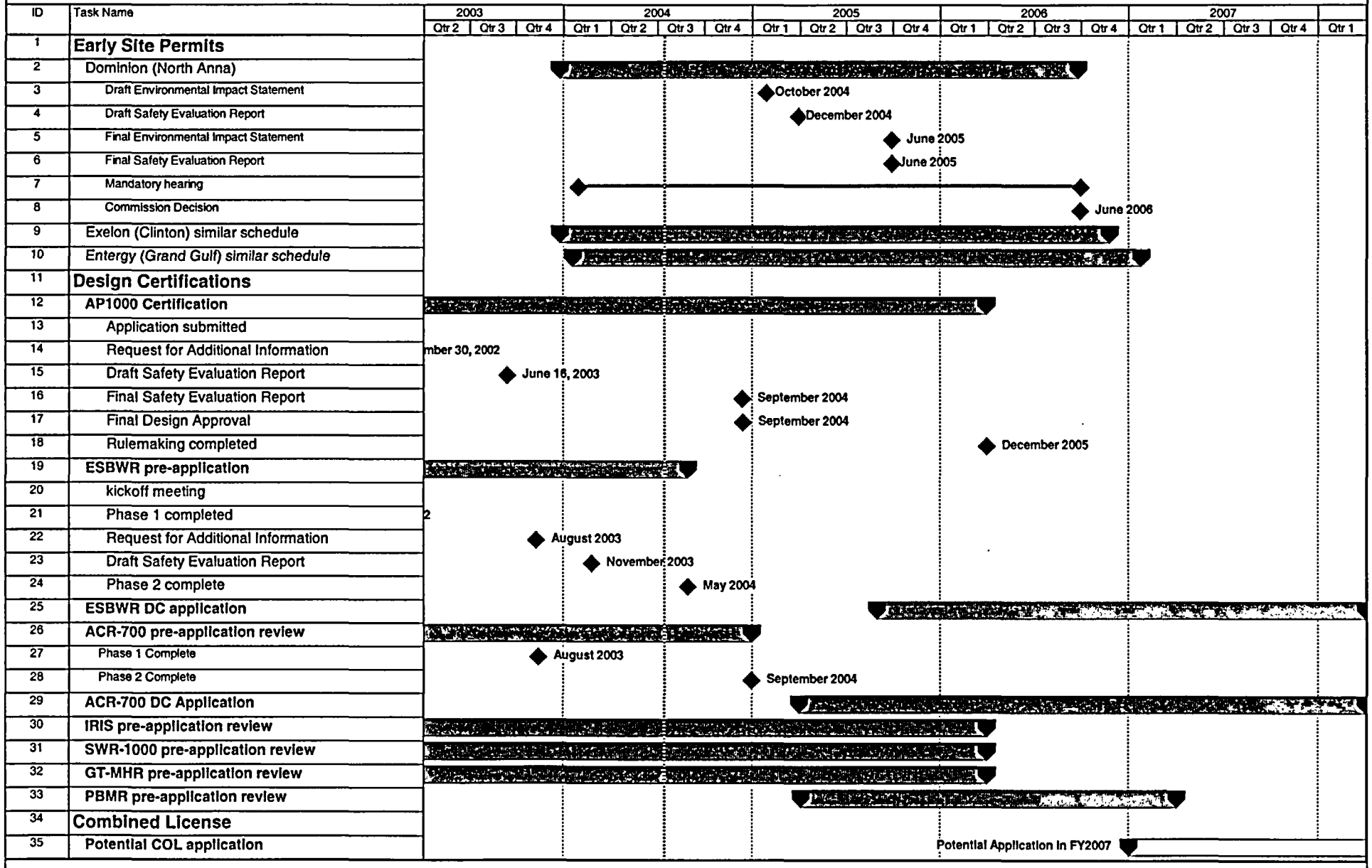
Agenda

Westinghouse/NRC IRIS Pre-application Review Meeting

April 15, 2004

Introductions	Westinghouse, NRC	20 minutes
Overview of IRIS pre-application documentation and proposed schedule	Westinghouse	20 minutes
Outline of IRIS design with emphasis on "safety-by-design"	Westinghouse	30 minutes
Outline of safety event sequences and expected response	Westinghouse	60 minutes
Lunch break		60 minutes
NRC feedback on presentations and submitted documentation	NRC, Westinghouse	90 minutes
Discussion of scope and schedule for next meetings	All	30 minutes

New Reactor Licensing Schedule
(by Fiscal Year)



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IRIS Pre-Application Licensing Meeting

NRC - April 15, 2004

AGENDA

Introductions	J. F. Williams	10 Min.
	M. D. Carelli	10 Min.
Overview of IRIS pre-application licensing documentation and proposed schedule	C. L. Kling	20 Min.
Outline of IRIS design with emphasis on safety-by-design	L. E. Conway	30 Min.
Outline of safety event sequences and expected response	L. Oriani	60 Min.
NRC feedback on above presentations and submitted documentation – W response	NRC/W	90 Min.
Discussion of scope and schedule for next meetings	All	30 Min.

IRIS PRE-APPLICATION LICENSING

Dr. Mario D. Carelli
Westinghouse Electric Co.
April 15, 2004

PREMISES

- IRIS embodies a new approach to LWR safety
- We have a two-year hiatus before starting design certification
- We want to optimally use this time to remove major sources of uncertainty in licensing process
- We want to rely as much as possible on previous AP experience whenever practical and acceptable

PRE-APPLICATION LICENSING

- It is not a preliminary design certification
- It is an interactive familiarization with IRIS safety outlook to attain two objectives
- First objective: Agreement on IRIS testing program
- Second objective: Agreement on procedure to eventually achieve licensing approval with no requirement for emergency response planning.

IRIS SAFETY-BY-DESIGN: THE BOTTOM LINE

	Advanced LWRs	IRIS
Class IV Accidents	(8)	1
Internal Events CDF	~1E-6 to 1E-7	~1E-8

IMPLICATIONS OF IRIS SAFETY BOTTOM LINE

Both advanced LWRs and IRIS are extremely safe plants (we do not want to characterize IRIS as "safer")

BUT

IRIS is unique in having the foundation to attain "next level licensing", i.e.,
NO EMERGENCY RESPONSE REQUIREMENT

SUMMARIZING

- We are not looking for an evaluation of the adequacy of our analyses (this is not a mini DC)
- Documentation submitted to NRC is to provide sufficient information in order to complete the two Pre-Application objectives

IRIS Pre-Application Licensing Documentation and Proposed Schedule

Dr. Charles L. Kling
Westinghouse Electric Co.
April 15, 2004

IRIS Pre-Application Licensing

- IRIS Licensing Approach
- Current Pre-Application Licensing Status
- Current Licensing Schedule
- Pre-Application Licensing NRC Feedback/Meetings

IRIS Licensing Approach

- Goal to obtain DC in 2008-2010
- IRIS licensing to follow AP1000 DC (~2005)
- IRIS will rely on AP1000 licensing to maximum extent practical
- Pre-Application licensing will address differences from AP1000, including:
  - Safety-by-Design Features
  - Testing of integral components (e.g., helical coil SGs, internal RCPs/CRDMs, etc.)
  - Risk-informed regulation (e.g., EPZ equal to exclusion boundary)

IRIS Pre-Application Objectives

- NRC review, feedback, approval of IRIS testing program

  (Long lead item)

- NRC review, feedback, concurrence on IRIS approach to "enhanced licensing objectives" through "highly risk informed" regulation

  (Novel item)

Current Pre-Application Licensing Status

- Documentation submitted to NRC
  - 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, "Preliminary Steam Generator Tube Rupture Analysis for IRIS"
- April 15 meeting on WCAP-16062, WCAP-16082 and STD-ES-04-09

IRIS Pre-Application Licensing Schedule

- Submit topicals on IRIS PIRT and test program - Summer 2004
- NRC concurrence on test program – End 2004
- Submit topicals on application of risk informed regulations - Spring 2005
- NRC concurrence on approach to no emergency response – End 2005
- Initiate IRIS DC review – Early 2006

2004 Pre-Application Licensing NRC Feedback/Meetings

Feedback/Meeting	Date
Feedback on 04/15 meeting to facilitate submittal of testing/PIRT topical	ASAP
Meeting to review documentation relative to IRIS PIRT and testing program	09/04
Feedback on proposed testing program	10/04
Eventual meeting to finalize concurrence on proposed IRIS test program	11/04

IRIS DESIGN REVIEW

Lawrence E. Conway
Westinghouse Electric Co.
April 15, 2004

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Content and Objective of Submitted Material (WCAP-16062, WCAP-16082 Section 1)

- IRIS Plant Design Description
  - Focus on the Integral Reactor Coolant System and Safety Systems
- IRIS Safety Concept Overview
  - Safety-By-Design Approach

Provide sufficient IRIS information to the NRC to allow revision and comments on the PIRT and testing plan

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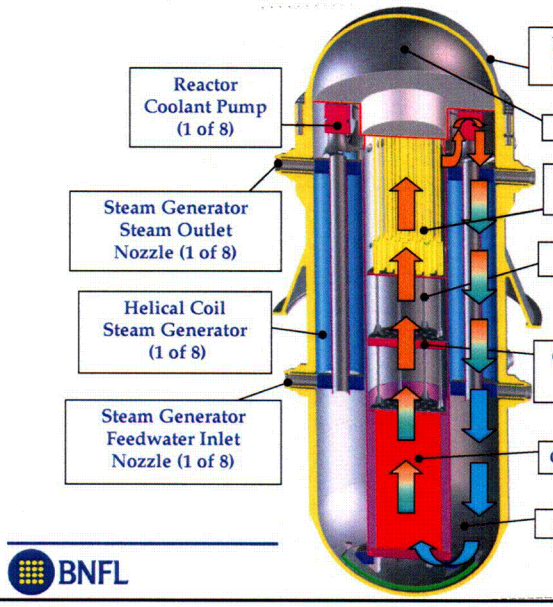
Objectives / Scope of NRC Review of IRIS Design Description

- Concurrence that the provided material is sufficient to address the the Pre-Application objectives;
- Identification of any major disagreement with the presented material.

Presentation Outline

- Very Brief Review of IRIS Design, with focus on Safety Systems
  - Provide an Update on the plant design with focus on later modifications to the provided material
  - Additional discussion only if specific questions or disagreements are voiced

INTEGRAL REACTOR COOLANT SYSTEM



ENSA Equipos Nucleares, S.A.

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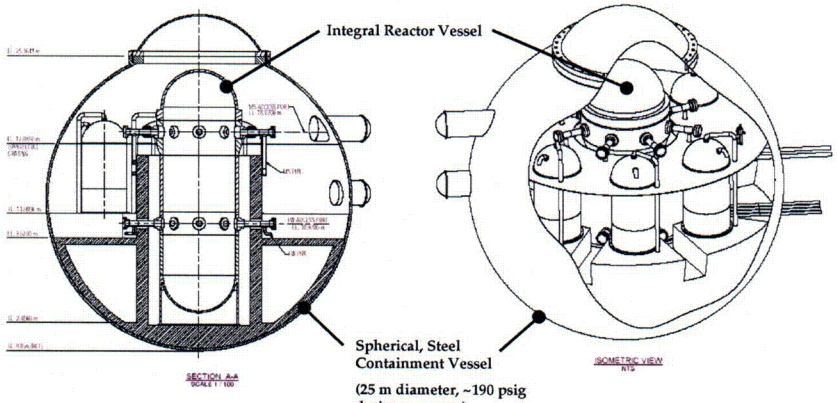
IRIS CONTAINMENT LAYOUT (Preliminary Design – All Major Equipment)

Integral RV enables containment vessel size to be greatly reduced and results in higher allowable pressure



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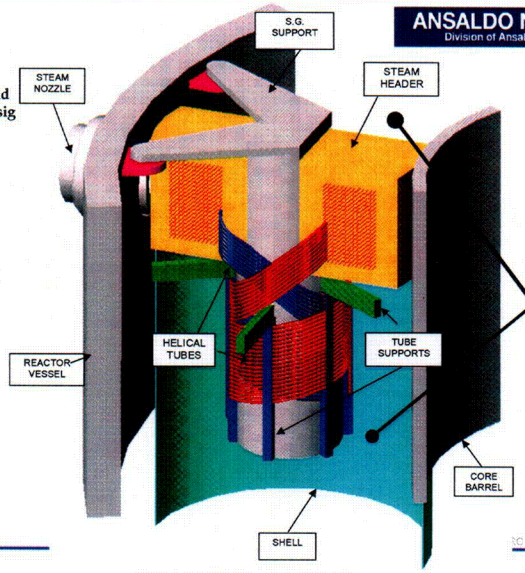
HELICAL COIL STEAM GENERATOR

Steam (upper) Header, Feedwater (lower) Header, and Tubes all designed for 2485 psig External Pressure

Redundant, monitored seals provide primary to secondary pressure boundary – similar to RV head seals



IRIS STEAM GENERATOR MODULE
Pictorial view

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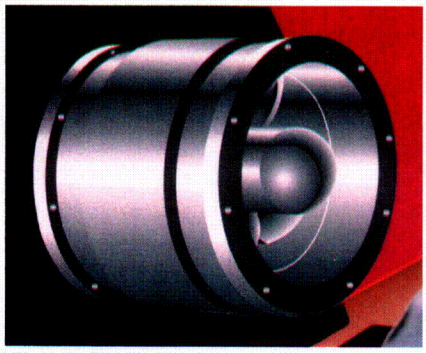
PRIMARY COOLANT SPOOL PUMPS

- Developed by W's former EMD (now Curtiss-Wright) for marine and chemical applications, requiring large flowrate and low developed head
- Completely immersed, no vessel penetration except electrical cable
- High temperature motor
- Water lubricated bearings
- Virtually no maintenance
- Reduced vibration
- Operating experience
- Tested up to 500°C
- Must be qualified for nuclear applications



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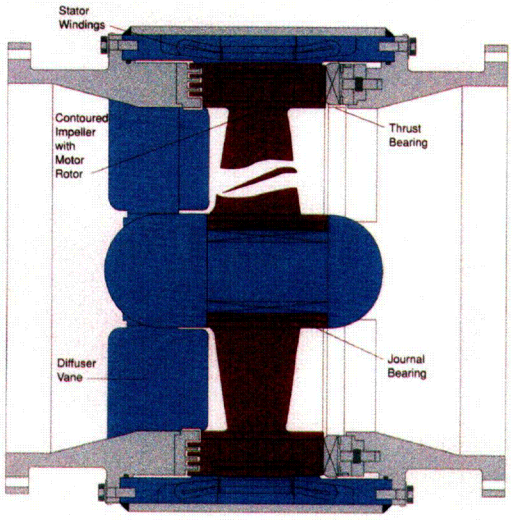
PRIMARY COOLANT SPOOL PUMPS



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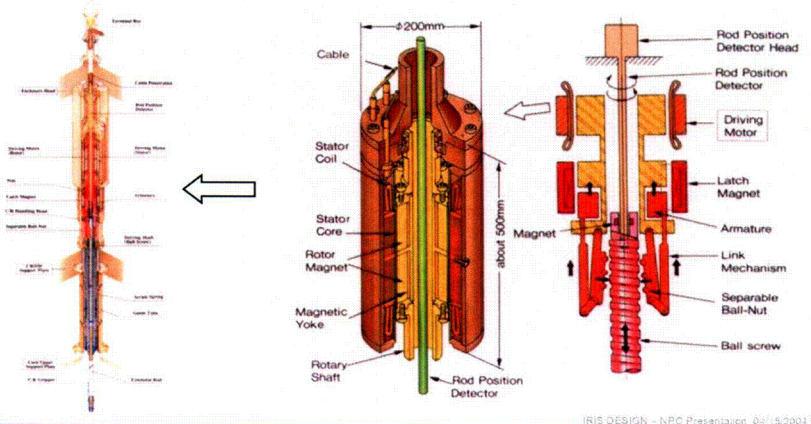
AN INTERNAL CRDM ELECTRO-MECHANICAL OPTION

- **IRIS design goals**
  - **Eliminate all thin-walled, sleeved penetrations**
  - **Eliminate all upper head penetrations (except SRVs)**



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C03

SAFETY APPROACH

- **"Safety By Design" minimizes challenges and consequences**
- **Active, non-safety systems normally available**
- **Passive, safety-related systems able to perform all nuclear safety functions**
  - » Safety functions automatically actuated, no reliance on operator action
  - » Passive features actuated by stored energy (batteries, compressed air)
  - » Once actuated, their continued operation relies only on natural forces (gravity, natural circulation) with no motors, fans, diesels, etc.
- **Heat sink designed to provide cooling for 7 days without operator action or off-site assistance for replenishing**
- **Diverse systems to minimize probability of Core Damage and Radioactivity Release**

IRIS SAFETY BY DESIGN APPROACH

Exploit to the fullest what is offered by IRIS' design characteristics (chiefly integral RV configuration) to:

- Physically eliminate accident sequences, if possible
- Decrease probability of occurrence of most remaining accident scenarios
- Lessen consequences if an accident occurs

IMPLEMENTATION OF SAFETY BY DESIGN

IRIS Design Characteristic	Safety Implication	Accidents Affected
Integral Layout	No large primary piping	- LOCAs
Large, Tall Vessel	Increased Water Inventory	- LOCAs - Decrease in Heat Removal
	Increased Natural Circulation	- Various Events
	Internal CRDMs *	- RCCA ejection, eliminate head penetrations
Heat Removal from inside the vessel	Depressurizes primary system by condensation and not by loss of mass	- LOCAs
	Effective heat removal by SG/EHRS	- LOCAs - All events for which effective cooldown is required - ATWS
Reduced size, higher design pressure containment	Reduced driving force through primary break	- LOCAs
Multiple coolant Pumps	Decreased importance of single pump failure	- Locked Rotor, Shaft Seizure/Break
High design pressure steam generator system	No SG safety valves	
	Primary system cannot over-pressure secondary system	- Steam Generator Tube Rupture
	Feed/Steam System Piping designed for full RCS pressure reduces piping failure probability	- Steam Line Break - Feed Line Break
Once Through steam generator	Limited Water Inventory	- Steam Line Break - (Feed Line Break)
Integral Pressurizer	Large pressurizer volume/reactor power	- Decrease in Heat Removal, including Feed Line Break - ATWS

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TYPICAL PWR CLASS IV ACCIDENTS AND THEIR RESOLUTION IN IRIS DESIGN

Condition IV Design Basis Events	IRIS Design Characteristic	Results of IRIS Safety-by-Design
Large Break LOCA	Integral RV Layout – No loop piping	Eliminated by design
Steam Generator Tube Rupture	High design pressure once-through SGs, EHRS, piping, and isolation valves	Reduced consequences, simplified mitigation
Steam System Piping Failure	High design pressure SGs, piping, and isolation valves. SGs have small water inventory.	Reduced probability, reduced (limited containment effect, limited cooldown) or eliminated (no potential for return to power) consequences
Feedwater System Pipe Break	High design pressure SGs, piping, and isolation valves. Integral RV has large primary water heat capacity.	Reduced probability, reduced consequences
Reactor Coolant Pump Shaft Break	Spool pumps have no shaft	Eliminated by design
Reactor Coolant Pump Seizure	No DNB for failure of 1 out of 8 RCPs, even without Reactor Trip.	Reduced consequences
Spectrum of RCCA ejection accidents	With internal CRDMs there is no ejection driving force	Eliminated by design
Design Basis Fuel Handling Accidents	No IRIS specific design feature	No impact

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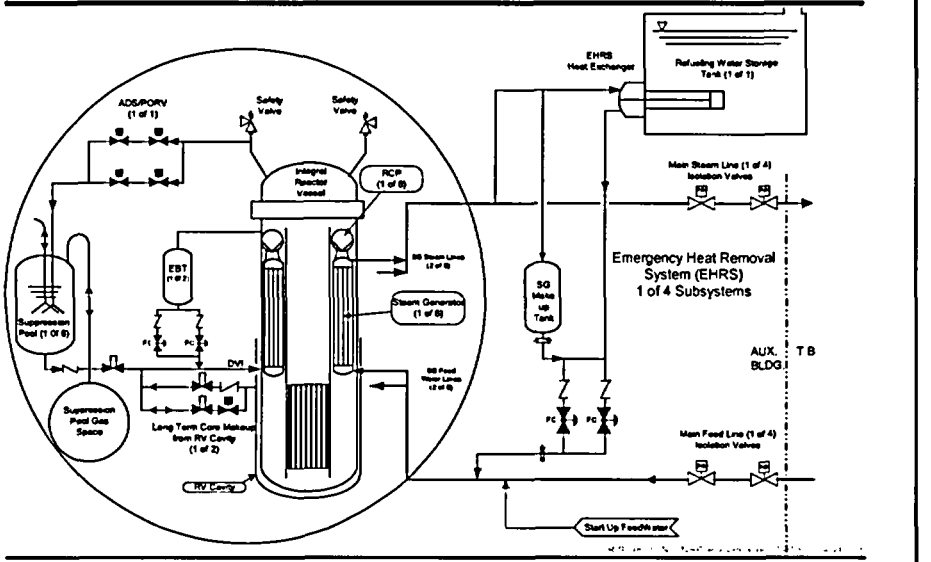
Safety Systems and Functions



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Engineered Safety Features Design

- LOCA Mitigation
  - Remove heat from inside RV - condense steam, reduce RV pressure, decrease break flow
  - Equalize RV and CV pressure to minimize mass loss
  - CV pressure follows decreasing RV pressure
- Transient Mitigation
  - Large primary mass provides thermal inertia
  - Large PZR steam volume reduces pressurization
- Secondary Break Mitigation
  - Simple direct SGTR isolation/pressure equalization
  - Small SG inventory reduces CV pressurization, RCS cooldown
- Loss of Flow
  - Multiple RCPs – No DNB for locked rotor
  - Inherently large inertia for LOF – no flywheel required
- Loss of Heat Sink
  - RV heat removal to outside containment water tank – no steaming in CV

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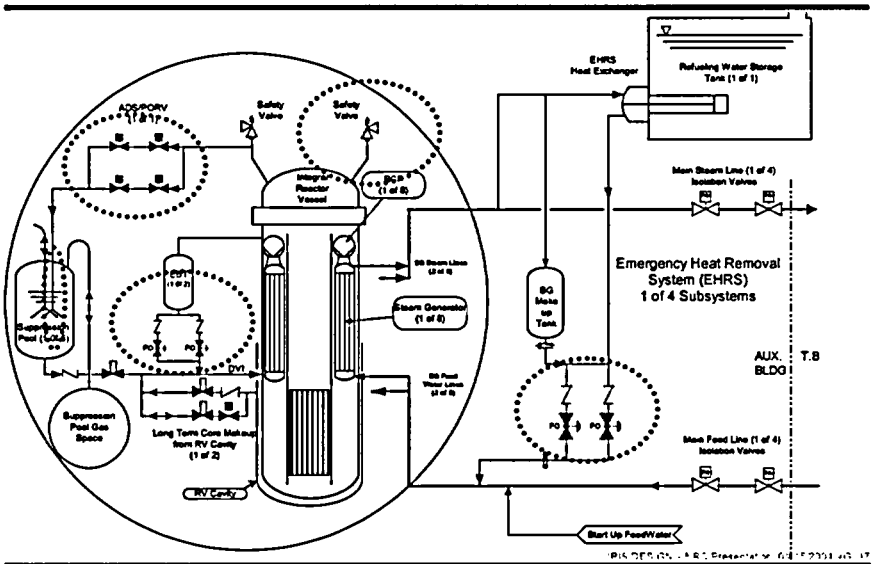
Critical Items in Safety Systems Design Optimization



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Safety Systems Design Update

- **ADS design**
  - In the original design, ADS was connected directly to one of the pressure suppression tanks.
  - SBLOCA sensitivity studies indicated the advantage of moving the ADS discharge to a dedicated quench tank. This also prevents possible scenarios under which the ADS would lead to a degraded performance of the pressure suppression system.
- **Containment design**
  - Original design had 6 tanks with a common air expansion tank. Different containment layouts are being explored to optimize the use of available containment volume.
- **Pressurizer Safety Valves**
  - Number of valves and total relief capacity has been increased for improved mitigation of beyond design events (e.g., ATWS).
- **EHRS, EBT and ADS design**
  - Currently being optimized on the basis of probabilistic considerations, to improve plant reliability.

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IRIS SAFETY REVIEW

Dr. Luca Oriani
Westinghouse Electric Co.
April 15, 2004

Content and Objective of Submitted Material (WCAP-16082, STD-ES-04-9)

- **IRIS Safety Concept Overview**
- **Preliminary safety assessment of Chapter 15 events**
  - Demonstrate mitigation of anticipated transients and postulated accidents;
  - Initial verification of the IRIS Safety Concept;
  - Support development of IRIS PIRT;
  - Support development of IRIS testing program.

Provide sufficient IRIS information to the NRC to allow revision and comments on the PIRT and testing plan

Objectives / Scope of NRC Review of IRIS Safety Assessment

- NOT a review of the adequacy of IRIS safety analyses and of compliance with SRP acceptance criteria
- Objectives are:
  - Concurrence that the list of events discussed (both qualitatively and quantitatively) in WCAP-16082 is complete, and no major sequence is missing;
  - Concurrence that the provided material is sufficient for the first objective of this Pre-Application phase
  - Identification of any major disagreement with the presented material
  - Concurrence with the focus on Small Break LOCA as the main area where differences from current PWRs exist.

Presentation Outline

- Very Brief Review of IRIS Safety Features and Safety Analyses (provided in WCAP-16082 Section 2 and STD-ES-04-9)
  - Only a brief summary slide will be presented for each Section of the Topical Report (which follows the structure of the NRC SRP)
  - Additional discussion only if specific questions or disagreements are voiced

Preliminary IRIS Safety Analyses (WCAP-16082 Section 2, STD-ES-04-09)

Safety Analysis Overview

- **Objective of IRIS Preliminary Safety Analysis**
  - Verify the applicability of PWRs Chapter 15 events to IRIS.
  - Confirm the adequacy of IRIS safety concept in mitigating the consequences of Chapter 15 events.
  - Identify those events for which IRIS response is, from a phenomenological point of view, significantly different from other PWRs (i.e. small break LOCA, Steam Generator Tube Rupture).
  - For these events, develop a Phenomena Identification and Ranking Table and identify the requirements for the testing program.

SRP Section 15.1
Increase in Heat Removal from the Primary System

- **Conclusions/Summary**
  - IRIS features that influence the evolution of the events in this category are:
    - » **Increased RCS inventory,**
    - » **Small Inventory of Once Through Steam Generators,**
    - » **Main Steam System Design (i.e. no Safety Valves).**
  - No quantitative analysis is presented in WCAP-16082. The events in this category are expected to have milder consequences, while not presenting significant phenomenological differences from other PWRs.

SRP Section 15.2
Decrease in Heat Removal by the Secondary System

- **Conclusions/Summary**
  - Main IRIS features that influence the evolution of the events in this category are:
    - » **Large Pressurizer Steam Volume,**
    - » **Once Through Steam Generators with small inventory,**
    - » **EHRS design (1-out-of-4 trains sufficient for decay heat removal and plant cooldown),**
    - » **Large RCS inventory.**
  - Quantitative, albeit preliminary, analyses were performed for the main events in this category. Significant differences from current PWRs are expected in the transient evolution. However, these events are similar to current PWRs from a phenomenological point of view.

SPR Section 15.3
Decrease in Reactor Coolant Flow Rate

- **Conclusions/Summary**
  - Main IRIS features that influence the evolution of the events in this category are:
    - » **Number of reactor coolant pumps,**
    - » **Internal pumps inertia.**
  - No significant phenomenological differences from other PWRs.
  - Need development of improved low flow DNB correlations if additional margin is desired.

SRP Section 15.4
Reactivity and Power Distribution Anomalies

- **Conclusions/Summary**
  - IRIS reactor core similar to other Westinghouse PWRs. No phenomenological difference expected, and thus the same evaluation models will be used.
  - No analysis presented at this stage.
  - The rod ejection accident is eliminated by the adoption of internal control rod drive mechanisms.
  - Other events are the same as those included in Westinghouse SARs.

SRP Section 15.5
Increase in Reactor Coolant Inventory

- **Conclusions/Summary**
  - The main IRIS feature that influences the evolution of the events in this category is:
    - » **No High Pressure Injection System for LOCA mitigation**
  - Because of the IRIS LOCA Mitigation Approach, these events will have very mild consequences, and are not considered important for this stage of the investigation.

SRP Section 15.1 to 15.5
Conclusion

- **For the considered events the IRIS response is similar or identical to other PWRs from a phenomenological point of view. Thus, Westinghouse evaluation models for PWRs can be adopted with minor modifications. Development and Qualification effort can be minimized, with focus only on some IRIS specific features.**

SRP Section 15.6
Decrease in Reactor Coolant Inventory

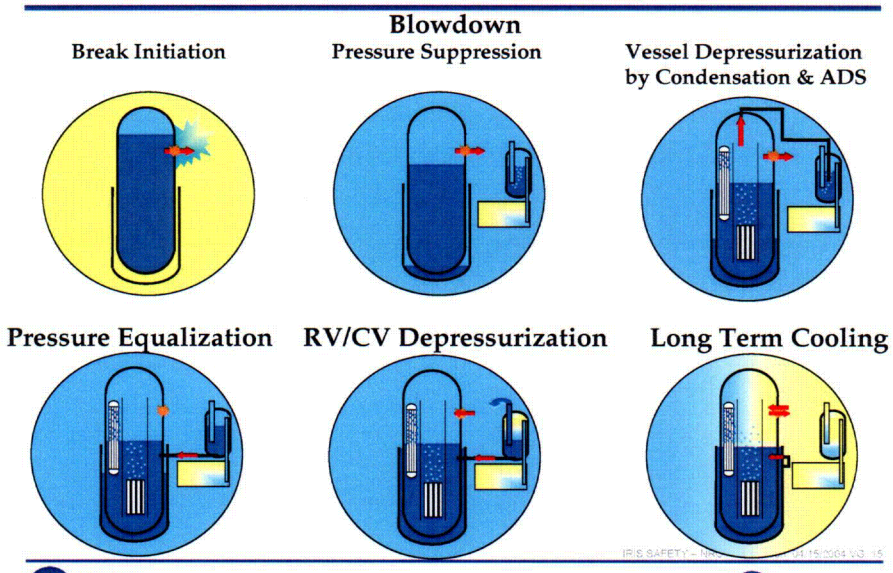
- Anticipated transients in this category are expected to be very similar to other Westinghouse PWRs.
- Accidents in this category (Loss of Coolant Accidents and Steam Generator Tube Rupture) present significant differences from other PWRs, and thus emphasis is placed on these events for the IRIS Pre-Application.

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, Overview -

- SBLOCA Analysis
  - Perform preliminary analysis to understand and characterize the system
  - Develop a PIRT, supported by scaling analysis, to identify important phenomena and thus requirements for the analysis tools and for the testing program
  - Select Codes, complete assessment database, define evaluation models

(This approach is consistent with the NRC EMDAP (DG-1120) procedure and is based on the CSAU development for BE LOCA)

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, Overview of SBLOCA Sequence -



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SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, Overview of SBLOCA Sequence -

- SBLOCA Sequence of Events and Mitigation
  - **Blowdown:** Reactor Vessel depressurizes and loses mass to the containment. Containment pressure rises.

    Mitigation sequence is initiated with Rx trip and RCP trip. EBT actuated to provide boration. EHRS actuated to depressurize primary system by condensing steam on the Steam Generators (depressurization without loss of mass). ADS actuated to assist the EHRS in depressurizing the system.

    Containment pressure limited by Pressure Suppression System and EHRS.
  - **Pressure Equalization:** RV and CV pressure become equal (CV pressure peak <8 bar_g), break flow stops, gravity makeup of borated water from suppression pool becomes available.
  - **Containment and RV depressurization:** the coupled CV-RV system is depressurized by the EHRS (steam condensation inside the RV exceeds decay heat boiloff), break flow reverses reducing containment pressure, a portion of suppression pool water is pushed out and assists in flooding the containment cavity.
  - **Long Term Cooling:** RV and CV pressure reduced to <2 bar_g in <12 hours, gravity makeup of borated water from both suppression pool and RV cavity available as required. Long term break flow limited to containment heat loss.

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C04

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, Analysis Conclusions and Follow-up -

- A preliminary assessment of the IRIS reactor SBLOCA response has been completed (WCAP-16082, Volume II)
- The results will be used to support development of:
  - PIRT for IRIS SBLOCA,
  - IRIS testing program, and
  - IRIS evaluation model for SBLOCA Analyses
- The results initially confirm that the IRIS safety by design approach and simplified passive systems are effective in maintaining the core covered for IRIS design basis LOCAs
- Some areas of design optimization (location of SG shroud check valves, ADS layout, Protection System Logic) were identified and are under considerations

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, Additional Analyses -

Additional SBLOCA sensitivity studies are being performed to support the PIRT development:

#1 – Sensitivity to EHRS performance
#2 – Sensitivity to Containment Pressure
#3 – Sensitivity to Suppression Pool Performance
#4 – Sensitivity to ADS performance
#5 – Sensitivity to Initial Conditions
#6 – Sensitivity to Stored Energy and Decay Heat
#7 - Sensitivity to Break Size, Location, Critical Flow Model

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SBLOCA, PIRT Program and Panel -

- **PIRT Development program initiated. Final Report due June 15, 2004**

- **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)**

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SGTR, Overview -

- **Conclusions/Summary**
  - Analysis Documented in STD-ES-04-09. Will be included in WCAP-16082.
  - Main IRIS Features in SGTR Transient Evolution are:
    - » **No steam generator safety and relief valves,**
    - » **Steam lines designed for full reactor coolant system design pressure** (loss of primary inventory terminated by a steamline isolation signal from low pressurizer pressure),
    - » **Reduced Once through Steam Generator Inventory** (Once isolated, reactor coolant system fluid will fill the faulted steam generators pair, without this having a large impact on the reactor coolant system inventory),
    - » **Increased reactor coolant system inventory.**
  - Sensitivity analyses confirm that the number of tubes assumed to fail has limited effect on the system response and does not impact the final plant state.

SRP Section 15.6
Decrease in Reactor Coolant System Inventory
- SGTR, PIRT -

- While the analyses of the SGTR show significant differences from PWRs, the sequence is benign and does not present significant phenomenological concerns
- A PIRT for the SGTR will be developed together with the PIRT for the other transient events, but it is not considered as critical an item as the SBLOCA PIRT

Preliminary IRIS Safety Analyses

CONCLUSIONS

CONCLUSIONS

WCAP-16082 Volumes I & II, STD-ES-04-09, should provide:

- Sufficient information on IRIS safety systems design and safety analyses to support NRC review of IRIS testing plan;
- Sufficient information on IRIS safety analyses to allow the NRC to provide feedback on whether the events considered in WCAP-16082 constitute a complete and sufficient set for IRIS Chapter 15 Analyses;
- Provide sufficient quantitative and/or qualitative information to focusing the testing program (including PIRT) on SBLOCA events.