EPR Containment Design

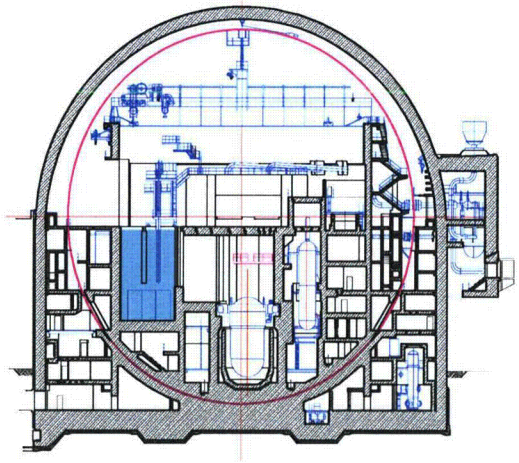
Marty Parece
Manager, Technical Integration
New Plants Deployment

EPR Development
Containment System Requirements

- > Maintain peak pressure from all postulated DBAs below the design limit
- > Limit radiological effects to the public due to leakage during LOCA and severe accidents
- > Ensure design pressure is not exceeded during severe accidents for 12 hours without active cooling
- > Protect SSCs inside containment from external hazards
- > Control concentration of combustible gases during DBAs and severe accident

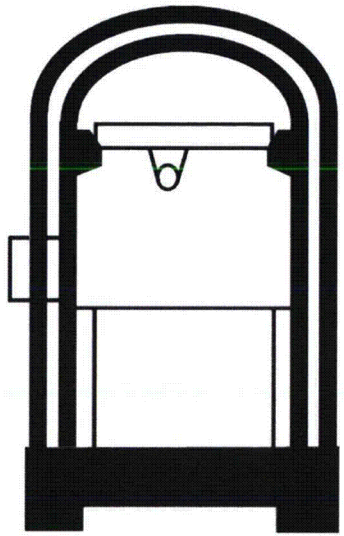
Containment Options
General

KONVOI



- Steel containment
- No fan coolers
- No sprays
- Military aircraft protection
- Spent fuel storage inside

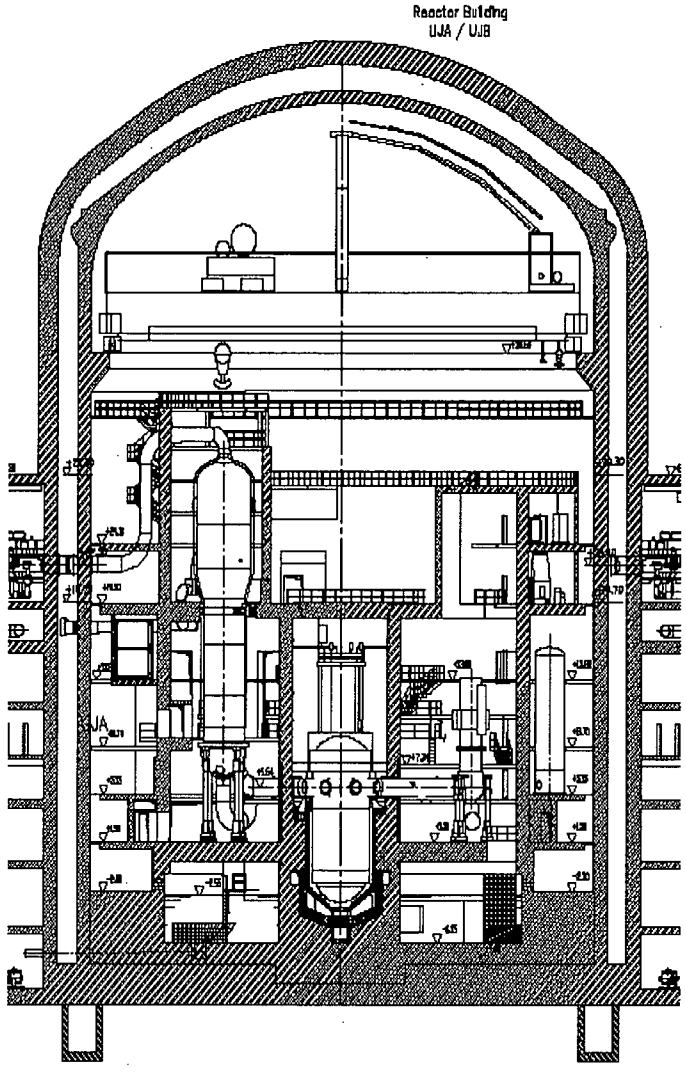
N4



- Double concrete containment
- No liner
- No fan coolers
- Sprays
- Protection from gen. aviation

EPR Reactor Building

- Containment wall post-tensioned concrete with steel liner
- Shield wall reinforced concrete
- Free volume = 2.8 Mft^3
- Design pressure = 62 psig
- Annulus filtered to reduce radioisotope release
- In-containment refueling water storage tank (~500,000 gal)
- Severe accident mitigation features
- Design leak-rate at design pressure is less than 0.25% by volume (U.S. EPR)
- No fan coolers – non-safety HVAC controls equipment space < 130 F and service spaces < 86 F during operation
- Non-safety spray as part of severe accident heat removal system



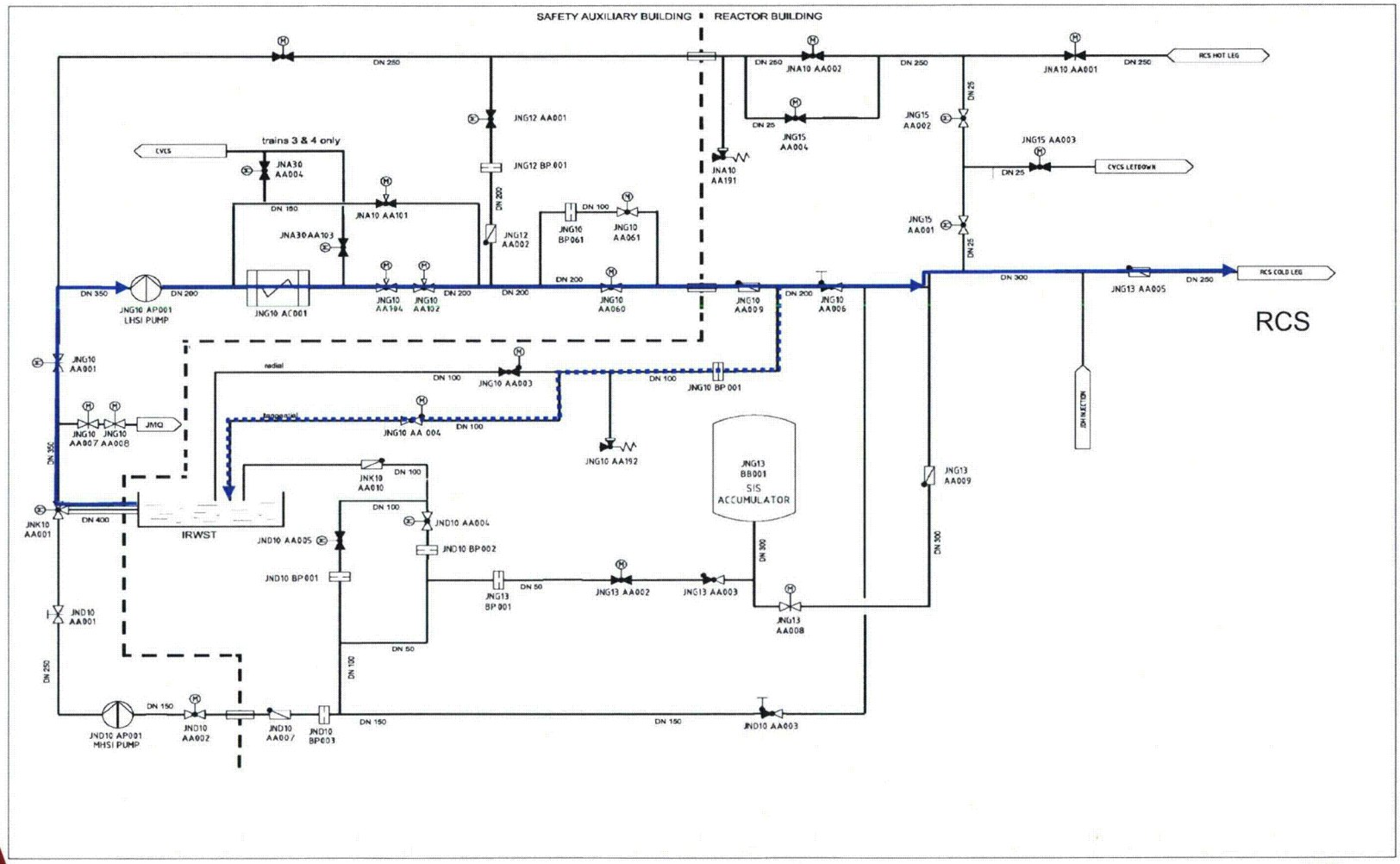
Containment System Response
LOCA

- Break opening allows RCS inventory to blow down to containment
  - Foils on SG compartments rupture and dampers on RCP cubicles open, creating a "one-room" containment and fill the building with vapor
  - Condensation begins on steel and concrete heat structures
  - Liquid begins to pool on the heavy floor and drain to the IRWST
- Core covered by accumulator injection and LHSI flow
  - Core sensible heat is transported to containment
  - Broken loop LHSI dumps to heavy floor (cold leg breaks)
  - Condensation on heat structures

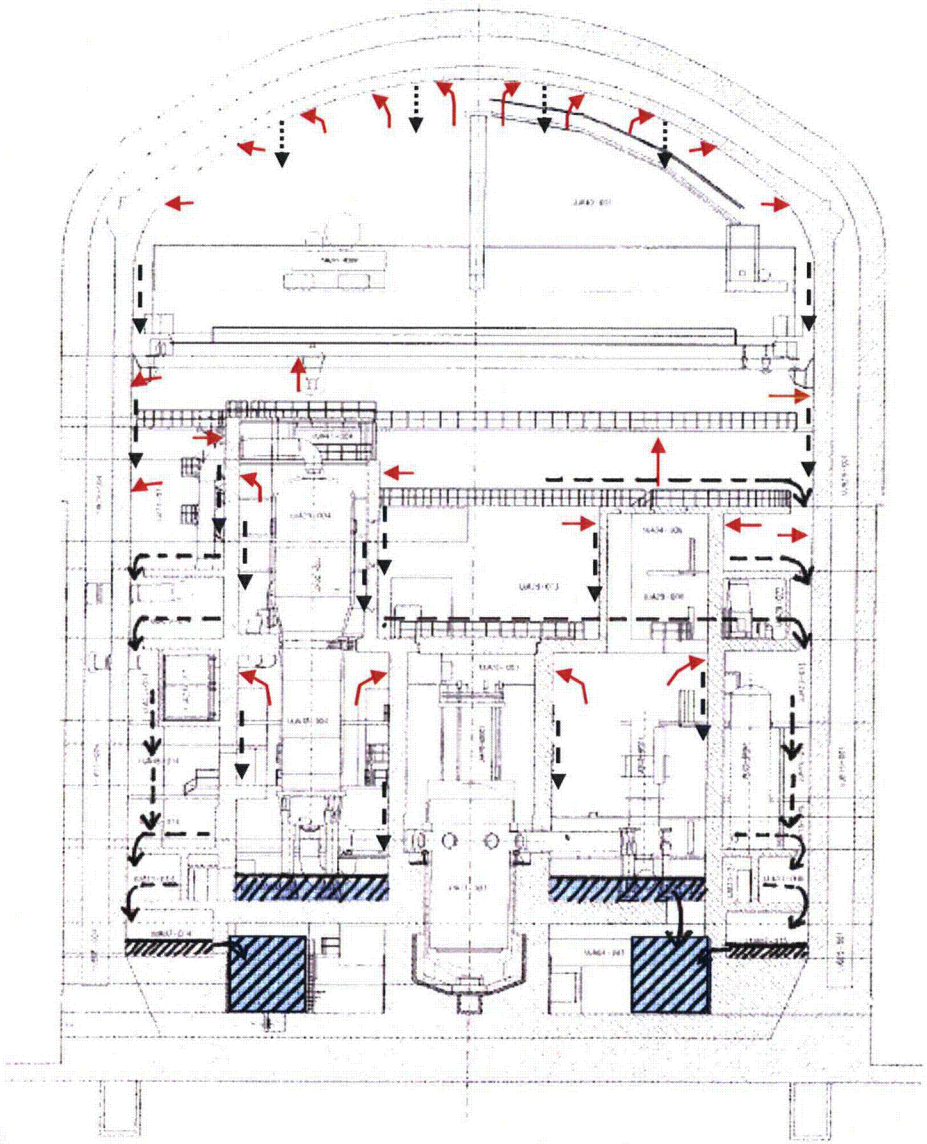
Containment System Response
LOCA

> Post-reflood
- SI to hot leg terminates steaming from the vessel (not explicitly modeled)
- Fully developed recirculation path exists from the IRWST to the RV (through the RHR heat exchangers), out the break onto the heavy floor and through drains back to IRWST
- Excess safety injection spills on the heavy floor
- Water leaving the RV will be cooler than the saturation temperature of containment, promoting condensation (conservatively not credited)

IRWST Circulation

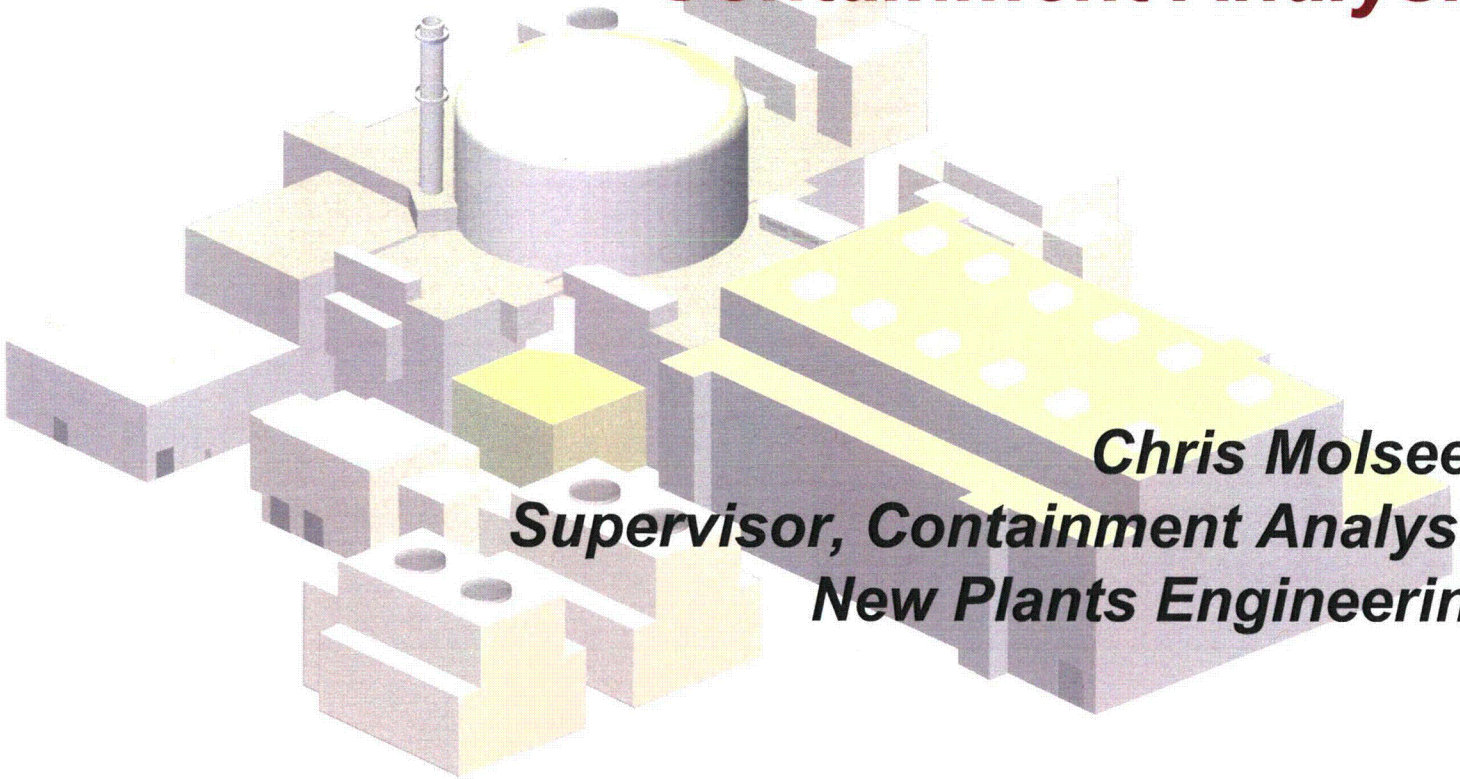


Principle of Circulation



- LOCA pressurizes containment
- Water vapor condenses on cold steel and concrete surfaces
  - Surface area of concrete slabs is ~427,000 sq.ft.
  - Total surface, incl. concrete and steel is ~733,000 sq.ft.
  - Well distributed
- Floor grates and drains designed to direct liquid to IRWST

Containment Analysis



Chris Molseed
Supervisor, Containment Analysis
New Plants Engineering

Overview

- > U.S. EPR containment
  - ◇ Comparison to operating plants
  - ◇ Containment phenomena during a LOCA
- > Mass and energy release
  - ◇ Codes and methods used
  - ◇ Applicability to U.S. EPR
- > Containment response to a LOCA
  - ◇ Results vs. acceptance criteria
  - ◇ Key phenomena
  - ◇ Sensitivity results

U.S. EPR Containment Comparison

	NSSS Vendor	Loops	MWt	Free Volume ($x10^6$ ft^3)	Containment Wall (ft^2)	Floor and Sump (ft^2)	Internal Concrete (ft^2)	Internal Steel (ft^2)	Total Heat Sink surf. area (ft^2)
U.S. EPR (62 psig)	AREVA	4	4590	2.82	98,781	43,861	328,283	262,003	732,928
Seabrook [1] (55 psig)	W	4	3411	2.70	94,562	11,639	110,828	158,217	375,246
St. Lucie [2] (44 psig)	CE	2	2700	2.51	86,700	29,631	72,323	280,023	468,677
TMI [3] (55 psig)	B&W	2	2568	2.00	81,700	17,000	117,800	106,100	322,600

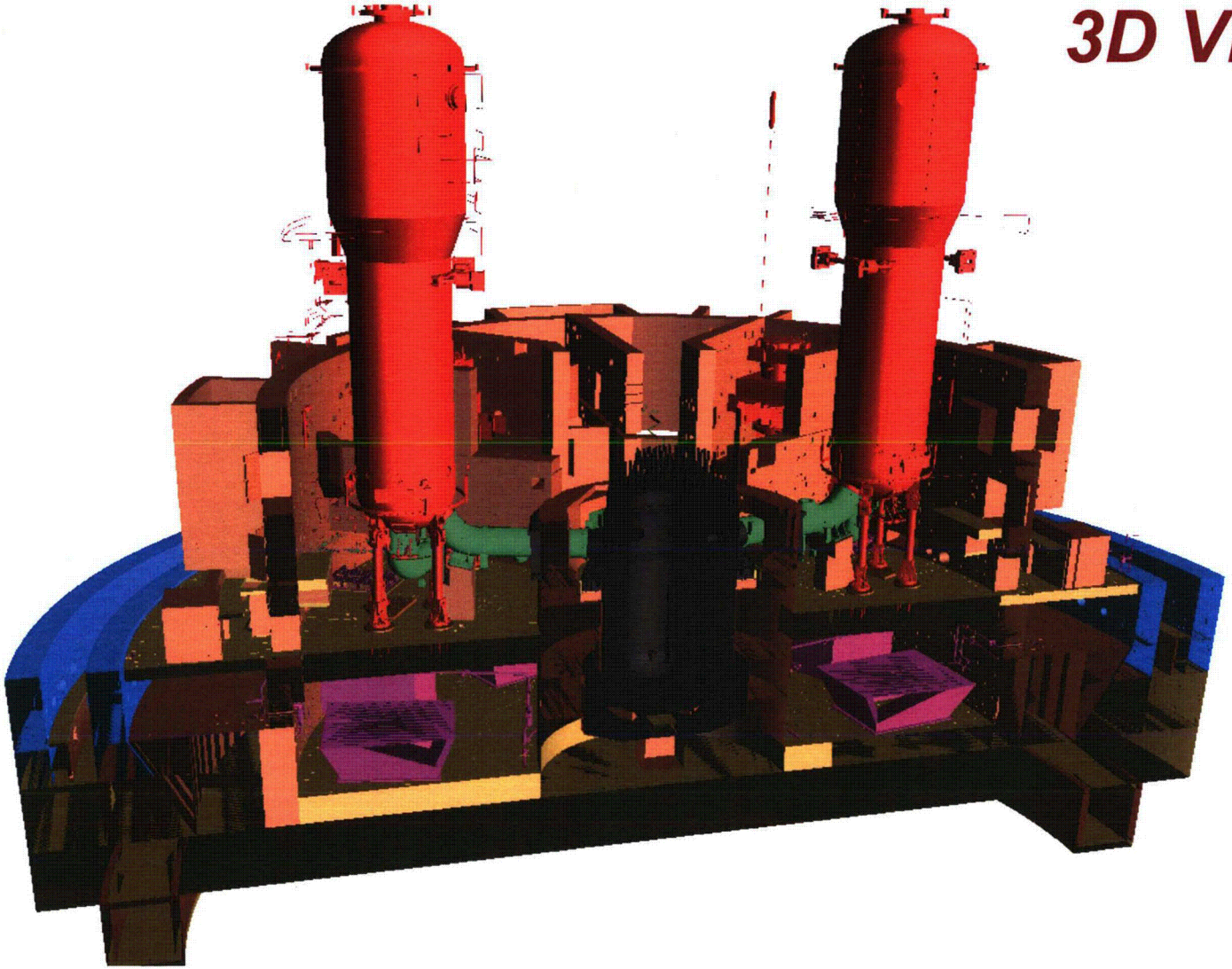
Notes

1. *Seabrook Unit 1 UFSAR Revision 8. Passive heat structures from Table 6.2-3, free volume from Table 6.2-1*
2. *St Lucie Unit 2 USAR Am. 15. Passive heat structures from Table 6.2-8*
3. *TMI USAR Am. 18, Table 6B-6*

U.S. EPR has nearly twice the heat sink surface area of comparable large dry PWR containments.

AREVA

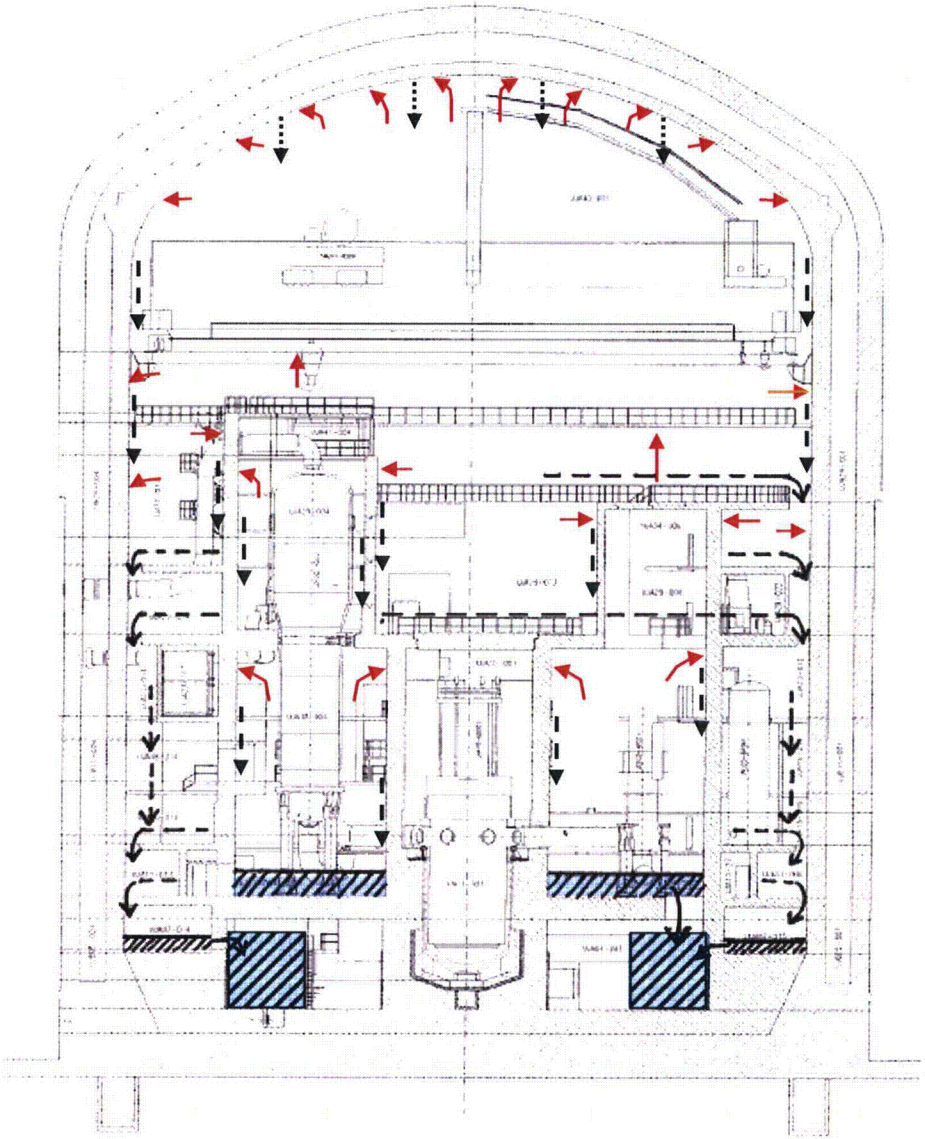
3D View



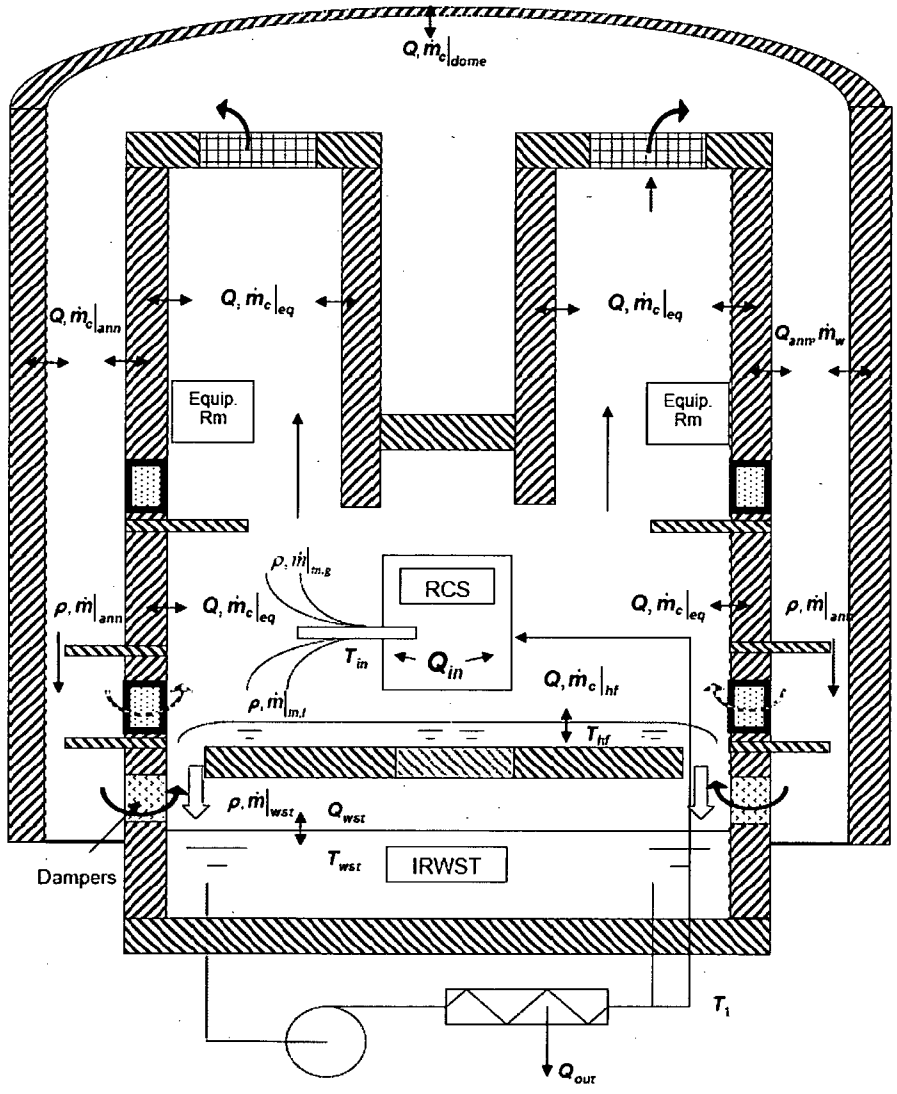
U.S. EPR Arrangement

EPR

Principle of Circulation



Principle of Mass and Heat Transfer Mechanisms



Distributed concrete structures promote condensation and circulation.

Mass and Energy Release Methodology

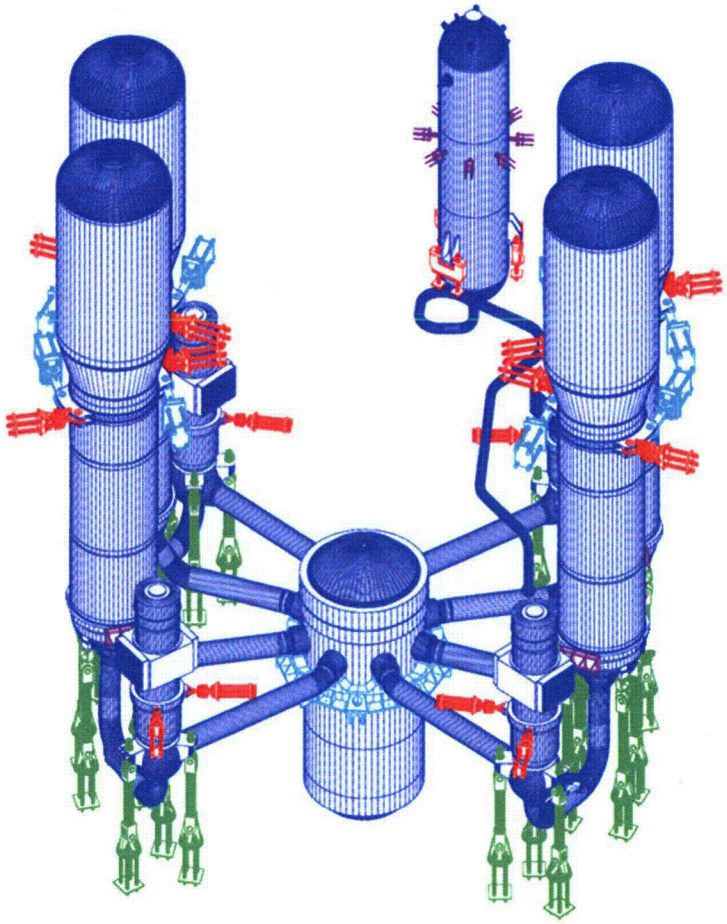
> The mass and energy release methodology outlined in Topical Report BAW-10252(P)(A) is based on approved Appendix K methods utilizing the RELAP5/MOD2-B&W computer code

- BAW 10164(P)(A) – RELAP5/MOD2-B&W – An Advanced Computer Program for Light-Water Reactor LOCA and non-LOCA Transient Analysis
- BAW-10166(P)(A) – BEACH – Best Estimate Analysis Core Heat Transfer, A Computer Program for Reflood Heat Transfer during LOCA
- BAW-10168(P)(A) – BWNT Loss-of-Coolant Accident Evaluation Model for Recirculating Steam Generator Plants

Biasing of key parameters to develop conservative mass and energy release rates discussed in BAW-10252(P)(A).

Bases for Mass and Energy Release Method Applicability

- Conventional 4-loop design proven by decades of design, licensing and operating experience
- Same range of RCS conditions as conventional 4-loop design
- Comparable geometry
- No new phenomena



LOCA Analysis

> Phases of a LOCA
  - Blowdown
  - Refill / reflood
  - Post-reflood
  - Long-term decay heat removal

LOCA Analysis

- > Blowdown phase
  - ◇ Release of liquid and steam from the break
  - ◇ Break liquid exceeds the saturation temperature of the building
  - ◇ Increase in the partial steam pressure
  - ◇ Condensation on heat structures begins
- > Mass and energy release calculated by RELAP5
  - ◇ Maximized core heat transfer modeled
  - ◇ Conservative critical break flow model applied

LOCA Analysis

> Refill/reflood phase

- Reduction in the mass and energy release rates compared to blowdown
- Accumulator injection and safety injection reflood and cover the core
- Energy is removed from the fuel assemblies and transported to containment
- Containment heat structures control the pressure peak

LOCA Analysis

- Refill/reflood phase (continued)
  - Safety injection from the broken loop spills on the heavy floor
  - Condensation on the pool of water on the heavy floor begins
  - Metal heat sinks quickly approach equilibrium with the containment atmosphere
- Mass and energy release calculated by RELAP5
  - Maximized heat transfer from the core modeled to increase energy contribution to the containment
  - Steam quenching and entrainment models benchmarked to FLECHT tests results
  - Short lower plenum refill time controlled by ECCS modeling

LOCA Analysis

> Post-Reflood Phase

- Safety injection to hot leg terminates steaming (not explicitly modeled)
- A fully developed recirculation path exists from the IRWST to the RV (through the RHR heat exchangers) out the break and to the heavy floor
- Excess safety injection spills on to the heavy floor
- Water leaving the RV will be cooler than the saturation temperature of containment

LOCA Analysis

> Long-term mass and energy release

- Transition from RELAP5 to GOTHIC includes a summation of NSSS sensible heat. This sensible heat is removed by the safety injection at a constant rate until the NSSS returns to equilibrium.
- The constituent energy sources remaining at the transition time include:
  - Primary system fluid stored energy
  - Primary system passive metal (including core metal)
  - Secondary system stored energy (fluid and metal)
  - Core decay heat

Containment Analysis Approach

- Containment pressure and temperature were calculated using the approved GOTHIC computer code and methodology
  - BAW-10252(P)(A) - Analysis of Containment Response to Postulate Pipe Ruptures Using Gothic, Revision 00, December 2005
    - Code description
    - Code validation
    - Analysis approach
    - Sample problems
- AREVA's approach complies with conservative regulatory guidance
  - SRP, App. K, ANSI-ANS-564.4-1983
  - Not best-estimate

Approved methods were used for calculating containment pressure and temperature

Bases for Containment Response Method Applicability

- Similar plant configuration
- Similar range of operating conditions
- Comparable geometry
- Phenomenological equivalence to operating PWRs
  - Condensation on heat sinks
  - Liquid draining to a sump
  - Presence of noncondensible gases

Code Applicability

- OECD sponsored SOAR on containment thermal-hydraulics (NEA/CSNI(1999)(16)) presents a PIRT for containment response metrics (pressure, temperature, and composition) for long-term containment response following a LOCA
- Principal phenomena with rank (pressure only)
  - Free convection (condensation/evaporation) - High
  - Structure conduction - High
  - Spray/fans - Medium (N/A for U.S. EPR)
  - Local buoyancy/stratification - Low/Medium
  - Liquid advection (transport only) - Low/Medium

Code Applicability

> GOTHIC models and correlations based on both first principles and empirical derivations

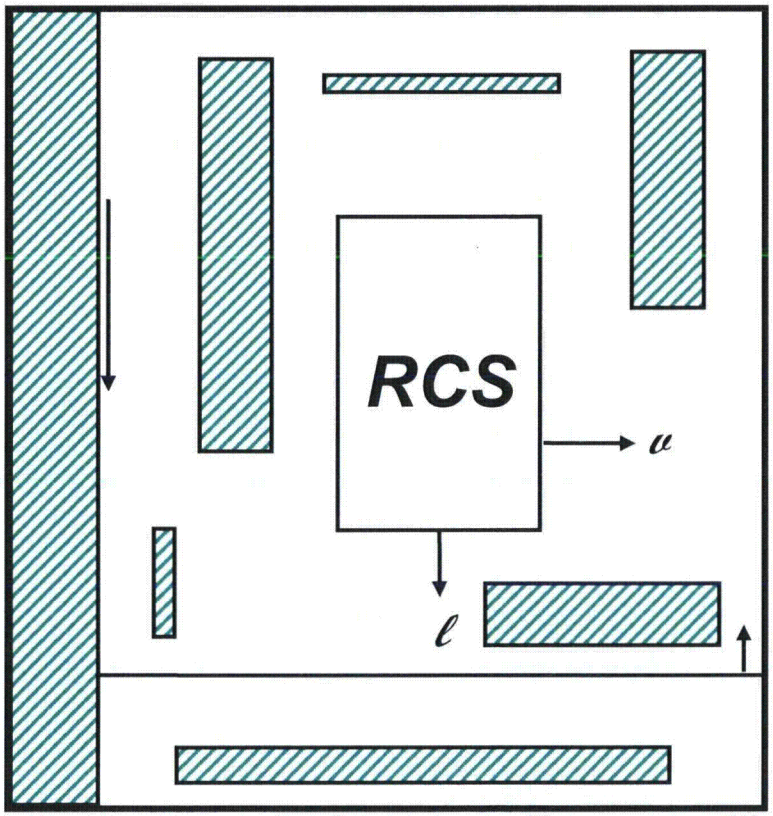
Phenomena	GOTHIC model applied
Condensation/evaporation	Various
Structure conduction	1-D conduction
Spray/fans	N/A
Local buoyancy/stratification	Momentum balance at junctions
Liquid advection	Momentum balance at junctions

Analytical Approach

- Single node GOTHIC model was used with the following important modeling choices consistent with the approved methodology:
  - Following blowdown the droplet model at the break was deactivated and the liquid break flow falls to the IRWST, which eliminates a condensation mechanism
  - Containment free volume was conservatively reduced
  - Containment basemat was not included as a heat sink
  - The interfacial heat transfer between the IRWST and the containment atmosphere was modeled to include condensation/vaporization to/from the IRWST pool surface
  - The heavy floor was modeled as a heat sink

Simplified Nodal Diagram

- 11 heat sinks
- Break location splits phasic break flow
- Liquid/vapor interface controlled by the IRWST surface area

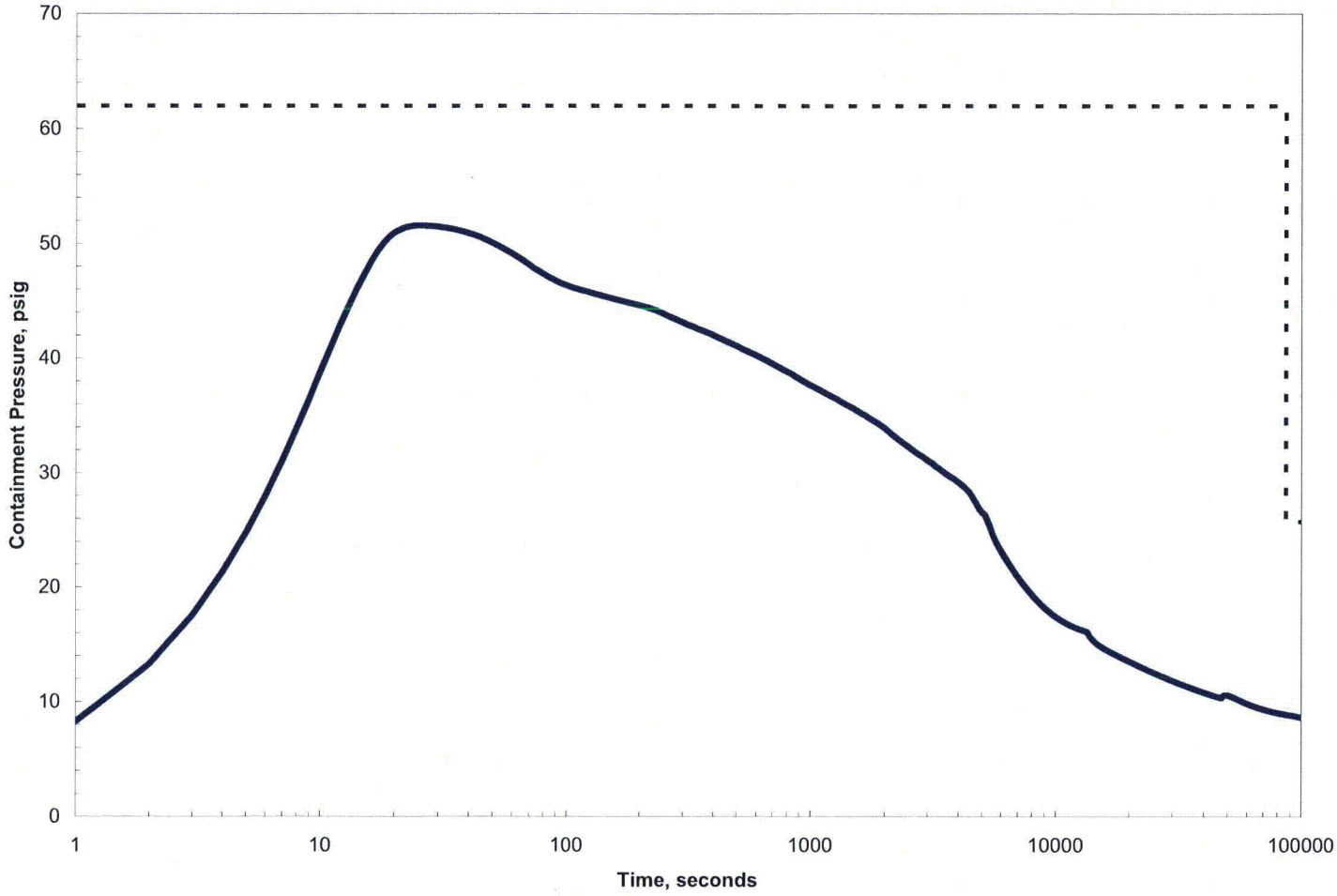


Analytical Results

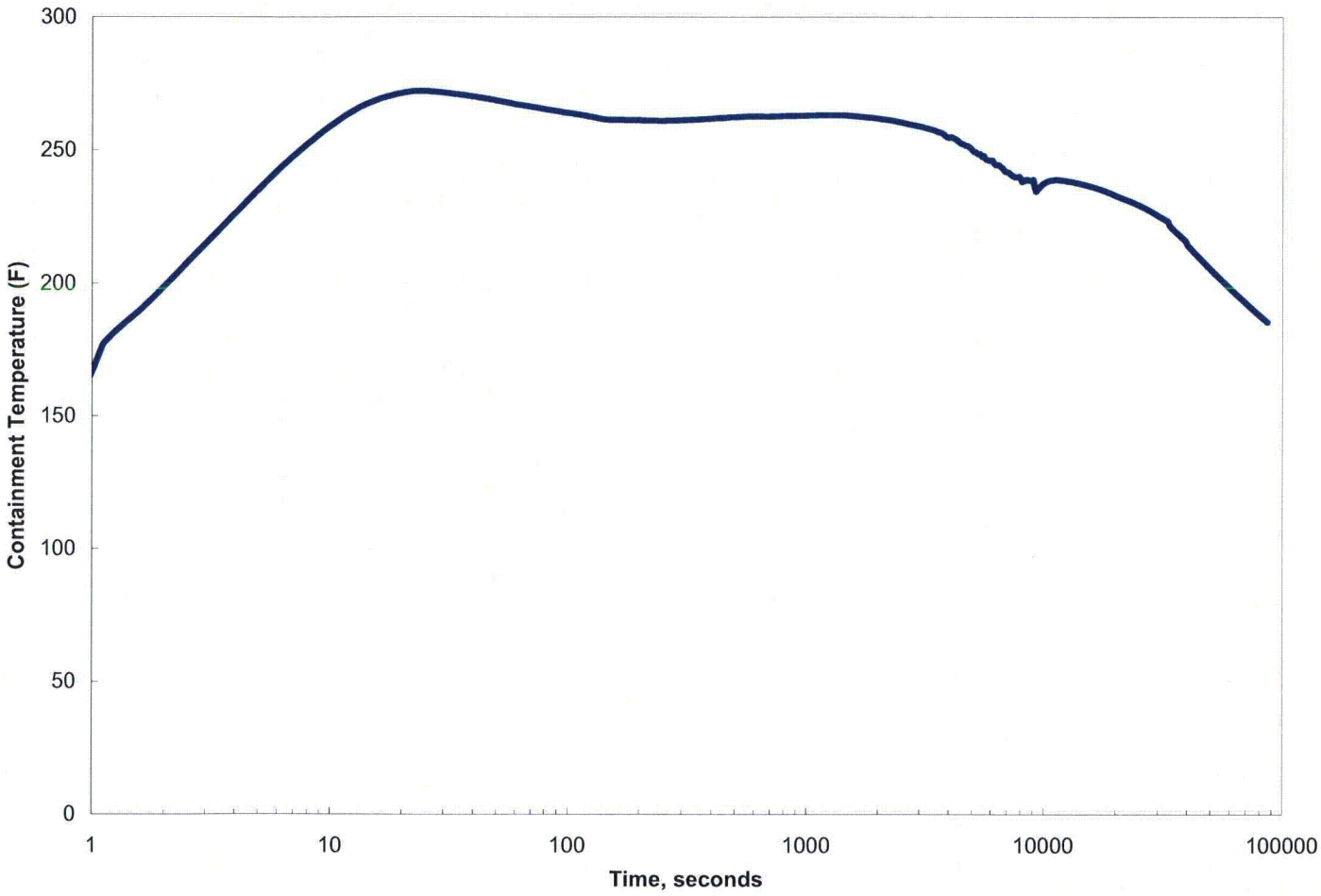
Summary of Containment Results

Break Type	Peak Pressure, psig	Time of Peak Pressure, sec	1/2 of Peak Pressure, psig	Time of ½ Peak Pressure, sec (hrs)
Hot Leg	51.5	26	25.8	5300 (1.47)
Cold Leg Suction	52.1	40	26.1	9400 (2.61)
Cold Leg Discharge	50.7	24	25.4	14200 (3.94)

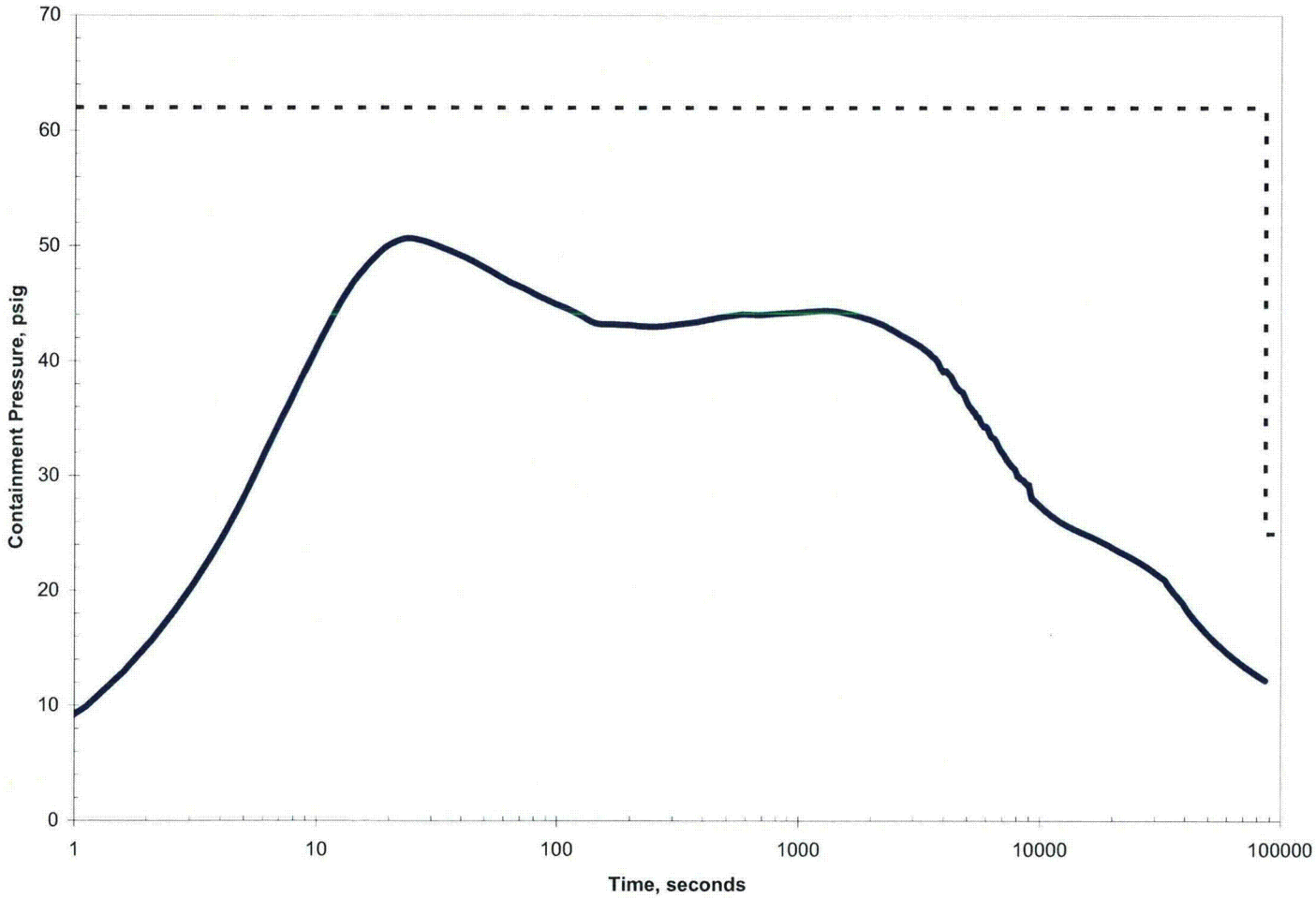
Containment Pressure Response (Hot Leg Break)



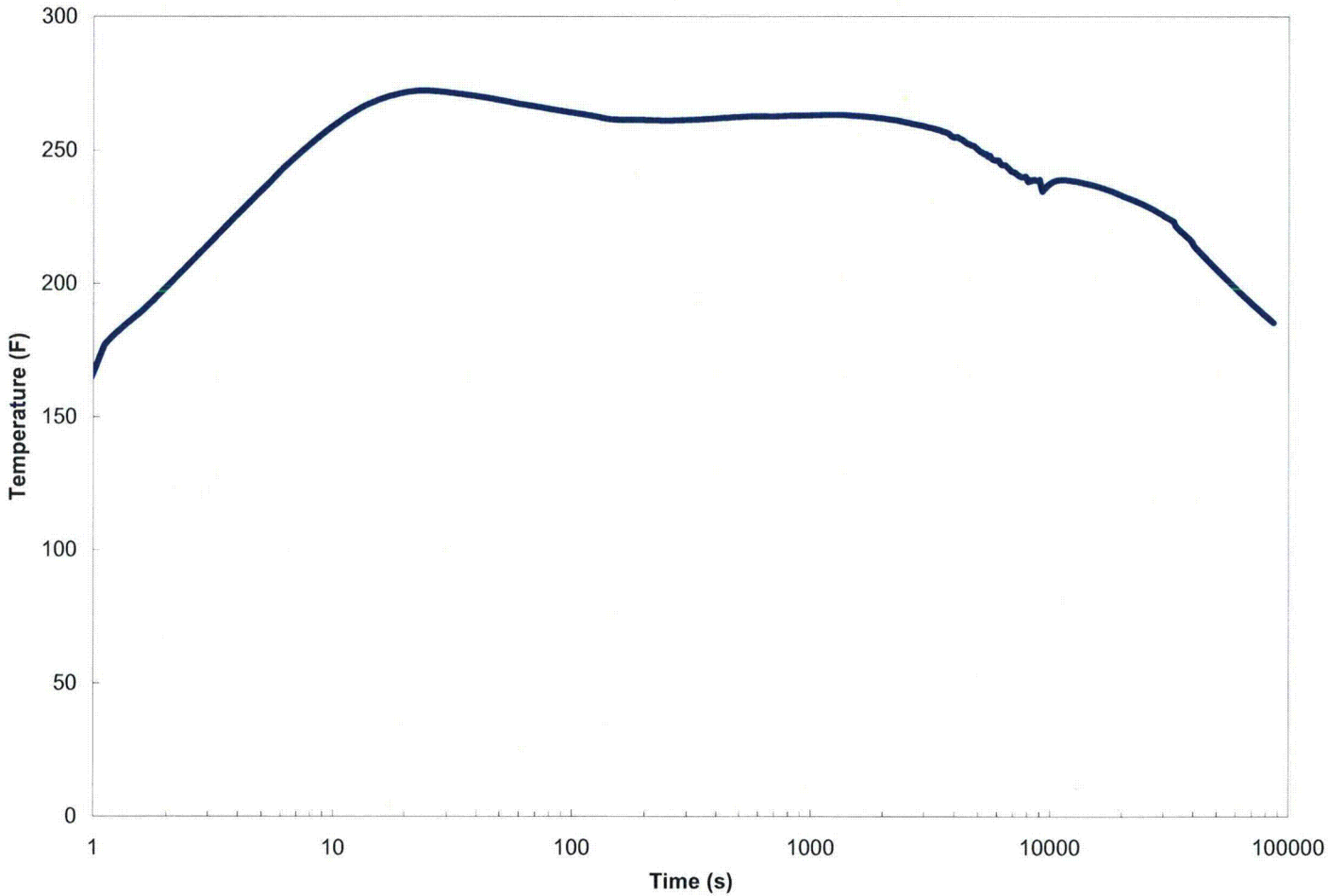
Containment Temperature Response (Hot Leg Break)



Containment Pressure Response (Cold Leg Pump Discharge)



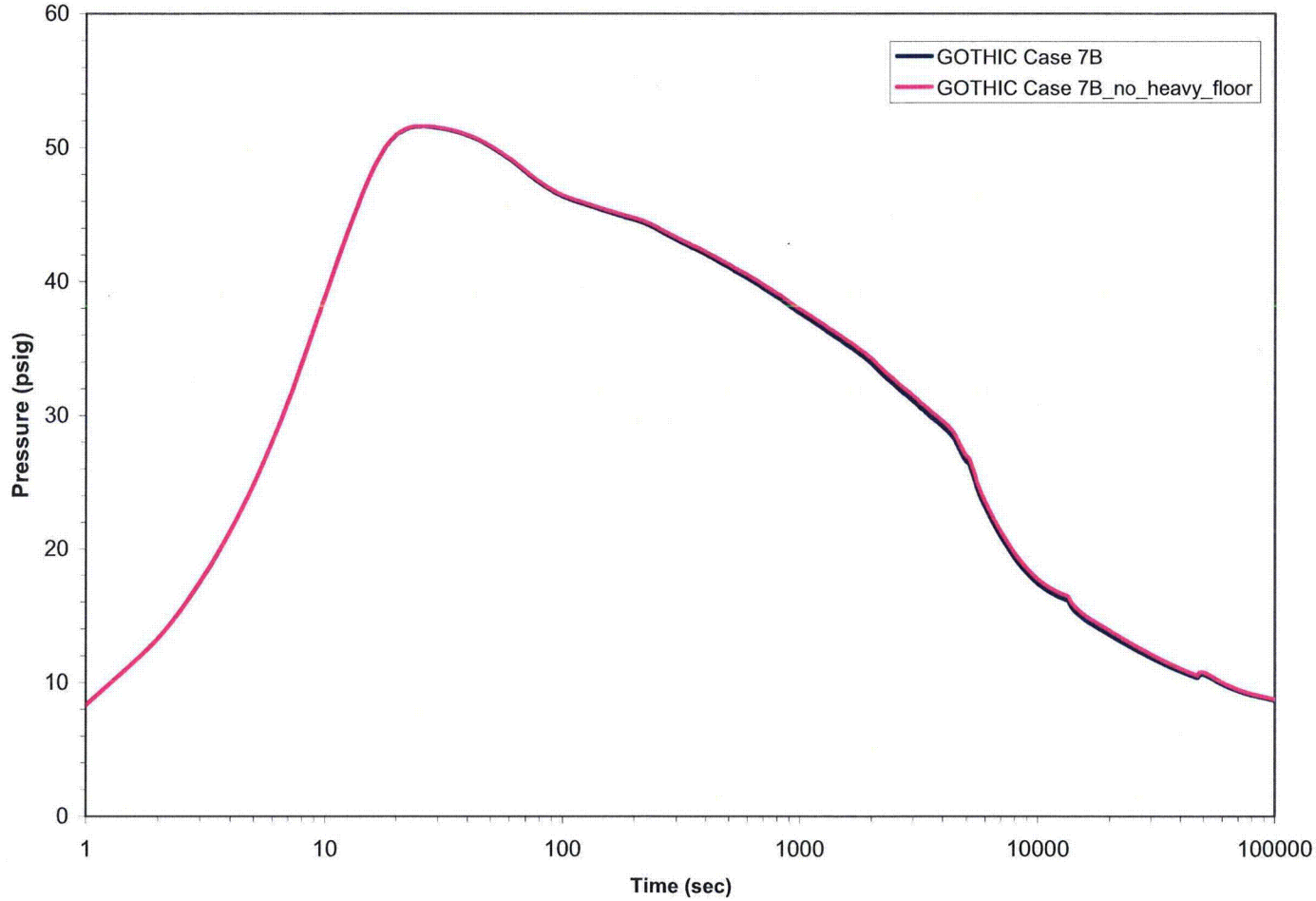
Containment Temperature Response (Cold Leg Pump Discharge)



Heavy Floor Heat Sink Sensitivity

> Only 7600 ft^2 of the heavy floor surface was exposed to containment atmosphere in GOTHIC (~1 % of the total surface area)

Heavy Floor Heat Sink Sensitivity

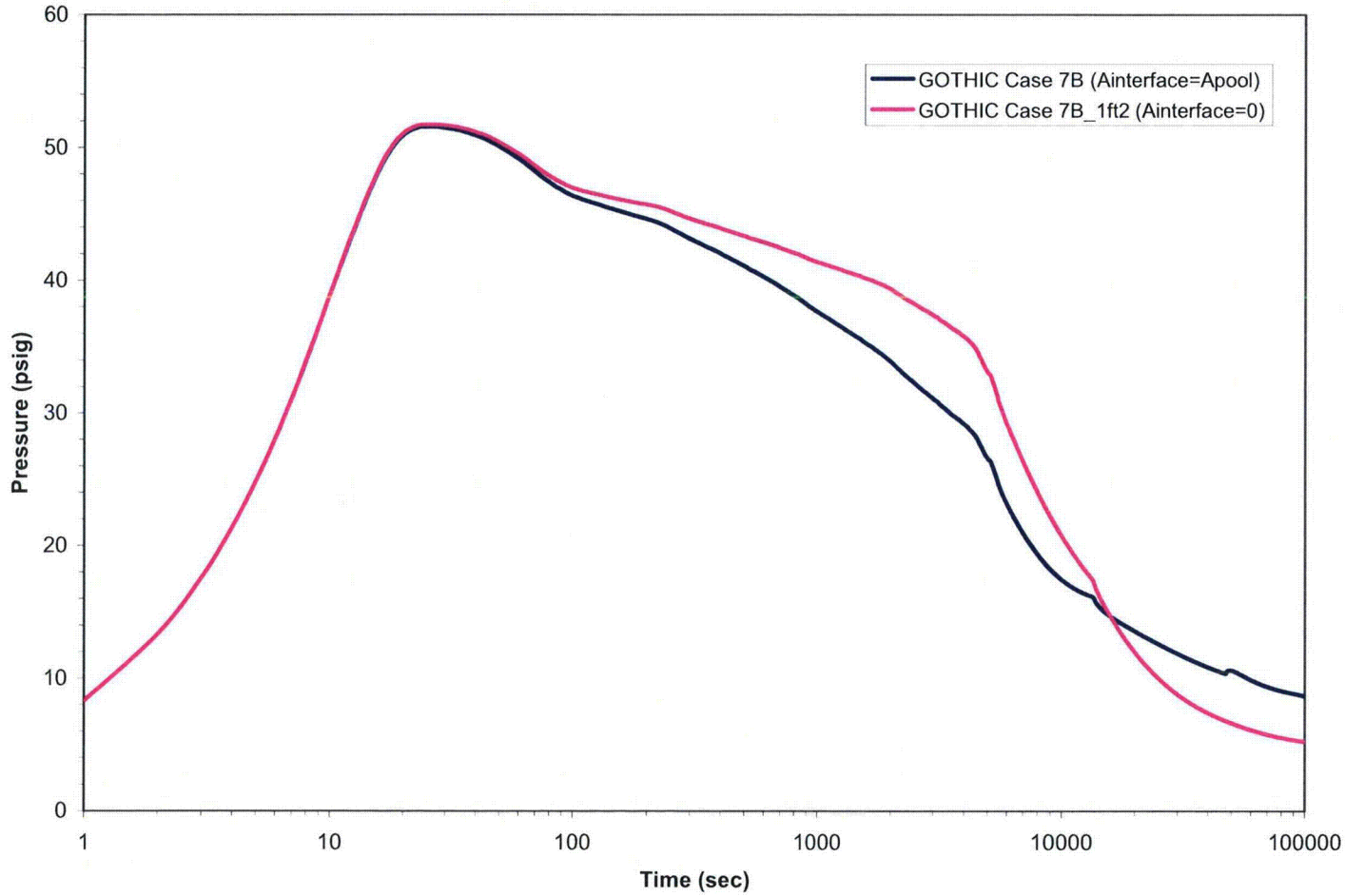


Pool Heat Transfer Sensitivity

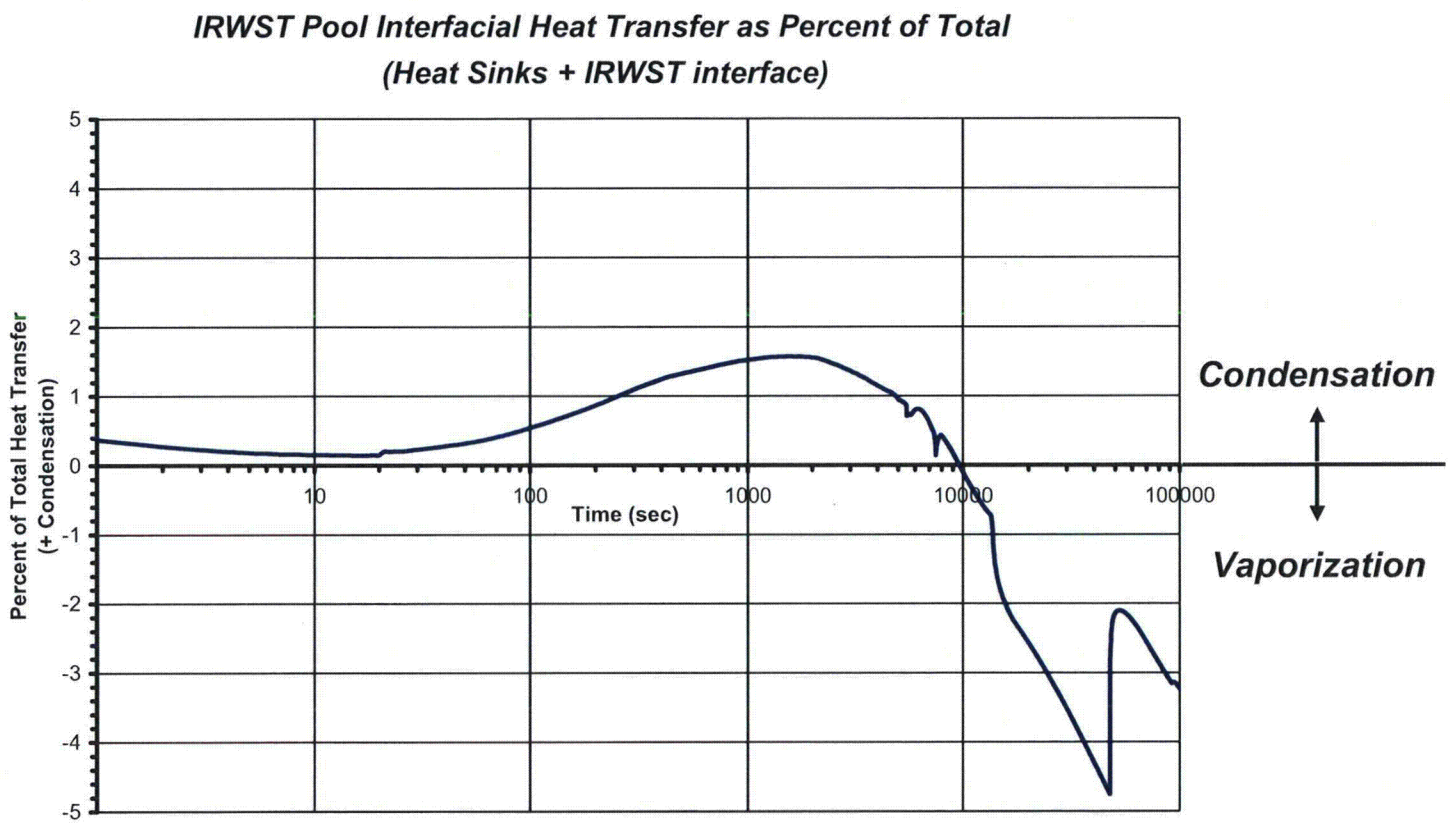
> The FSAR GOTHIC calculation used the actual IRWST pool surface area to model the liquid to vapor interfacial area

> The impact of this heat transfer mechanism was evaluated by setting the interfacial area to near zero

Pool Heat Transfer Sensitivity



Pool Heat Transfer Sensitivity



Interfacial condensation accounts for less than 2% of the total heat transfer

Pool Heat Transfer Sensitivity

- Competing effects were observed in the study
  - Pool condensation occurs early in the event
  - Evaporation occurs later in the event which increases the vapor partial pressure

Volumetric Heat Capacity

> Volumetric heat capacity (VHC) describes the ability of a given volume of a substance to store internal energy while undergoing a given temperature change, but without undergoing a phase change

$V_{concrete} \approx 843{,}000\ ft^3$

$\rho_{concrete} \approx 150\ lbm/ft^3$

$C_{p\ concrete} \approx 0.2298\ BTU/lbm\text{-}F$

$V_{steel} \approx 8{,}000\ ft^3$

$\rho_{steel} \approx 490\ lbm/ft^3$

$C_{p\ steel} \approx 0.1194\ BTU/lbm\text{-}F$

$$VHC = \rho V C_p \approx 2.95 \times 10^7\ BTU/F$$

Hot Leg LOCA Energy Release

- Blowdown energy ≈ 420×10^6 BTU
- At the end of the M&E analysis (~5400 seconds)
  - Integrated break energy = 1.64×10^9 BTU

$$\Delta \bar{T}_{HS} \approx 1.64 \times 10^9 \text{ BTU} / 2.95 \times 10^7 \text{ BTU/F} \approx 55\ ^{o}\text{F}$$

- Vapor temperature at 5400 seconds ≈ 230 °F
- Heat sink temperature at 5400 seconds < 230 °F
  - Equipment rooms ≈ 131 °F + 55 °F ≈ 186 °F
  - Accessible rooms ≈ 86 °F + 55 °F ≈ 141 °F

Heat sinks have not reached equilibrium with the containment atmosphere in 90 minutes

Multi-Node GOTHIC Model Sensitivity Study

> 30 control volumes

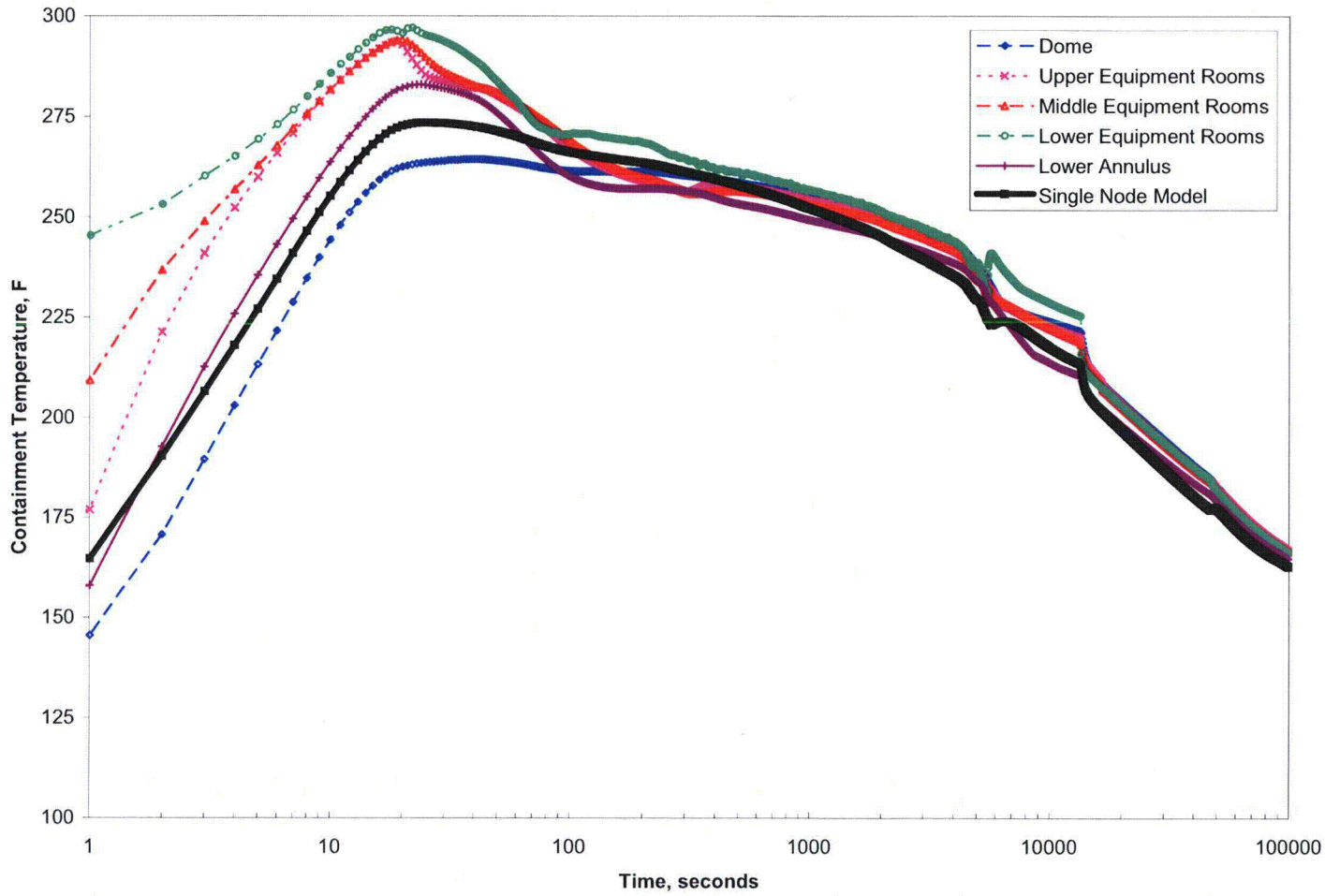
> Control volumes divided based on flow commonality. Junctions modeled at physical locations that would limit flow.

> 123 heat sinks distributed throughout the 30 control volumes

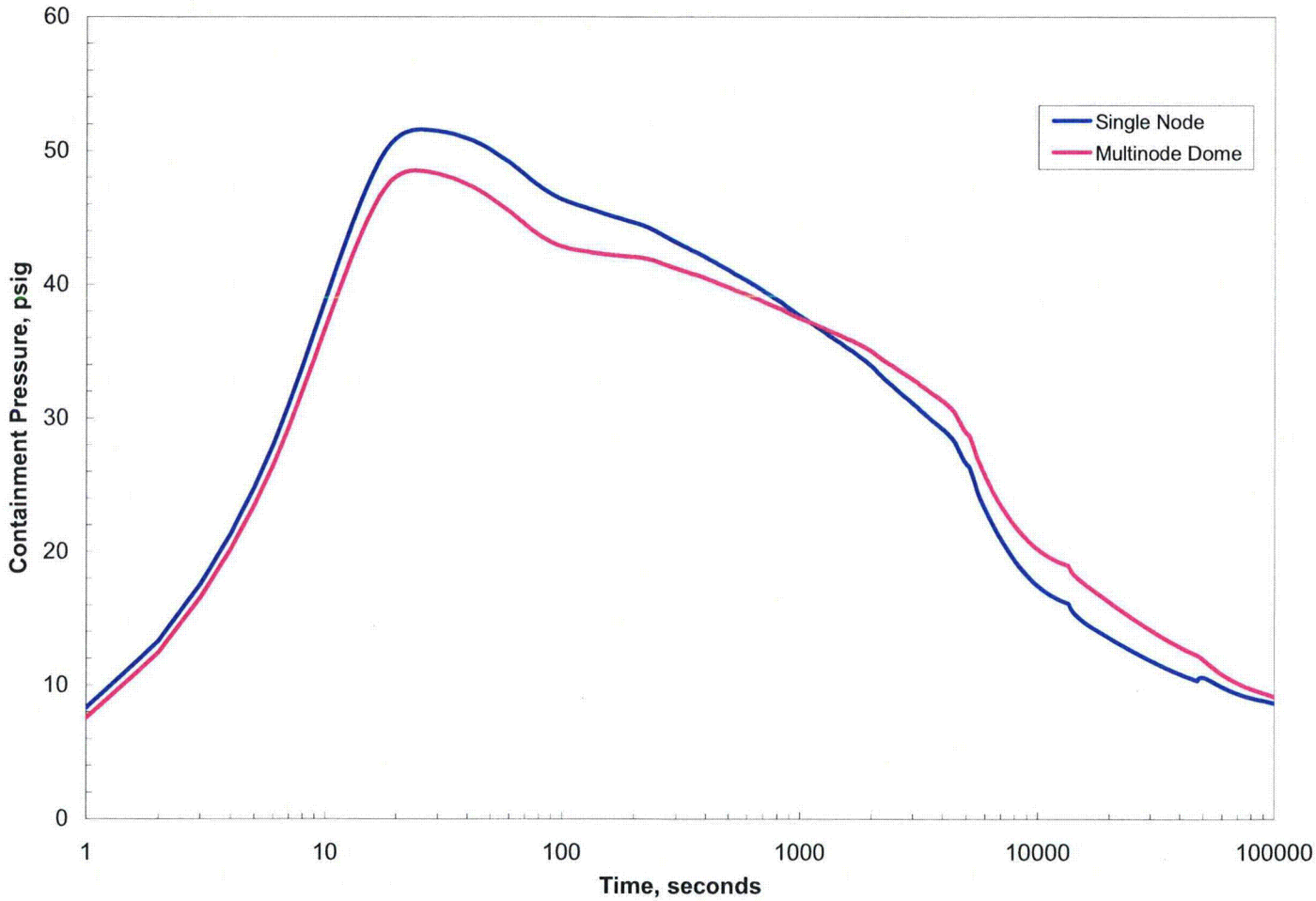
Multi-Node GOTHIC Model Sensitivity Study

> Containment pressure results of the sensitivity runs are comparable to the results from the single node model
  - Distribution of heat sinks promotes condensation on walls and metal structures in every control volume
  - Continued condensation promotes circulation of the air/steam mixture

Multi-Node GOTHIC Model



Multi-Node GOTHIC Model



Summary

- Peak pressure for the U.S. EPR:
  - Meets design limits with margin
  - Mitigated solely via passive heat sinks
- Long-term containment pressure is reduced to less than half the peak pressure in much less than 24 hours due to condensation on the passive containment heat sinks
- Approved methods used to evaluate the pressure and temperature response
- The methods used are applicable for the U.S. EPR because the important phenomena are represented in the analyses and the physical arrangement of the U.S. EPR is comparable to operating PWRs
- Additional sensitivity analyses support the single node model
  - Interfacial heat transfer
  - Heavy floor heat sink
  - Multi-node model

Conclusions

> U.S. EPR containment phenomena essentially the same as for currently operating plants

> Approved evaluation methods are applicable to U.S. EPR containment analysis

> U.S. EPR containment meets acceptance criteria with substantial margin

AREVA

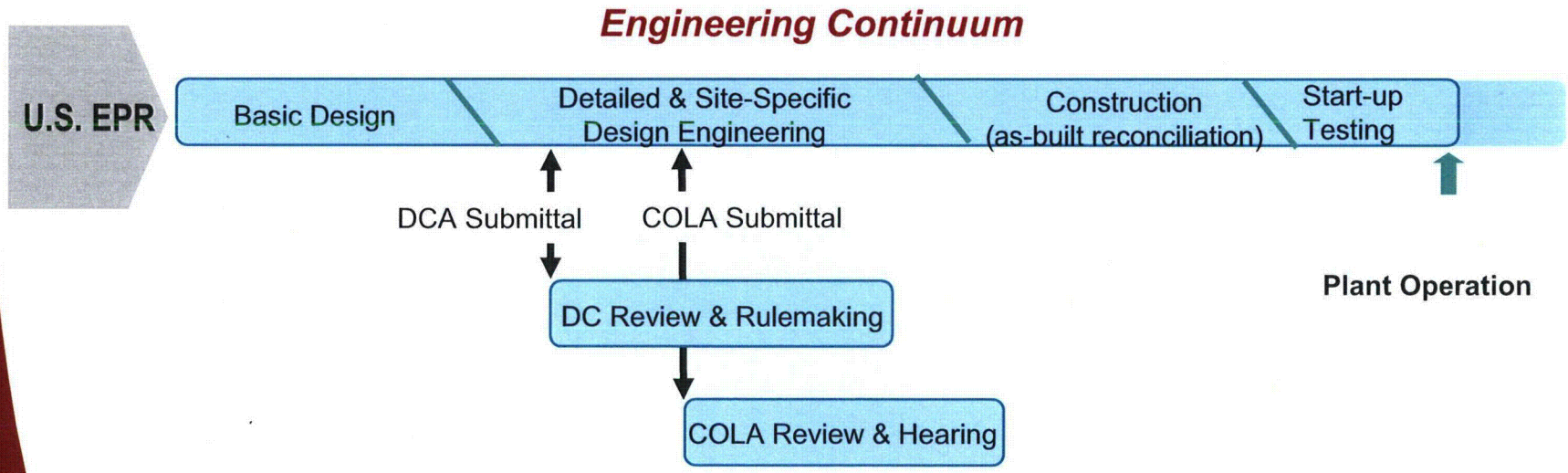
U.S. EPR Design Acceptance Criteria / Design ITAAC

Brian A. McIntyre
Project Manager, U.S. EPR Design Certification
New Plants Deployment

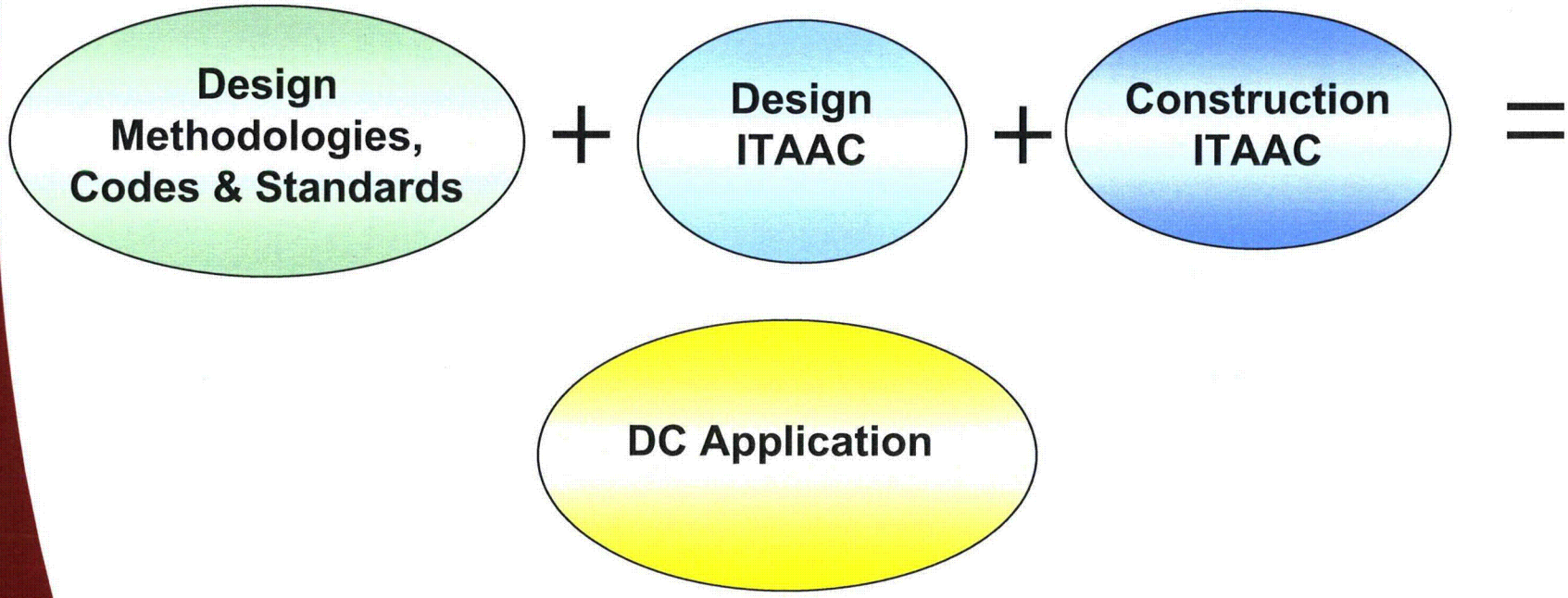
EPR

Design/Engineering/Construction Timeline

NOTE: Conceptual only. Not to scale.



Design ITAAC Concept



U.S. EPR Approach for Design ITAAC

- Advance submittal of related design and analysis methodologies for review and approval
  - Piping Analysis and Pipe Support Design Topical Report
  - I&C Topical Reports
  - Human Factors Engineering Program Topical Report
- Implementation in FSAR
  - Design ITAAC + Construction ITAAC
- Closure of selected design ITAAC during review of FSAR
  - Engineering work complete
  - Closure mechanism dependent on type of design ITAAC
  - Revision of FSAR to delete closed design ITAAC from Tier 1 and supplement design information in Tier 2

Example
Piping ITAAC - Methodology

> **U.S. EPR Piping Analysis and Pipe Support Design Topical Report (ANP-10264NP)**

- **Submitted September 29, 2006**

Example
Piping ITAAC - Process for Closure

> **Design ITAAC**
  - ◇ Completed via analyses
  - ◇ Documented in reports

> **Construction ITAAC**
  - ◇ Completed via inspections
  - ◇ Documented in reports

FSAR Tier 1 Example Piping ITAAC

U.S. EPR FINAL SAFETY ANALYSIS REPORT

Table 2.2.1-5—RCS Inspections, Tests, Analyses, and Acceptance Criteria (6 Sheets)

Design ITAAC

Construction ITAAC

	Design Commitment	Inspection, Test, or Analysis	Acceptance Criteria
3.4a	The piping identified as being within the ASME Code Section III boundary as indicated on Figure 2.2.1-1 has been designed in accordance with ASME Code Section III Requirements including seismic loads.	Analysis of the as-designed piping will be performed in accordance with ASME Code Section III requirements for the piping indicated on Figure 2.2.1-1.	ASME Code Section III stress reports exist and conclude that the as-designed piping identified as ASME Code Section III in Figure 2.2.1-1 meets ASME Code Section III requirements.
3.4b	The piping identified as being within the ASME Code Section III boundary as indicated on Figure 2.2.1-1 has been welded and hydrostatically tested in accordance with ASME Code Section III.	Inspections will be of the as-built piping as indicated on Figure 2.2.1-1 for the following: a. Welding has been performed per ASME Code Section III. b. Hydrostatic testing per ASME Code Section III was performed.	A report exists and concludes that the piping as indicated on Figure 2.2.1-1 as ASME Code Section III has been: a. Welded in accordance with ASME Code Section III welding requirements. b. Hydrostatically tested in accordance with ASME Code Section III requirements.

Abbreviations and Acronyms

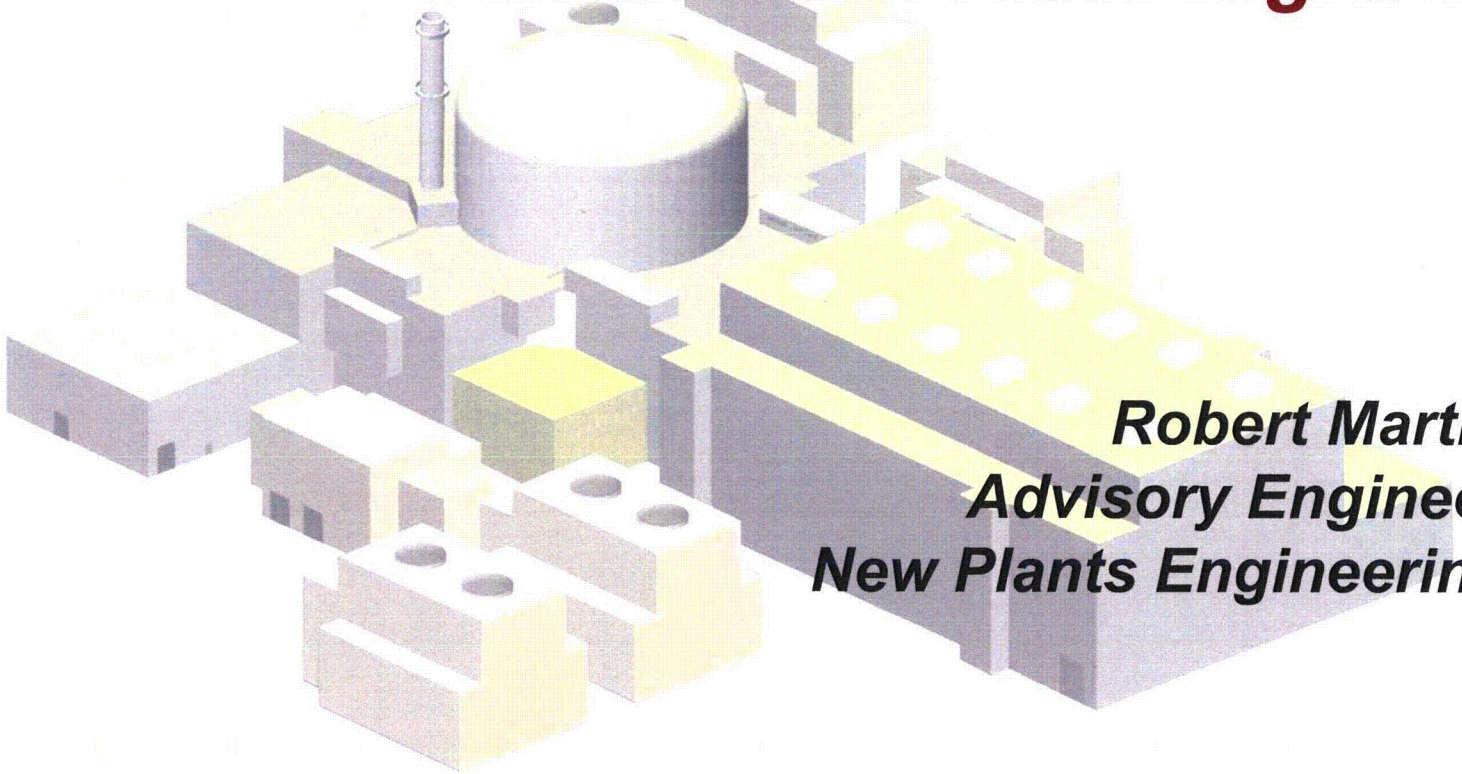
> DBA	Design basis accident
> DCA	Design certification application
> COLA	Combined license application
> ECCS	Emergency core cooling system
> FSAR	Final safety analysis report
> HVAC	Heating, ventilation, and air conditioning
> I&C	Instrumentation and control
> IRWST	In-containment refueling water storage tank
> ITAAC	Inspections, tests, analyses, and acceptance criteria
> LHSI	Low head safety injection
> LOCA	Loss of coolant accident
> M&E	Mass and energy
> NSSS	Nuclear steam supply system
> OECD	Organisation for Economic Co-operation and Development
> PIRT	Phenomena identification and ranking table

Abbreviations and Acronyms (continued)

> PWR	Pressurized water reactor
> RCP	Reactor coolant pump
> RCS	Reactor coolant system
> RHR	Residual heat removal
> RV	Reactor vessel
> SSC	Structures, systems, and components
> SG	Steam generator
> SI	Safety injection
> SOAR	State of the art report

AREVA

Containment Test Programs



Robert Martin
Advisory Engineer
New Plants Engineering

EPR

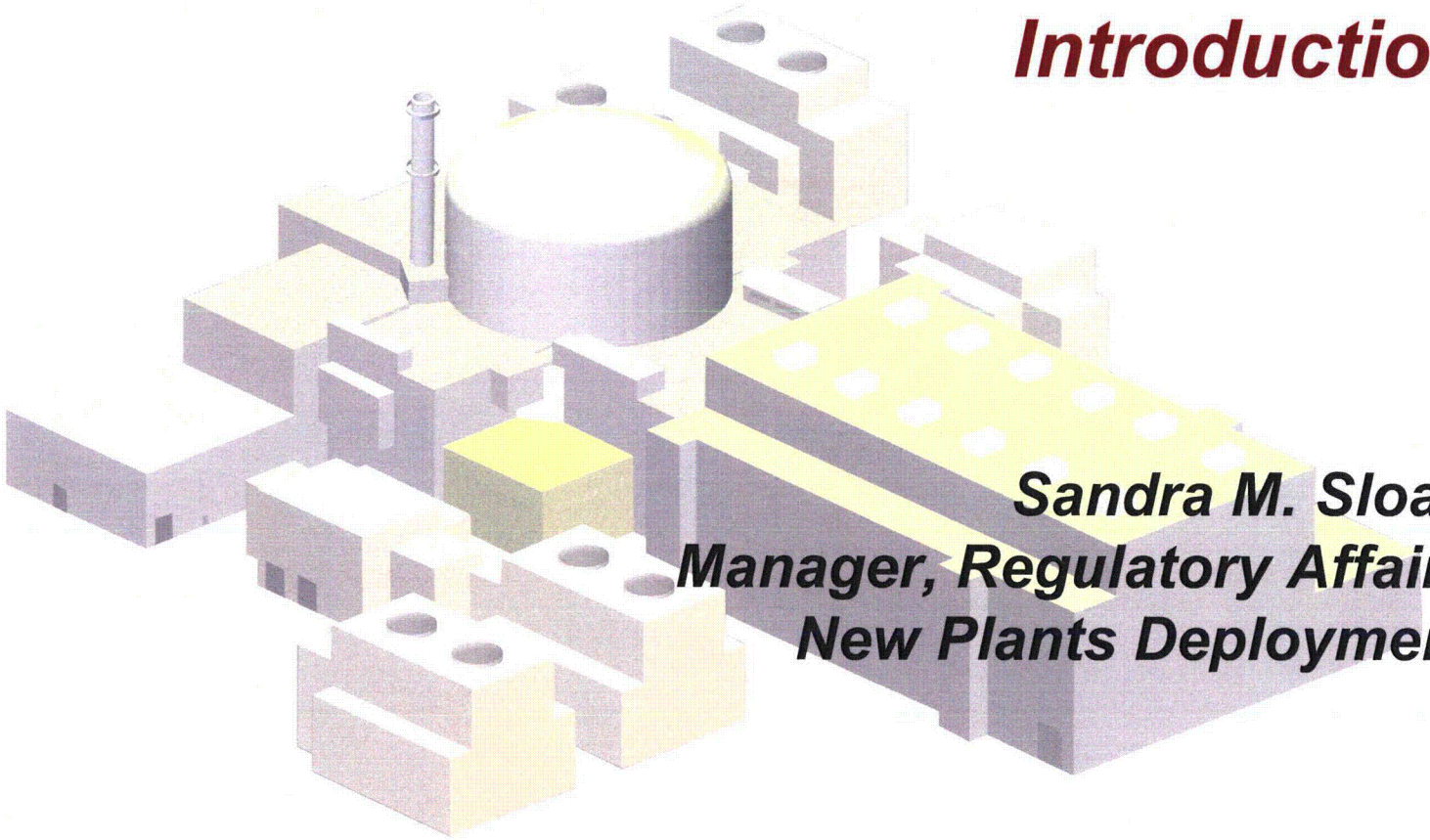
AREVA

NRC Acceptance Review of the U.S. EPR Design Certification Application

AREVA NP and the NRC
January 29, 2008

EPR

AREVA



Introduction

Sandra M. Sloan
Manager, Regulatory Affairs
New Plants Deployment

EPR

Meeting Objectives

> To address questions raised during the NRC acceptance review of the U.S. EPR design certification application

> To present sufficient information on identified topics so that NRC can predictably schedule detailed technical review

Outline

> EPR Containment Design (M. Parece)

> Containment Analysis (C. Molseed)

> U.S. EPR Design Acceptance Criteria / Design ITAAC (B. McIntyre)

Test Program and ISP Lessons-Learned

> **NEA/CSNI(1999)(16) – SOAR on containment TH and NEA/CSNI(2007)(10) – ISP-47 provide a summary of recent containment code/test program developments**

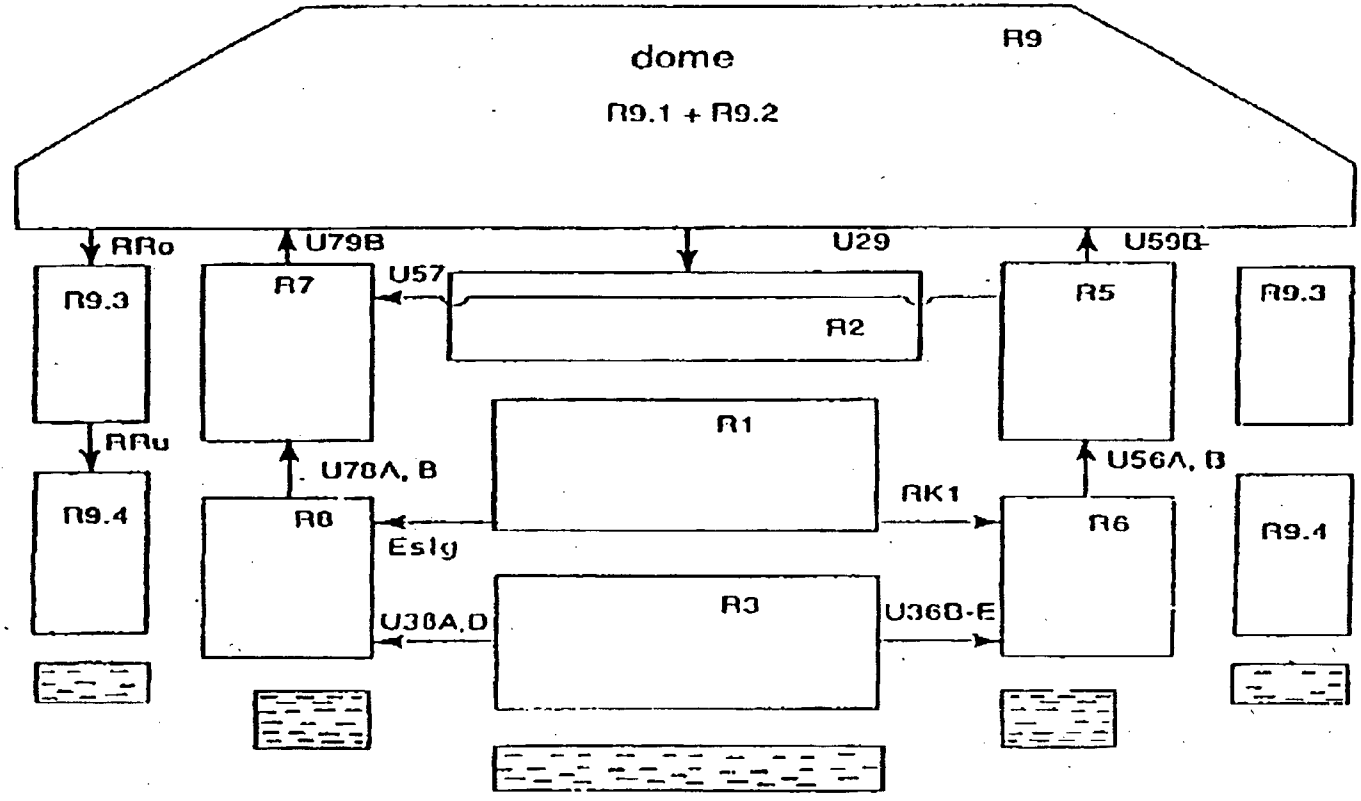
ISP Name	Facility/Experiment	Description
ISP-23	HDR/T31.5	LBLOCA with natural cooldown
ISP-29	HDR/E11.2	SBLOCA, long-term gas distribution, high elevation injection
ISP-35	NUPEC/M-7-1	Gas distribution with containment sprays
ISP-37	BMC/VANAM M3	Gas distribution with aerosol injection
ISP-47	TOSQAN/ThAI/MISTRA	Both separate and integral effects study of dominant containment phenomena (i.e., wall condensation, buoyancy, stratification, and turbulence)

Test Program and ISP Lessons-Learned

- From NEA/CSNI(1999)(16)
  - *"global containment...pressure, is not very sensitive to the degree of simulation error measured for mixture distributions and expected for containment analyses."*
  - *"...stratifications are difficult to introduce when either the injection source is located low in the containment or when engineering safety systems like sprays are operating."*
  - Serious degradation in code ability to predict global pressure trends in the presence of stratification phenomena has not been among the conclusions drawn from these experiments
- From NEA/CSNI(2007)(10)
  - Field code results were not substantially better than results from lump parameter codes employing appropriate user modeling for expected phenomena

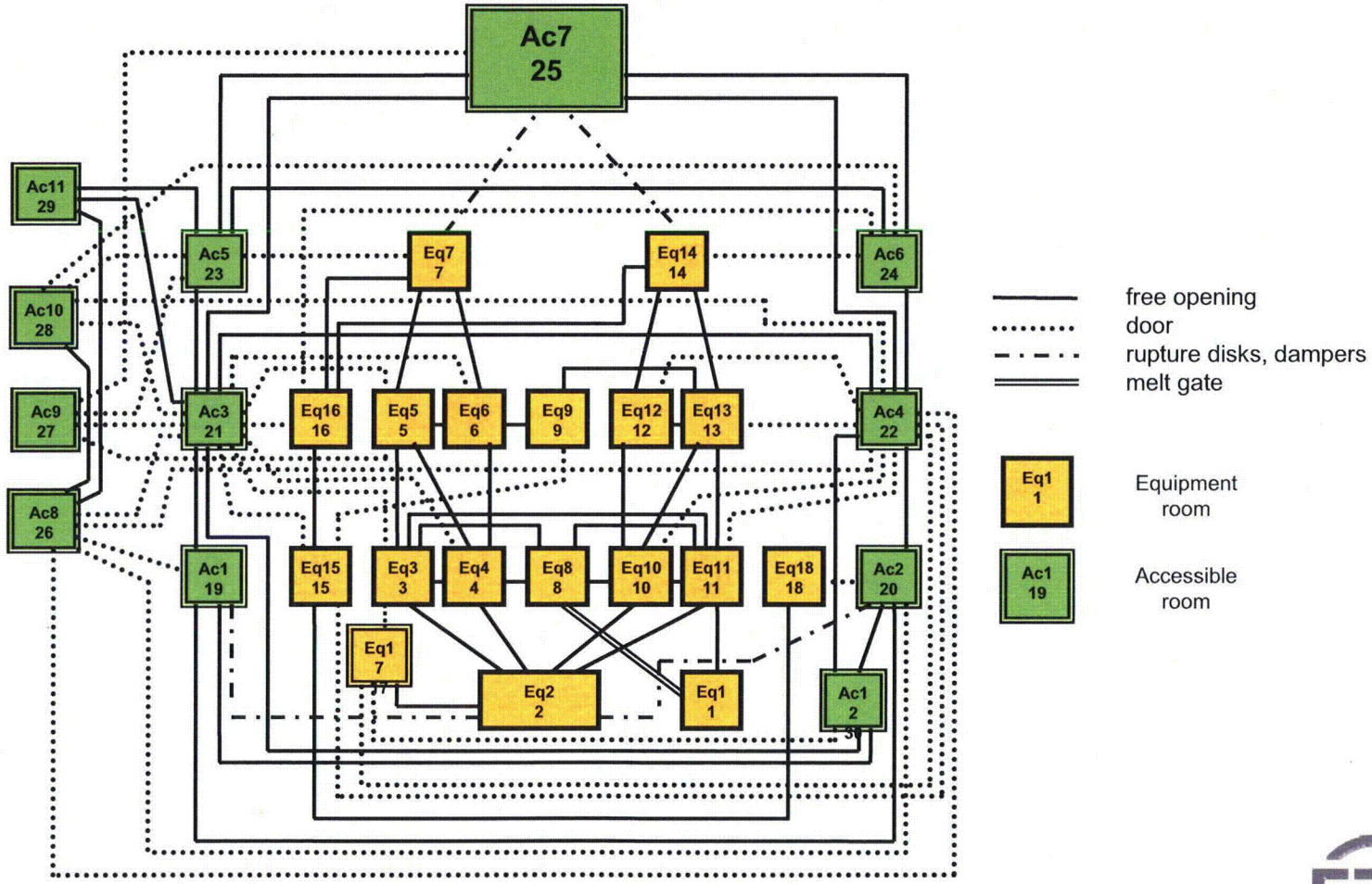
Test Program and ISP Lessons-Learned

> From NEA/CSNI(1999)(16) – ISP-37 "Calculations without stratification in the annulus used unfavourable changes from the proposed nodalization"



Test Program and ISP Lessons-Learned

GOTHIC multi-node model for the U.S. EPR



Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
I&C Hardware and Software	Table 2.4.1-9 (Protection System), item 4.14 Table 2.4.2-2 (Safety Information and Control System), item 4.5 Table 2.4.4-5 (Safety Automation System), item 4.5 Table 2.4.9-3 (Process Automation System), item 3.1	The [PS, SICS, SAS, PAS] hardware and software are developed using a design process with the following life cycle phases: • Basic design phase. • Detailed design phase. • Manufacturing phase. • Testing phase. • Installation and Commissioning phase.	Inspections will be performed on the design process for the [PS, SICS, SAS, PAS] hardware and software development. An analysis will be performed to verify that the [PS, SICS, SAS, PAS] hardware and software are developed in accordance with the design process.	1a) A design report exists and provides the design outputs of the basic design phase of the [PS, SICS, SAS, PAS] hardware and software design process. 1b) V&V reports exist that address the Concept and Requirements Activities and conclude that the design outputs generated in the basic design phase conform to the requirements of this phase. 2a) A report exists and provides the design outputs of the detailed design phase of the [PS, SICS, SAS, PAS] hardware and software design process. 2b) V&V reports exist that address the Design and Implementation Activities and conclude that the design outputs generated in the detailed design phase conform to the requirements of this phase. 3) A report exists and provides the design outputs of the manufacturing phase of the [PS, SICS, SAS, PAS] hardware and software design process. 4a) A report exists and provides the design outputs of the testing phase of the [PS, SICS, SAS, PAS] hardware and software design process. 4b) A V&V report exists that address the Test Activity and concludes that the design outputs generated in the testing phase conform to the requirements of this phase. 5a) A report exists and provides the design outputs of the installation and commissioning phase of the [PS, SICS, SAS, PAS] hardware and software design process. 5b) A V&V report exists that addresses the Installation and Checkout Activity summary report, if required, for any changes following testing phase and concludes that the design outputs generated in the installation and commissioning phase conform to the requirements of this phase.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
I&C Setpoint Analysis	Table 2.4.1-9 (Protection System), item 4.6	Setpoints associated with the automatic reactor trips listed in Table 2.4.1-3 and the automatically actuated engineered safety features listed in Table 2.4.1-4 are determined using a methodology that addresses the determination of applicable contributors to instrumentation loop errors, the method in which the errors are combined, and how the errors are applied to the design analytical limits.	An inspection will be performed to verify the existence of a document that describes the methodology for setpoint determination in the PS. An analysis will be performed to verify that the PS setpoints are determined using the documented methodology.	A report exists and concludes that the PS setpoints associated with the automatic reactor trips listed in Table 2.4.1-3 and the automatically actuated engineered safety features listed in Table 2.4.1-4 are determined using a methodology which provides a method: (1) For the determination of applicable contributors to instrument loop error. (2) For combining instrument loop errors. (3) For how the errors are applied to the design analytical limits.
Human Factors	Table 3.4-1 (Human Factors), item 1	HFE operating experience review is performed in accordance with the prescribed process. Results of the operating experience review are incorporated in the HSI design.	a. An evaluation of the process for conducting operating experience review has been performed.	a.1 The process provides a method to: • Identify predecessor/related plants. • Identify recognized industry HFE issues. • Identify OE of related HFE technology. • Identify issues identified by plant personnel. • Identify risk-important human actions requiring special attention during the design process. • Analyze, document, track, and review issues.
			b. An evaluation of the output summary has been performed.	b.1 The output summary demonstrates that the lessons learned from the reviewed operating experience have been incorporated into the HIS design.
	Table 3.4-1 (Human Factors), item 2	Functional requirements are translated from the predecessor design engineering documentation.	a. An evaluation of the output summary (included with the V&V documentation) has been performed.	a.1 The output summary includes: • A list of functions in-scope for meeting plant safety objectives. • Details of the differences between functional requirements for safety functions between predecessor designs and the U.S. EPR. • Technical justification and design basis for each difference between predecessor and U.S. EPR functional requirement.
	Table 3.4-1 (Human Factors), item 3	Functional allocation decisions are made based on a set of automation criteria which is defined and validated with the prescribed process.	a. An evaluation of the process for allocating functions has been performed.	a.1 The process provides: • A structured method to allocate functions to human and machine resources. • A method to document and keep the function allocation current over the life of the plant. • A method to identify the technical basis for all function allocations.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Human Factors (cont'd)			b. An evaluation of the output summary (included with the V&V documentation) has been performed.	b.1 The output summary includes: • The complete set of automation criteria used including the established control hierarchy between automatic and manual actions. • A list of the functions automated for predecessor EPRs and the differences between the predecessors and the U.S. EPR. • Technical justification for each difference in functional allocation.
	Table 3.4-1 (Human Factors), item 4	A task analysis is documented by validation of operating procedure guidelines containing HAs that the PRA found to be risk significant.	a. An evaluation of the output summary (included with the V&V documentation) has been performed.	a.1 The output summary includes a description of how iterations of the procedure development task analyses, the procedures themselves, and training programs result in an HSI design that supports in-scope control, information, and support requirements. a.2 The draft operating procedure guidelines identify functions needed to complete the given series of tasks.
	Table 3.4-1 (Human Factors), item 5	The staffing and qualification analysis includes an evaluation of the number and qualifications of personnel needed to operate, maintain, and test the U.S. EPR based on HSI design features.	a. An evaluation of the output summary (included with the V&V documentation) has been performed.	a.1 The output summary describes: • How staffing assumptions were validated. • How minimum staffing meets regulatory requirements while maintaining roles and responsibilities.
	Table 3.4-1 (Human Factors), item 6	Human reliability analysis evaluates the potential for, and mechanisms of, human errors that may affect plant safety. Integration of human reliability analysis findings with HFE design is performed in accordance with the prescribed process.	a. An evaluation of the process for integration of human reliability analysis with HFE design activities has been performed.	a.1 The process provides a method for: • Identifying risk-important human actions. • Addressing risk-important human actions in the HFE program. • Validating HRA assumptions.
			b. An evaluation of the output summary has been performed.	b.1 The output summary documents: • The results of the human reliability analysis and how HFE design efforts were affected. • The validation of the human reliability analysis through plant-specific control room mockup or simulator.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Human Factors (cont'd)	Table 3.4-1 (Human Factors), item 7	HSI design is performed in accordance with the prescribed process to translate the function and task requirements into HSI characteristics and functions.	a. An evaluation of the process for HSI design has been performed.	a.1 The process: • Allows for incorporation of personnel task requirements. • Considers system requirements, regulatory requirements, and other requirements in the HSI design. • Includes development of a concept of operations. • Includes development of a functional requirement specification. • Provides a method to develop the HSI design. • Includes development of design guidance (i.e., a style guide). • Provides a method to develop the HSI detailed design and integration. • Provides a method for determining the minimum inventory of alarms, displays, and controls. • Describes a method to determine the complete list of accident monitoring instrumentation • Provides a method for developing HSI tests and evaluations. • Describes how the HSI design is documented.
			b. An evaluation of the output summary has been performed.	b.1 The output summary: • Demonstrates that the HSI design was performed in accordance with the prescribed process. • Documents the HSI descriptions including how the design requirements and design characteristics were met. • Documents the outcome of tests and evaluations performed in support of V&V of HSI design.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Human Factors (cont'd)	Table 3.4-1 (Human Factors), item 8	The process for HSI design describes minimum inventory criteria and the methodology for selecting and validating the final minimum inventory.	a. An evaluation of the criteria and the process for selecting and validating the final minimum inventory has been performed.	a.1 The methodology for selecting the final minimum inventory includes: • The selection criteria. • How the functions and tasks that need to be supported by the minimum inventory are identified. • The technical requirements that apply to the design of the minimum inventory including those imposed by regulatory requirements including those for qualification, independence, and accessibility. • How the plant-specific PRA is used to identify operator actions or tasks that are risk-important. • How the guidance related to defining post-accident monitoring variables is addressed. • The operator actions credited in the safety analysis or plantspecific EPGs for safety and non-safety success paths. • How the diversity and defense in- depth evaluation is used to identify any specific operator actions credited for coping with common cause failures of the protection systems. • The criteria that are used to determine which SICS components need to be spatially dedicated, continuously visible, continuously available, or accessible by taking only one action (i.e., MCR design and concept of operations). a.2 The methodology for verifying the completeness of the minimum inventory in the MCR and the RSS includes: • How generic technical guidelines or design-specific guidelines are used for developing EOPs. • How task analysis activities related to procedure development describe the operator actions necessary to bring the reactor to safe shutdown. • How the risk-important operator actions identified through the plant-specific HRA are incorporated into the HSI design. • How the critical operator actions credited for diversity and defense-in-depth are incorporated into the HSI design. • How the full-scope simulator is utilized in the verification process.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Human Factors (cont'd)	Table 3.4-1 (Human Factors), item 9	HFE integration with procedure development is performed so that procedures are technically accurate, comprehensive, explicit, easy to use, and validated (i.e., the user can comply with the requirements of each step).	a. An evaluation of the process for HFE integration with procedure development has been performed.	a.1 The process for HFE integration with procedure development describes: • The basis or starting point for procedure development (i.e., how the TA and procedure development interrelate). • The content of procedures. • How the HSI style guide integrates with the procedure writer's guide. • How procedures are verified and validated. • The justification for use of electronic operating procedures instead of paper-based procedures.
			b. An evaluation of the output summary has been performed.	b.1 The output summary: • Addresses the final set of procedures and support equipment developed using the established methodology. • Includes the results of verification and validation activities as they relate to procedure development. • Describes how procedures will be maintained and updates controlled. • Gives a description of how operators access and use procedures, especially during operational events including: • Storage of procedures. • Ease of operator access to the correct procedures.
	Table 3.4-1 (Human Factors), item 10	HFE integration with training program development is performed so that a methodical analysis of job and task requirements and a systematic approach to training are used to provide plant personnel with required knowledge, skills, and attributes to perform assigned tasks.	a. An evaluation of the process for HFE integration with training program development has been performed.	a.1 The process describes training program scope including: • Categories of personnel to be trained. • Specific plant conditions, operational activities (e.g., operations, maintenance, testing and surveillance), and HSIs which effect training scenarios and methods.
			b. An evaluation of the output summary has been performed.	b.1 The output summary addresses: • The roles of organizations that contributed to the training program. • How learning objectives were developed and translated into the use of associated knowledge, skills, and attributes. • The use of resources (e.g., lectures, simulators, computerbased training, schedule) for training. • Methods used to evaluate effectiveness of the program.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Human Factors (cont'd)	Table 3.4-1 (Human Factors), item 11	HFE verification and validation establishes that the design of the HSI meets design requirements and that the HSI is effective in supporting the performance of personnel tasks.	a. An evaluation of the process for conducting HFE V&V has been performed.	a.1 The process provides a method: • For sampling operational conditions. • For identifying appropriate sampling dimensions. • To identify scenarios. • To inventory and characterize the HSI defined in the scope of the HSI design review. • To verify that the HSI provides alarms, information, and control capabilities required for personnel tasks. • To verify that the characteristics of the HSI and the environment in which it is used conform to HFE guidelines. • To evaluate the integrated system to determine whether it acceptably supports safe operation of the plant. • To address and resolve human error discrepancies.
			b. An evaluation of the output summary has been performed.	b.1 The output summary: • Demonstrates that the V&V was performed in accordance with the prescribed process. • Demonstrates that the design conforms to HFE design principles. • Demonstrates that the design enables plant personnel to successfully perform their tasks to achieve plant safety and other operation goals. • Provides results of V&V activities and conclusions from these activities.
	Table 3.4-1 (Human Factors), item 12	Design implementation validates that the as-built design conforms to the standard design resulting from the HFE V&V process and that issues defined as human engineering discrepancies identified in the HFE Issues Tracking Database are addressed.	a. An evaluation of the process for conducting design implementation has been performed.	a.1 The process provides a method: • For evaluating aspects of the design that were not addressed in the V&V step of the design process. • To validate that the final asbuilt HSIs conform to the design that resulted from the HFE design process and V&V activities.
			b. An evaluation of the output summary has been performed.	b.1 The output summary demonstrates that: • The design implementation was performed in accordance with the prescribed process. • Appropriate issues identified in the HFE issues tracking database have been adequately addressed.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Piping Supports	Table 2.2.1-5 (RCS), item 3.10 Table 2.2.2-3 (IRWST), item 3.4 Table 2.2.3-3 (SIS/RHRS), item 3.5 Table 2.2.4-3 (Emergency Feedwater), item 3.5 Table 2.2.5-3 (Fuel Pool), item 3.5 Table 2.2.6-3 (CVCS), item 3.5 Table 2.2.7-3 (EBS), item 3.5 Table 2.3.3-3 (SAHRS), item 3.5 Table 2.5.4-3 (Emergency Diesel Generator), item 3.3 Table 2.7.1-3 (Component Cooling Water System), item 3.5 Table 2.7.2-3 (Safety Chilled Water System), item 3.5 Table 2.7.11-3 (Essential Service Water System), item 3.5 Table 2.8.2-3 (Main Steam), item 3.4 Table 2.8.6-3 (Main Feedwater), item 3.5 Table 2.8.7-3 (SG Blowdown), item 3.4	Supports for piping shown as ASME Section III on Figure 2.2.x-1 will be designed in accordance with ASME section III.	An analysis will be performed.	a. Supports for piping shown as ASME Section III on Figure 2.2.x-1 are designed in accordance with ASME section III. b. Snubbers have been identified, including those analyzed for fatigue for piping shown as ASME Section III on Figure 2.2.x- 1. c. Support mass is less than ten percent of the adjacent pipe span for piping shown as ASME Section III on Figure 2.2.x-1.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Fatigue Analysis	Table 2.2.1-5 (RCS), item 3.11 Table 2.2.3-3 (SIS/RHRS), item 3.6 Table 2.2.6-3 (CVCS), item 3.6 Table 2.2.7-3 (EBS), item 3.6 Table 2.5.4-3—(Emergency Diesel Generator), item 3.3	Components listed as ASME Code Class I in Table 2.2.x-1 will be analyzed for fatigue per ASME Section III Class I.	An analysis will be performed.	a. Fatigue analysis has been performed for components listed as ASME Code Class I in Table 2.2.x-1. b. For components listed as ASME code Class I in Table 2.2.x-1, operating modes where peak stresses are within ten percent of allowable have been identified.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Component Analysis	Table 2.2.1-5 (RCS), item 3.1 Table 2.2.2-3 (IRWST), item 3.1 Table 2.2.3-3 (SIS/RHRS), item 3.1 Table 2.2.4-3 (Emergency Feedwater), item 3.1 Table 2.2.5-3 (Fuel Pool), item 3.1 Table 2.2.6-3 (CVCS), item 3.1 Table 2.2.7-3 (EBS), item 3.1 Table 2.2.8-2 (Fuel Handling), item 3.1 Table 2.7.1-3 (Component Cooling Water System), item 3.1 Table 2.7.2-3 (Safety Chilled Water System), item 3.1 Table 2.7.11-3 (Essential Service Water System), item 3.1 Table 2.8.2-3 (Main Steam), item 3.1 Table 2.8.6-3 (Main Feedwater), item 3.1 Table 2.8.7-3 (SG Blowdown), item 3.1 Table 3.5.-3 (Containment Isolation), item 3.1	The components designated as ASME Code Section III in Table 2.2.x-1 are designed to ASME Code Section III requirements.	Inspections will be conducted of ASME design, NDE, and hydrostatic test reports for the components listed as ASME Section III in Table 2.2.x-1.	A report exists and concludes that the components listed as ASME Code Section III in Table 2.2.x-1 have been designed and hydrostatically tested in accordance ASME Code Section III requirements.

Design ITAAC Topic	Tier 1 Location	Commitment	Inspection, Test, or Analysis	Acceptance Criteria
Piping Analysis	Table 2.2.1-5 (RCS), item 3.4a Table 2.2.2-3 (IRWST), item 3.2a Table 2.2.3-3 (SIS/RHRS), item 3.3a Table 2.2.4-3 (EFWS), item 3.3a Table 2.2.5-3 (Fuel Pool), item 3.3a Table 2.2.6-3 (CVCS), item 3.3a Table 2.2.7-3 (EBS), item 3.3a Table 2.5.4-3—(Emergency Diesel Generator), item 3.2 Table 2.7.1-3 (Component Cooling Water System), item 3.3a Table 2.7.2-3 (Safety Chilled Water System), item 3.3a Table 2.7.11-3 (Essential Service Water System), item 3.3a Table 2.8.2-3 (Main Steam), item 3.2a Table 2.8.6-3 (Main Feedwater), item 3.3a Table 2.8.7-3 (SG Blowdown), item 3.2a Table 3.5-3 (Containment Isolation), item 3.3a	The piping identified as being within the ASME Code Section III boundary as indicated on Figure 2.2.x-1 has been designed in accordance with ASME Code Section III Requirements including seismic loads.	Analysis of the as-designed piping will be performed in accordance with ASME Code Section III requirements for the piping indicated on Figure 2.2.x-1.	ASME Code Section III stress reports exist and conclude that the as-designed piping identified as ASME Code Section III in Figure 2.2.x-1 meets ASME Code Section III requirements.