IRIS Pre-Application Review Meeting

February 22, 2005

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AGENDA
IRIS Pre-Application Review

Introductions	D. Szwarc	5 Min.
	M. D. Carelli	5 Min.
Discussion of Westinghouse expectations of NRC review	All	30 Min.
Testing Program overview	L. Conway	30 Min.
Break		10 Min.
Discussion of Westinghouse's PIRT and Scaling submittals	L. Oriani M. Dzodzo	60 Min.
Discussion of scope and schedule for next meetings	All	15 Min.
Public comment period	All	10 Min.
Summary and Conclusion	NRC/W	15 Min.

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Westinghouse Expectations of NRC Review

- Status of interactions to date
- Discussion of items included in pre-licensing
  - Adequacy of IRIS testing program
  - Westinghouse/IRIS support of NRC advanced plant licensing, focused on reduced emergency planning
- Interest from US power producers
- Anticipated near term schedule and budget

Status of Interactions to Date

- Submitted documentation:
  - Eleven IRIS overview papers
  - WCAP-16062-P, "IRIS Plant Description Document"
  - WCAP-16103-P, "IRIS Scaling Analysis, Part I"
  - WCAP-16082-P, "IRIS Preliminary Safety Assessment"
  - STD-ES-04-09, Attachment 1, "Preliminary Steam Generator Tube Rupture Analysis for IRIS"
  - WCAP-16318-P, "IRIS Small Break LOCA PIRT" and Addendum 1 "IRIS SBLOCA Sensitivity Report ..."
- Near Term Submittals (April 2005):
  - WCAP-16392-P, "IRIS Test Program"
  - WCAP-16103-P, "IRIS Scaling Analysis, Part II"

Status of Interactions to Date

- NRC feedback on the information submitted to date was provided by an informal meeting in April 2004
- The main conclusions of this meeting were:
  - The NRC had no objections or reservations to the documentation submitted, and
  - Westinghouse appears to have a complete set of Chapter 15 safety analyses and the results appear to be acceptable

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PROJECTED IRIS SCHEDULE

Pre-application Licensing	
– Testing Program: Review and advice	3Q CY05
– Review of IRIS PRA guided design approach	Mid 2006
– Emergency Planning Requirements: Approach consensus, methodology review, plan forward	End 2006
Submission first draft DCD and request to initiate Design Certification	End 2006
Final design approval	2010
First deployment	2014

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WESTINGHOUSE EXPECTATIONS OF NRC REVIEW

1. TESTING REVIEW AND ADVICE

   Comments on testing program (some documents submitted, others will be soon)

   Is planned program adequate in terms of:

   - Proposed tests
   - Items investigated in various tests
   - Test scaling approach
   - Selected facilities

WESTINGHOUSE EXPECTATIONS OF NRC REVIEW (Cont'd)

2. EMERGENCY PLANNING REQUIREMENTS

   – Background
   - In March 14-16 Workshop discussion for longer term assessment of modifications to EPZ
   - IRIS has prepared top level strategy/methodology
   - Five IRIS organizations participate to IAEA CRP on this subject

   – Projected effort (later this year, after testing)
   - Review of IRIS suggested approach
   - Cognizance of IRIS work performed under IAEA CRP
   - Suggestions/discussion/agreement future effort

CY 05 SUGGESTED EFFORT/SCHEDULE

- IRIS funding for staff review: 6 MM
- This meeting
  - Outline from W of SBLOCA PIRT and overall testing program. No immediate feedback required.
  - Outline from W of work performed to date and future work on scaling approach. For info only.
- Next submittals from W (April)
  - IRIS testing program
  - Part II scaling approach

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CY 05 SUGGESTED EFFORT/SCHEDULE (Cont'd)

- Next meeting (June-July)
  - NRC review feedback on testing program
- Submittals from W (July-August)
  - Revisions to testing program, addressing NRC review feedback
  - First set of info on emergency planning
- Next meeting (October)
  - Documented consensus on testing program
  - Kick off emergency planning effort

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CY06 EFFORT

- Estimated effort ~ 1 – 1.5 MY
- Review of IRIS PRA guided design approach and its implications
- Consensus on emergency planning scope and methodology
- Close pre-application licensing

IRIS TEST PLAN OVERVIEW

L. E. Conway

Presentation to the U.S. NRC

February 22, 2005

IRIS TEST PLAN
- Presentation Overview -

- New IRIS Design Features/Components
  - Integral Reactor Coolant System
  - Passive Safety Features
  - Reactor Vessel and Containment Interaction
- Features/Components Based on Previous Tests
- Types of Tests Required
- Test Program Overview

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NEW DESIGN FEATURES & COMPONENTS
-Integral Reactor Coolant System-

- **Integral RCS**
  - **Entire RCS in a single pressure vessel**
  - **No connecting loop piping, supports**
- **Integral Reactor Vessel includes:**
  - **Axial-flow, "spool-type," coolant pumps with high-temperature bearings & high-temperature sealed rotor and stator windings**
  - **Helical-coil, once-through SGs**
  - **Internal CRDMs (I-CRDMs) designed for in-vessel environment**
  - **Pressurizer & heaters**

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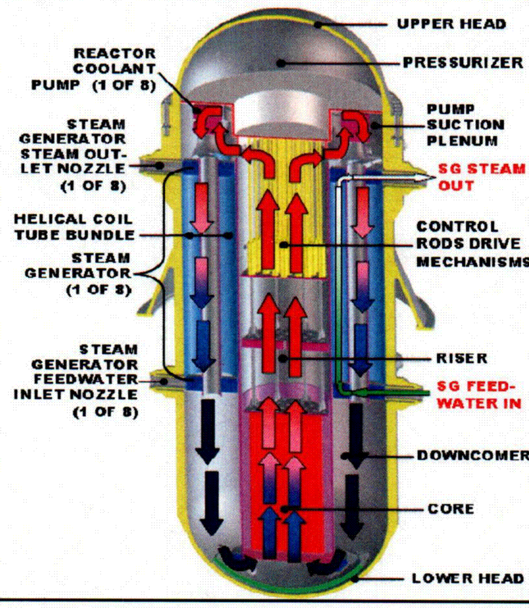
INTEGRAL REACTOR COOLANT SYSTEM

ENSA Equipos Nucleares, S.A.



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NEW DESIGN FEATURES & COMPONENTS -Passive Safety Systems-

- **EHRS (Emergency Heat Removal System)**
  - Removes heat directly from RCS using SGs as the heat transfer surface for all DBEs
  - Depressurizes RV thus reducing LOCA break flow rate
  - CV pressure reduced (RV/CV interaction)
  - 4 EHRS HXs submerged in RWST outside the CV
  - EHRS HX connects to SG steam & feed lines
- **PSS (Pressure Suppression System)**
  - Limits CV peak pressure
  - Floods RV cavity following CV pressurization
- **PCCS (Passive Containment Cooling System)**
  - PCCS HX provides CV cooling diverse from EHRS HXs

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NEW DESIGN FEATURES & COMPONENTS
-Additional Features-

- Fuel Assembly
  - 17x17 with increased moderation
- In-vessel, ex-core flux detectors
  - Based on established SiC detector development
- SG shroud check valves
  - Provide natural circ. cooling path when RCS water level is reduced
- RV electrical penetrations and connections
  - In-vessel component power cables
  - In-vessel instrumentation signal cables

IRIS DESIGN FEATURES & COMPONENTS
-Previously Tested-

- EBTs (Emergency Boration Tanks)
  - Similar to AP600/1000 CMTs but much smaller (450 ft^3 vs. 2000 ft^3)
- ADS (Automatic Depressurization System)
  - Similar to AP600/1000 ADS/IRWST but much smaller (equivalent to the AP 1st stage)
- Spargers for PSS
  - AP600 air clearing loads simulate IRIS CV N_2
  - AP600 single-phase steam test data applicable
- LGMS (Long-term Gravity Makeup System)
  - Similar to AP600/1000 containment sump recirculation
- IVR (In-vessel retention of corium)
  - Same as AP600

IRIS TEST PLAN
-Types of Tests to be Performed-

- Engineering Development Tests
  - Demonstrate feasibility
  - Verify engineering capability before fabricating large scale or prototype components
  - Not scaled and not part of design certification, EMDAP
- Separate Effects Component Tests
  - Includes the design, fabrication, operation, and qualification (accelerated aging, radiation, seismic, etc.) of large scale prototype components
  - Data/performance input for and verification of computer models
  - Establishes boundary conditions and equipment parameters for IETs
- Integral Effects Tests
  - Scaled simulations of combined systems/features
  - Demonstrates integrated performance
  - Shows interactions between systems (safety & non-safety)
  - Thermal-hydraulic performance input for and verification of analysis models

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PRELIMINARY IRIS TEST PLAN
-Engineering Development Tests-

TABLE 1
BASIC ENGINEERING DESIGN TESTS

Test Description	Test Objective(s)	Scale	Pressure/ Temp.
RCP Pump Impeller and Diffuser Preliminary Design Verification Test	Perform preliminary design and verify the pump impellor and diffuser to define the overall pump layout		
RCP Stator and Rotor Winding Design Test	Demonstrate the materials and techniques for manufacturing the RCP canned, high temperature stator and rotor windings		
RCP High Temperature, Water Lubricated Bearing Test	Verify the materials and manufacturability of the high temp water lubricated bearings		
I-CRDM Design Test	Demonstrate the materials and techniques for manufacturing CRDM for in-vessel environment		
I-CRDM Rod Position Indicator Design Test	Verify materials and operation of the I-CRDM in-vessel rod position instrument		
Steam Generator Tube to Tube Sheet Attachment Test	Verify the materials, insertion, expansion, rolling seal welding, electro-heating requirements		
Steam Generator Tube Bundle Manufacturability Test	Produce, coil, and heat treat a prototypic SG tube. Confirm tube bundle assembly techniques		
Steam Generator Heat Transfer and Tube to Tube Flow Stability Test	Verify overall heat transfer performance and tube inlet orifice size needed to prevent excessive parallel flow path instability in the helical coil bundle		
Steam Generator Instrumentation Test	Simulate and verify acceptable secondary side level measurement at low power		
Steam Generator Tube Cleaning and Inspection Test	Determine tube inspection tooling parameters and verify that the SG tubes can be effectively cleaned, inspected, and maintained		

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PRELIMINARY IRIS TEST PLAN
-Separate Effects Component Tests-

TABLE 2 (Sheet 1 of 2) SEPARATE EFFECTS COMPONENT TESTS			
Component Description	Test Objective	Scale	Pressure/ Temp.
EHRS HX	Verify heat transfer characteristics of the EHRS HX and mixing characteristics in the RWST		
Reactor Coolant Pump	Demonstrate manufacturability and operation of prototype canned, high temperature stator and winding		
	Demonstrate manufacturability and operation of full size, prototype high temperature, water lubricated bearing		
	Demonstrate pump performance parameters and operability at full range of fluid temperatures/pressures		
	Demonstrate pump coast down performance		
	Demonstrate long-term operability and qualify pump for nuclear application		
Internal Control Rod Drive Mechanism	Demonstrate manufacturability, operability, and qualify mechanism and RPI		
In-core instrumentation tests	Demonstrate in-vessel instrumentation, ex-core neutron detector performance and long-term operability		
Reactor vessel flow test	Demonstrate that no abnormal flow distribution occurs in the reactor vessel downcomer and lower plenum		
	Demonstrate that no abnormal flow distribution occurs in the reactor vessel upper riser/RCP suction plenum		
	Demonstrate boron addition to downcomer and mixing		
Internal Component electrical connections	Demonstrate electrical penetration and connection performance		
Passive Containment Cooling System HX	Verify heat transfer characteristics of the PCCS HX versus CV pressure with and without the presence of non-condensable gas		

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PRELIMINARY IRIS TEST PLAN
-Separate Effects Component Tests (Cont'd)-

TABLE 2 (Sheet 2 of 2) IRIS SEPARATE EFFECTS COMPONENT TESTS			
Component Description	Test Objective	Scale	Pressure/ Temp.
Steam Generator	Demonstrate SG heat transfer performance and SG operability over entire range of flow, pressure, and temperature		
	Verify tube inlet orifices prevent parallel channels flow instability		
	Verify absence of primary and secondary side flow induced vibration, and acceptable tube support performance		
	Demonstrate ability to clean, inspect, plug, and re-orifice tubes via header nozzles		
SG Shroud Check Valve	Determine flow vs. differential pressure for prototypic SG shroud check valves		
Pressurizer	Demonstrate acceptable operating characteristics including annulus venting, fluid mixing, heat losses, and insurge and outsurge DP		
Internal Component Electrical Connections	Verify acceptable electrical penetration performance		
Fuel Assembly	Determine the critical heat flux correlation for IRIS fuel assembly DNB analyses including flow conditions simulating a LOFA		
	Qualify IRIS fuel assembly (vibration, mixing, seismic response, etc)		

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PRELIMINARY IRIS TEST PLAN
-Integral Effects Tests-

TABLE 3 IRIS INTEGRAL EFFECTS TESTS			
Test Description	**Test Objective**	**Scale**	**Pressure/ Temp.**
EHRS and SG Integrated Performance Test	Simulate heat transfer operation from the SG to the RWST via the EHRS and verify EHRS operability over the full range of expected operating conditions.		
IRIS Integral Systems Test	Provide data to evaluate the integrated operation of the RCS, ADS, SG/EHRS/RWST, containment, PSS, and LGMS, with and without active systems operating, to mitigate postulated events including transients such as a loss of feed water, and accidents SBLOCA, SLB, SGTR, and station blackout.		
Long-term Cooling Test	Provide data to evaluate the long-term core makeup operation of the LGMS at low RCS pressures		

IRIS TEST PLAN OVERVIEW
-Comments/Conclusions-

- Separate Effects Component Tests will include qualification of new components for nuclear application (environmental, aging, radiation, seismic, etc.)
- Separate & Integral Effects Tests will address PIRT guidance and will be designed to support EMDAP
  - Component / facility / test conditions will be scaled for important phenomena
  - Test parameters and test matrix selected to provide data required for V&V of computer models used for safety analyses

IRIS Small Break LOCA (SBLOCA) Phenomena Identification and Ranking Table (PIRT)

Dr. Luca Oriani, Westinghouse Electric Co.

Presentation for NRC
February 22nd, 2005

IRIS SBLOCA PIRT
- Presentation Overview -

- IRIS SBLOCA PIRT Documentation
- IRIS SBLOCA PIRT Program Overview
  - Topical Report Review
  - Panel Composition
  - PIRT Process
  - Key Results
- Westinghouse Interpretation of SBLOCA PIRT Results
- Westinghouse Expectations of NRC Review

IRIS SBLOCA PIRT
- PIRT Documentation -

- **Final PIRT Report (WCAP-16318-P and WCAP-16318-NP) Issued to the NRC in September 2004**
  - Final Report Includes a 200 pages Addendum with SBLOCA Sensitivity Studies
- **Key PIRT Results Presented in a ICAPP 2005 paper**
  - T. K. Larson, F. J. Moody, G. E. Wilson; W. L. Brown, C. Frepoli, J. Hartz, B. G. Woods; L. Oriani, "*IRIS Small Break LOCA Phenomena Identification and Ranking Table*," International Congress on Advances in Nuclear Power Plants, ICAPP 2005, May 15-19 2005, Seoul, Korea
- **PIRT Process Overview in a BE2004 Paper**
  - Brent E. Boyack and Gary E. Wilson, "*Lessons Learned in Obtaining Efficient and Sufficient Applications of the PIRT Process*," Proceedings of BE-2004 Topical Meeting, ANS Winter Meeting, November 14-18, 2004, Washington, DC.

IRIS SBLOCA PIRT
- Program Overview, WCAP-16318 -

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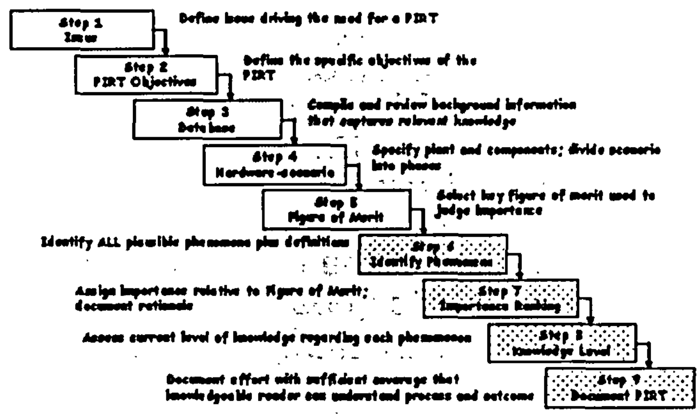
IRIS SBLOCA PIRT
- Program Overview, PIRT Process -

- **PIRT Program Follows Approach Outlined in Boyack and Wilson (2004)**



IRIS SBLOCA PIRT
- Program Overview, Step 1&2 -

- <u>Issue</u>: "*From the perspective of the IRIS Program, the primary issue is to insure that a sufficient experimental and analytical database exists to support the licensing process*" **(Wilson, WCAP-16318)**

- <u>Objectives</u>:
  1. To provide expert technical evaluations of the relative importance of phenomena occurring during a SBLOCA (primary objective),
  2. To identify the "state of knowledge" relative to the phenomena in the context of adequate, marginal or inadequate experimental databases and analytical tools with which to conduct safety analyses (primary objective), and
  3. To provide the framework whereby the phenomena relative importance and state of knowledge assessments can be used to guide continued experimental database and analysis tool development in a cost effective manner (secondary objective).

IRIS SBLOCA PIRT
- Program Overview, Step 3 -

- <u>Database</u>:
  1. Extensive IRIS Design Information made available to the panel, with full access to IRIS designers and analysts,
  2. Panel Selection to cover all anticipated critical areas and assure complete independence from the IRIS consortium

PIRT Panel Composition
- Independent Experts: Mr. G. E. Wilson, Dr. F. J. Moody, Dr. T. K. Larson (INEEL)
- AP1000/AP600 Experts: Mr. W. L. Brown, Dr. C. Frepoli, Mr. J. Hartz, Dr. B. Woods (OSU)

IRIS "Experts" Present at the PIRT meeting to address key Panelists questions/issues
- IRIS Experts: Mr. L. E. Conway; Dr. M. Dzodzo; Dr. L. Oriani

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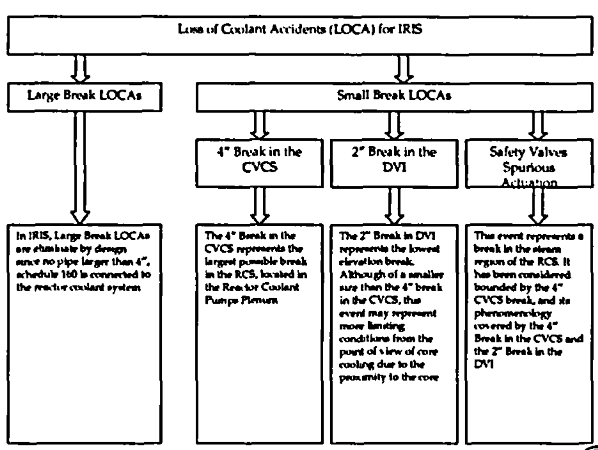
IRIS SBLOCA PIRT
- Program Overview, Step 4 -

- **Detailed System/Components Description and System Decomposition**
- **Scenario Identification:**



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IRIS SBLOCA PIRT
- Program Overview, Step 5 -

Figure of Merit	Rationale
RV coolant inventory	Maintain sufficient vessel coolant inventory to remove the inital stored energy and subsequent decay heat without significant fuel clad temperature excursions (Core Cooling)
Containment pressure and successful heat removal to the environment	*Prevent an initial over-pressurization of the containment, followed by* [illegible] containment depressurization.

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IRIS SBLOCA PIRT
- Program Overview, Independent Panel Members Evaluations -

- <u>Appendix E of WCAP-16318-P provides independent comments from each of the panel members</u>
- <u>Identifies limitations and major successes of the program</u>
- <u>G.E Wilson:</u>
  - *"The IRIS <u>design/experimental/analytical database provided to the panel was impressive in its breadth</u> and contributed largely to the panel obtaining sufficient knowledge to feel confident in its conclusions concerning potential plant behavior"*
  - *"Although four members of the panel were either Westinghouse employees or an experimental subcontractor, their complete independence from the IRIS project and their objectiveness was noticeable. Thus, <u>an original minor concern with a potential conflict of interest was quickly alleviated early in the project</u>."*
  - *"As might be expected from a panel of highly informed and knowledgeable individuals, expert in a broad range of fields, there were occasional strong differences of opinions. Fortunately, [..], almost without exception, <u>the panel was able to resolve these differences to come to an acceptable consensus</u>."*
  - *"In summary, <u>execution of this project is considered one of the best of the several such projects undertaken</u>, in the context of efficiency, sufficiency, accuracy and usefulness of the results"*

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IRIS SBLOCA PIRT
- Program Overview, Step 6-8 -

- **Phenomena Identification**: Over 50 phenomena identified and discussed
- **Importance Ranking**: 158 ranking rationales discussed
- **Knowledge Level**: 85 states of knowledge discussed

- Detailed Documentation of Results in WCAP-16318. Final PIRT Panel Recommendation:

  "[..] Experimental data and 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 IRIS Program:
  1. *Steam generator;*
  2. *Pressure Suppression System, Containment Dry Well and their interactions;*
  3. *Emergency Heat Removal System (this item and #2 immediately above are considered to have the same level of significance);*
  4. *Core, Long Term Gravity Makeup System, Automatic Depressurization System, and Pressurizer;*
  5. *Direct Vessel Injection System and Reactor Vessel Cavity."*

IRIS SBLOCA PIRT
- Westinghouse Interpretation of IRIS PIRT -

- A PIRT developed for a new plant design has inherent differences from traditional (i.e. CSAU-like) PIRTs:
  - It is understood by Westinghouse that the incomplete level of knowledge existing at this time requires that the PIRT be considered a living document, that will be used to guide experimental activities and analytical methods development;
  - Rather than being used to justify the capability of a methodology in analyzing a given scenario on the basis of existing experimental data, the PIRT is used to guide the testing program. Thus, the PIRT will need to be re-evaluated during the development of the testing program to evaluate its continued validity;
  - Uncertainty breeds conservatism: in the current PIRT it can be expected that several medium importance phenomena have been ranked high, and several low importance phenomena had been ranked medium. Analysis of test data will allow a thorough review of the PIRT and development of a final PIRT.
- This limitations are considered acceptable for the primary objective of this PIRT which is to provide an effective guidance to the test program.
- Note that several of these issues have been highlighted by the Panel Members in their individual feedback in Appendix E of WCAP-16318

IRIS SBLOCA PIRT
- Westinghouse Expectations of NRC Review -

- Concurrence that this PIRT is appropriate and sufficiently complete for defining and reviewing the IRIS test plan.

IRIS Scaling Analysis Program

Dr. Milorad B. Dzodzo

Presentation for NRC
February 22nd, 2005

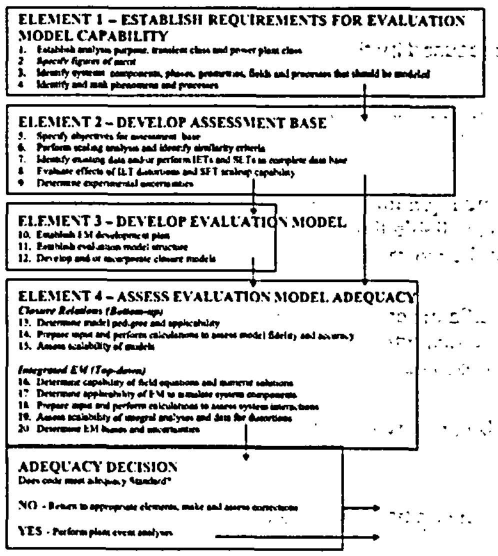
IRIS Scaling Analysis

- Outline
  - Submitted and Planned Documents
  - Applied scaling methodology - Hierarchical, Two-Tired Scaling Analysis (H2TS)
  - Stage 1 – IRIS System Decomposition
  - Stage 2 – IRIS Scale Identification
  - Stage 3 – IRIS Top-Down System Scaling Analysis
  - Stage 4 – IRIS Bottom-Up Process Scaling Analysis

IRIS Scaling Analysis – Submitted and Planned Documents

- SUBMITTED
  - Document WCAP-16103-P, IRIS Scaling Analysis Part I, was submitted in April 24, 2003
  - IRIS Scaling Analysis Part I covers Stage 1 (System Decomposition) and 2 (Scale Identification) of the Hierarchical, Two-Tired Scaling Analysis
- PLANNED
  - Stage 3 (Top-Down System Scaling Analysis) and Stage 4 (Bottom-Up Process Scaling Analysis) will be submitted as Part II and Part III respectively

IRIS Scaling Analysis – Applied Scaling Methodology



Scaling Analysis as a part of Transient and Accident Analysis Methods

(According to "Elements of Evaluation Model Development and Assessment Process – EMDAP")

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IRIS Scaling Analysis – Applied Scaling Methodology

- **Flow Diagram for Hierarchical, Two-Tired Scaling Analysis (H2TS)**

Stage 1 SYSTEM DECOMPOSITION	Stage 2 SCALE IDENTIFICATION	Stage 3 TOP-DOWN/SYSTEM SCALING ANALYSIS	Stage 4 BOTTOM-UP/PROCESS SCALING ANALYSIS
<u>PROVIDE:</u> System hierarchy <u>IDENTIFY:</u> Characteristic: Concentrations, Geometries, Processes	<u>PROVIDE HIERARCHY FOR:</u> Volumetric concentrations Area concentrations Residence times Process time scales	<u>PROVIDE:</u> Conservation equations <u>DERIVE:</u> Scaling groups and Characteristics time ratios <u>ESTABLISH:</u> Scaling hierarchy <u>IDENTIFY:</u> Important process to be addressed in bottom-up/ process scaling analyses	<u>PERFORM:</u> Detailed scaling analysis for important local processes <u>DERIVE AND VALIDATE:</u> Scaling groups

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IRIS Scaling Analysis – Applied Scaling Methodology

Time ratios represent the total change of a conserved property in the control volume, during the residence time, caused by the relevant transfer process.

Time ratios will be used to establish a hierarchy and ranking for various processes to be tested.

If time ratio is small (P<<1) only small quantity of the corresponding property would be transferred in the limited available time. As a consequence the specific process would not be important to the overall transient.

If time ratio is large (P>>1) the specific process has a high transfer rate of the conserved property during the residence time period. The larger the time ratio the more important is the transfer process.

The characteristic time ratio must be preserved for the prototype and the model ($P_m = P_p$).

The effect of a distortion in the model can be estimated from $D = (P_m - P_p)/P_p$.

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IRIS Scaling Analysis – Applied Scaling Methodology

The H2TS method is used to develop sets of specific and characteristic time ratios for the transfer processes. The control volume balance equation for constituent "i" is

$$\frac{dV_i\psi_i}{dt} = \Delta[Q_i\psi_i] \pm \sum_{k=1}^{m-1}(j_{ik}A_{ik}) + S_i$$

or in dimensionless form

$$\tau_i \frac{dV_i^+\psi_i^+}{dt} = \Delta[Q_i^+\psi_i^+] \pm \sum_{k=1}^{m-1}(\Pi_{ik} j_{ik}^+ A_{ik}^+) + \Pi_{si} S_i^+$$

Each specific time ratio is composed of a specific frequency and residence time constant.

$$\Pi_{ik} = \frac{j_{ik,0}A_{ik,0}}{Q_{i,0}\psi_{i,0}} = \left(\frac{j_{ik,0}A_{ik,0}}{V_{i,0}\psi_{i,0}}\right)\left(\frac{V_{i,0}}{Q_{i,0}}\right) = \omega_{ik}^S \tau_i$$

This is done for every component, constituent, phase and geometrical configuration interaction.

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IRIS Scaling Analysis – Stage 1 – System Decomposition

- IRIS Plant is decomposed into Systems (S), Subsystems (SS) and Modules (M)
- Various Materials – Constituents (C) are decomposed into Phases (P) and Geometrical Configurations (G)
- Mass, Momentum and Energy fields were considered as well as various Processes affecting them

An example:

SYSTEM (S)	S for example IRIS Engineered Safeguard Features (ESF)				
SUBSYSTEM (SS)	SS_1 for example Pressure Suppression System (PSS)	.	SS_K		
MODULES (M)	MM_1 · for example Pool (PSS_POOL)	MM_2			
CONSTITUENTS (C)	C_1 for example water	..	C_K		
PHASES (P)	g	liquid	e		
GEOMETRICAL CONFIGURATIONS (G)		G_1	G_2 droplets	.	G_K
FIELDS (F)		M	MM	Energy	
PROCESSES		P_1 P_2 P_1			

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IRIS Scaling Analysis – Stage 2 – Scale Identification

For example volume and residence time for water as one constituent are

$$V_{*,w} = \alpha_{*,w} V_{*} \qquad \tau_{*,w} = \frac{V_{*,w}}{\sum_P Q_P} = \frac{V_{*,w}}{Q_{*,w,l} + Q_{*,w,g}}$$

Volumes and residence times for various phases (liquid and gas) of water are

$$V_{*,w,l} = \alpha_{*,w,l} V_{*,w} \qquad \tau_{*,w,l} = \frac{V_{*,w,l}}{\sum_{l,G} Q_{l,G}} = \frac{V_{*,w,l}}{Q_{*,w,l,bulk} + Q_{*,w,l,drops} + Q_{*,w,l,film}}$$

$$V_{*,w,g} = \alpha_{*,w,g} V_{*,w} \qquad \tau_{*,w,g} = \frac{V_{*,w,g}}{\sum_{g,G} Q_{g,G}} = \frac{V_{*,w,g}}{Q_{*,w,g,bulk} + Q_{*,w,g,bubble}}$$

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IRIS Scaling Analysis – Stage 2 – Scale Identification

Volumes and residence times for various geometrical configurations (for example bulk liquid water) are

$$V_{*,w,l,bulk} = \alpha_{*,w,l,bulk} V_{*,w,l} \qquad \tau_{*,w,l,bulk} = \frac{V_{*,w,l,bulk}}{Q_{*,w,l,bulk}}$$

Transfer area concentrations for various geometrical configurations (for example for area between bulk liquid water and bulk steam) are

$$\frac{A_{(*,w,l,bulk),(*,w,g,bulk)}}{V_{*,w,l,bulk}}$$

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IRIS Scaling Analysis – Stage 2 – Scale Identification

Bulk liquid water process times (for example between bulk liquid water and bulk steam) are

$$\omega^{s}_{mass(*,w,l,bulk),(*,w,g,bulk)} = \frac{j_{mass(*,w,l,bulk),(*,w,g,bulk)}}{\rho_{*,w,l,bulk}} \frac{A_{(*,w,l,bulk),(*,w,g,bulk)}}{V_{*,w,l,bulk}}$$

$$\omega^{s}_{momentum(*,w,l,bulk),(*,w,g,bulk)} = \frac{j_{momentum(*,w,l,bulk),(*,w,g,bulk)}}{\rho_{*,w,l,bulk} \vec{v}_{*,w,l,bulk}} \frac{A_{(*,w,l,bulk),(*,w,g,bulk)}}{V_{*,w,l,bulk}}$$

$$\omega^{s}_{energy(*,w,l,bulk),(*,w,g,bulk)} = \frac{j_{energy(*,w,l,bulk),(*,w,g,bulk)}}{\rho_{*,w,l,bulk} u_{*,w,l,bulk}} \frac{A_{(*,w,l,bulk),(*,w,g,bulk)}}{V_{*,w,l,bulk}}$$

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IRIS Scaling Analysis – Stage 2 – Scale Identification

Bulk liquid water specific time ratios (for example between bulk liquid water and bulk steam) are

$$\Pi^{mass(*,w,l,bulk),(*,w,g,bulk)} = \omega^{s}_{mass(*,w,l,bulk),(*,w,g,bulk)}\tau_{*,w,l,bulk}$$

$$\Pi^{momentum(*,w,l,bulk),(*,w,g,bulk)} = \omega^{s}_{momentum(*,w,l,bulk),(*,w,g,bulk)}\tau_{*,w,l,bulk}$$

$$\Pi^{energy(*,w,l,bulk),(*,w,g,bulk)} = \omega^{s}_{energy(*,w,l,bulk),(*,w,g,bulk)}\tau_{*,w,l,bulk}$$

Other bulk liquid water specific time ratios (for example between bulk liquid water and bubbles) could be calculated by using the same procedure and subscripts

IRIS Scaling Analysis – Current Status

Stages 1 and 2 – System Decomposition and Scale Identification

- Report WCAP-16103-P, IRIS Scaling Analysis Part I, April 24, 2003 was submitted:
  - IRIS System Decomposition is performed (Stage 1)
  - IRIS Scale Identification is performed (Stage 2)
  - Interactions on all levels are identified (Stage 2)
    - » This was done to present all possible interactions
    - » This part of the report reflects formally Stage 1 – System Decomposition part

IRIS Scaling Analysis – Current Status
Stage 3 – Top-Down System Scaling Analysis

- **Report is in preparation**
  - **Small Break LOCA transients are considered**
    - » Includes interactions between Reactor Vessel and Containment
  - **Analyses performed are:**
    - » Derivation of governing equations
    - » Specification of time ratios
    - » Quantification of some specific time ratios
  - **Will guide the identification and selection of test facility**

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IRIS Scaling Analysis – Current Status
Stage 4 – Bottom-Up Process Scaling Analysis

- **Analysis will be performed following selection of test facilities.**
- **It will define:**
  - Geometrical configuration
    - Ratio of volumes
    - Ratio of areas
  - Power
  - Flow Rates
  - Operating Pressure and Temperature
  - Simulation Fluid
- **Key factor in the detailed design of scaled facilities to properly simulate complex phenomena**

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IRIS Scaling Analysis – Westinghouse Expectations of NRC Review

- **Concurrence that the IRIS implementation of scaling analyses and methodology are appropriate for selecting and defining characteristics of test facilities and adequacy of testing program**