro Kawaji**
  - 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.
  - 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.
  - 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, and compact heat exchangers.
  - 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), and International Conference on Heat Transfer and Fluid Flow in Microscale, among others.

PIRT Panel Organization – External Members

- **Annalisa Manera**
  - 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.

Components Considered in PIRT [ ]a,c,e

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[ ]

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Reactor Vessel Penetrations

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Reactor Vessel Penetrations

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Scenario Selection Process *(PIRT Figure ES-1)*

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SBLOCA Scenario Phases *(PIRT Table ES-2)*

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Westinghouse SMR During Normal Operation *(PIRT Figure 3-1)*

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SBLOCA Blowdown Phase (Phase 1) *(PIRT Figure 3-2)*

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SBLOCA CMT Natural Circulation and Draining Phase (Phase 2) *(PIRT Figure 3-3)*

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SBLOCA ADS Phase (Phase 3) *(PIRT Figure 3-4)*

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SBLOCA Long-term Core Cooling Phase (Phase 4) *(PIRT Figure 3-5)*

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Figures of Merit *(PIRT Table ES-1)*

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Figures of Merit *(PIRT Table 2-3)*

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Phenomena Ranking in PIRT

- Importance Ranking
  - Ranking is define based on the expected effect on the FoM
- State of Knowledge Ranking
  - This is found in recent PIRTs
  - This is particularly important for new plants

Importance Ranking Scale *(PIRT Table 2-2)*

- **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 (low).** 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 (SoK) Ranking Scale *(PIRT Table 2-3)*

- **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.**

Westinghouse SMR
PIRT Process Example *(PIRT Table 3.3)*

Ramsey Arnold, Engineer

Research & Technology

PIRT Process Example *(from PIRT Table 3-3)*

- Containment Vessel (CV)

Phenomena Ranking – Containment Vessel *(PIRT Table 3-3)*

a,c,e

Phenomena Ranking – Containment Vessel *(PIRT Table 3-3)*

a,c,e

Phenomena Ranking – Containment Vessel *(PIRT Table 3-3)*

a,c,e

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Phenomena Ranking – Containment Vessel *(PIRT Table 3-3)*

a,c,e

Phenomena Ranking – Containment Vessel *(PIRT Table 3-3)* (cont.)[a,c,e]

Westinghouse

Westinghouse SMR
PIRT Analysis & Conclusions

Dr. Richard Wright, Consulting Engineer
Passive Plant Technology

Areas where confirmatory experimental testing and continued analytical tool development 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

Westinghouse

PIRT Results Significant to Continued Experimental and Analytical Tool Development

- Phenomena with High Importance Ranking
  - High SoK (66)
  - Moderate SoK (30)
  - Low SoK (14)

Westinghouse

PIRT Analysis

a,c,e

[redacted]

PIRT Analysis (cont.)

a,c,e

Westinghouse

PIRT Conclusions

a,c,e

Westinghouse

PIRT Conclusions (cont.)

a,c,e

PIRT Conclusions (cont.)

a,c,e

[redacted]

PIRT Conclusions (cont.)

a,c,e

Westinghouse SMR Test Plan

Dr. Richard Wright, Consulting Engineer
Passive Plant Technology

Westinghouse SMR Test Plan

- Much of the existing **AP1000®** plant testing program can be applied to Westinghouse SMR phenomena
- All high safety ranked/low SoK phenomena can be addressed by two test programs

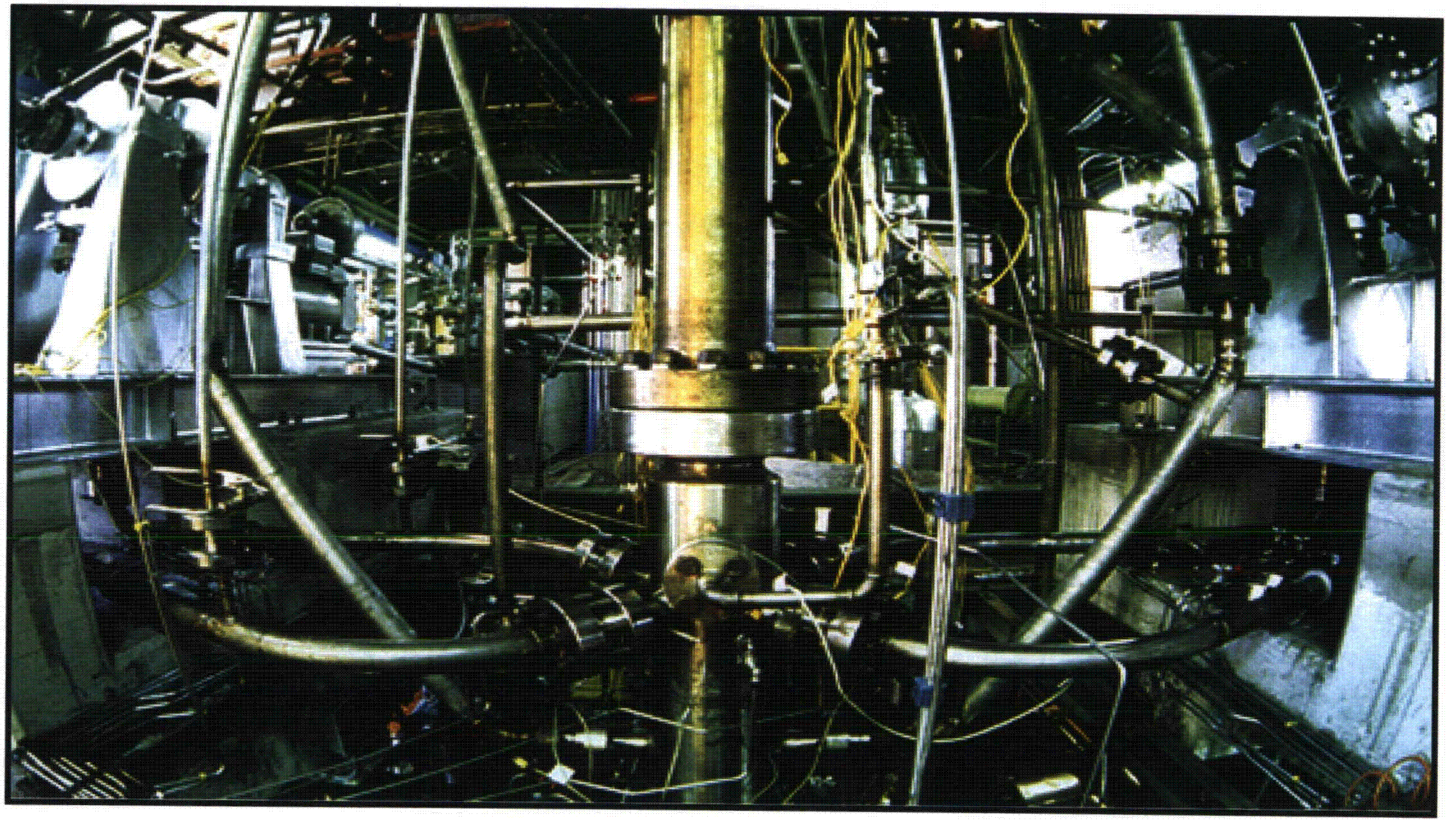
a,c,e

Westinghouse

Westinghouse SMR Test Plan(cont.)

a,c,e

IET – Full-height, Full-pressure SPES Test Facility at SIET



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Integral Effects Test Configuration for SPES

a,c,e

Separate Effects Test Configuration for PSU

a,c,e

[ ]

Westinghouse

Westinghouse SMR Test Plan

a,c,e

Path Forward

- NRC Staff review of Westinghouse SMR SBLOCA PIRT and Test Plan
  - Formal NRC Staff evaluation for ACRS and Westinghouse
- ACRS review of Westinghouse SMR SBLOCA PIRT and Test Plan
  - ACRS Letter evaluating PIRT and Test Plan
- Westinghouse Goal is to confirm adequacy of PIRT and Test Plan with the NRC staff and the ACRS as a basis for Westinghouse SMR Design Certification

Thank You

Backup Slides

PIRT Process Examples *(from PIRT Table 3-3)*

- Core Region
- Core Makeup Tank (CMT)
- Passive Residual Heat Removal (PRHR) Heat Exchanger (HX)

Phenomena Ranking – Core *(PIRT Table 3-3)*

a,c,e

Phenomena Ranking – Core *(PIRT Table 3-3)* (cont.)

a,c,e

Phenomena Ranking – Core Makeup Tank *(PIRT Table 3-3)*

a,c,e

Phenomena Ranking – Passive Residual Heat Removal Heat Exchanger *(PIRT Table 3-3)*

a,c,e

Westinghouse

PIRT Results Significant to Continued Experimental and Analytical Tool Development

- Phenomena with High Importance Ranking
  - **High SoK (66)**
  - Moderate SoK (30)
  - Low SoK (14)

High Importance/High SoK (1 of 4)

a,c,e

[ ]

High Importance/High SoK (2 of 4)

a,c,e

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High Importance/High SoK (3 of 4)

a,c,e

High Importance/High SoK (4 of 4)

a,c,e

PIRT Results Significant to Continued Experimental and Analytical Tool Development

- Phenomena with High Importance Ranking
  - High SoK (66)
  - **Moderate SoK (30)**
  - Low SoK (14)

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High Importance/Moderate SoK (1 of 2) *(PIRT Table ES-4)*

a,c,e

Westinghouse

High Importance/Moderate SoK (2 of 2) *(PIRT Table ES-4)*

a,c,e

Westinghouse

PIRT Results Significant to Continued Experimental and Analytical Tool Development

- Phenomena with High Importance Ranking
  - High SoK (66)
  - Moderate SoK (30)
  - **Low SoK (14)**

High Importance/Low SoK *(PIRT Table ES-4)*

a,c,e

Westinghouse

PIRT Analysis

a,c,e

High Importance/Low SoK Ranking Analysis (1 of 3) *(PIRT Table 4-1)*

a,c,e

Westinghouse

High Importance/Low SoK Ranking Analysis (2 of 3) *(PIRT Table 4-1)*

a,c,e

Westinghouse

High Importance/Low SoK Ranking Analysis (3 of 3) *(PIRT Table 4-1)*

a,c,e

Westinghouse

PIRT Analysis

a,c,e

High Importance/Moderate SoK Ranking Analysis (1 of 7) *(PIRT Table 4-2)*

a,c,e

High Importance/Moderate SoK Ranking Analysis (2 of 7) *(PIRT Table 4-2)*

a,c,e

Westinghouse

High Importance/Moderate SoK Ranking Analysis (3 of 7) *(PIRT Table 4-2)*

a,c,e

Westinghouse

High Importance/Moderate SoK Ranking Analysis (4 of 7) *(PIRT Table 4-2)*

a,c,e

Westinghouse

High Importance/Moderate SoK Ranking Analysis (5 of 7) *(PIRT Table 4-2)*

a,c,e

Westinghouse

High Importance/Moderate SoK Ranking Analysis (6 of 7) *(PIRT Table 4-2)*

a,c,e

Westinghouse

High Importance/Moderate SoK Ranking Analysis (7 of 7) *(PIRT Table 4-2)*

a,c,e