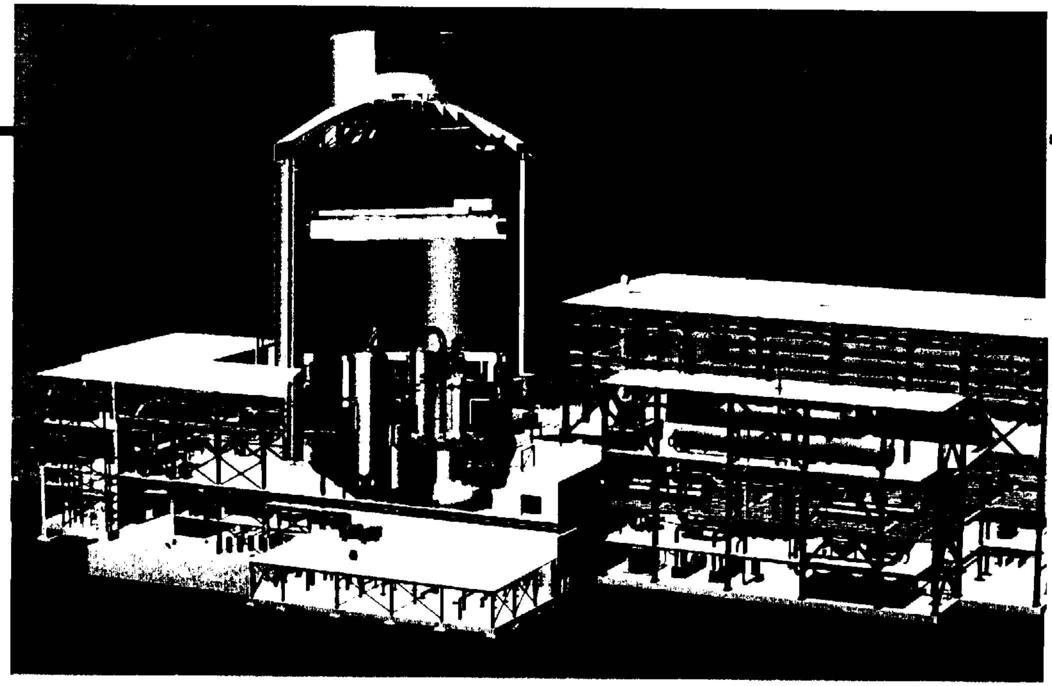

# AP1000 Pre-Certification Review

## Review of Applicability of AP600 Analysis Codes to AP1000

Enclosure 2

January 10, 2001

U.S. Nuclear Regulatory Commission

# Agenda

| | | |
|---|---|---|
| • 9:00 | AP1000 Pre-Certification Review Overview | Mike Corletti |
| • 9:45 | AP1000 Plant Description Overview | |
| • 10:30 | LOFTRAN<br>• AP1000 Transient Analysis Results<br>• Code Documentation – Phase 2 | Uriel Bachrach |
| • 11:15 | NOTRUMP<br>• AP1000 Small Break LOCA Results<br>• Code Documentation – Phase 2 | Andre Gagnon |
| • 12:00 | Lunch | |
| • 1:00 | WCOBRA-TRAC<br>• AP1000 Long Term Cooling Analysis Results<br>• Code Documentation – Phase 2<br>• Large Break LOCA Approach | Robert Kemper |
| • 1:30 | WGOTHIC<br>• AP1000 Containment Analysis Results<br>• Code Documentation – Phase 2 | Richard Ofstun |
| • 2:00 | Discussion of Logistics | All |

# AP1000 Pre-Certification Review Overview

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# AP1000 Pre-Certification Review

- OBJECTIVE
  - Obtain agreement on how AP600 Certification can be used as a basis for AP1000 Design Certification
    - Improve efficiency of licensing process
    - Identify potential barriers to leveraging AP600 Certification to AP1000
- How do we plan on meeting this objective?
  - 3 Phase Approach Suggested by NRC
    - Phase 1 - Identify issues to evaluate in Pre-certification review
      - Issues that potentially have a large impact on design certification licensing cost and schedule
    - Phase 2 - Pre-certification review of the issues identified
    - Phase 3 - Design Certification

# Phase 1 Review Summary

- W identifed 5 items for NRC to consider
- NRC staff evaluated issues and identified an additional item
  - Provided a cost estimate to resolve each issue
  - Identified detailed technical issues that should be considered for each item
- ACRS provided 2 letters during Phase1 providing their insights and guidance
- W has selected which items to pursue under Phase 2
  - Two items deferred due to W budget constraints
    - Deferred items considered during Phase 3 - Design Certification

# AP1000 Phase 2 Issues

1. Sufficiency of AP600 Test Program to meet 10 CFR Part 52 requirements for AP1000

2. Applicability of NRC-approved AP600 analysis codes for AP1000 Design Certification

3. Acceptability of using Design Acceptance Criteria in selected areas

4. Applicability of Exemptions granted to AP600

# Determinations in Phase 2
## Test and Code Issues

- Determine the applicability of the AP600 Test Program to AP1000
- Determine applicability of AP600 codes and models for AP1000

- What does applicability mean?
  - Tests:
    - No additional tests are required to be performed by Westinghouse for AP1000 design certification
  - Codes:
    - Agreement on the basis for applying AP600 codes to AP1000 Design Certification

# Review of Codes in Phase 2

- Phase 2:
  - Determine the basis for applying AP600 codes to AP1000 Design Certification
    - AP1000 phenomena similar (or different) than AP600
    - AP600 tests scale similarly (or differently) to AP1000
    - AP1000 safety margins are similar (or different) than AP600
    - Based on these comparisons, specify in Phase 2 the required changes to safety analysis codes, models, or methodologies to be implemented for AP1000 in Phase 3
- Phase 3:
  - Review application of the codes to AP1000
    - Review and approve safety analysis results
    - Review and approve application of codes

# W Deliverables in Phase 2

## Tests and Code Issues

- AP1000 Plant Description and Analysis Report
  - Overview Plant Description
    - Emphasizes AP600 and AP1000 design differences
    - Design margins assessments
  - Safety Analysis Assessments
    - Preliminary AP1000 design information
    - NRC-approved AP600 analysis codes

Report provides the basis for Phase 2 review of AP1000 design features and safety margins

# W Deliverables in Phase 2

## Tests and Code Issues

- AP1000 Scaling Assessment and Analysis Plan
  - Applicability of AP600 Test Program to AP1000
    - Comparisons of AP600 and AP1000 PIRT
    - Scaling studies to compare scalability of test programs to AP600 / AP1000
      - Demonstrate AP600 Test Programs scale sufficiently in areas where scaling was the basis for acceptability of AP600 analysis codes
  - Applicability of AP600 Analysis Codes to AP1000
    - Acceptability of AP600 Analysis Codes
      - Acceptance of Codes for Operating Plants
      - Validation of AP600 Codes Against AP600 Test Program for passive plant design differences
      - Large safety margins where appropriate

Report provides the basis for applicability of AP600 codes for AP1000

# Objectives of this Meeting

- Consider what is necessary for Phase 2 applicability review
  - Determine schedule and logistics for additional review of AP600 codes for applicability to AP1000
    - Guidance taken from DG-1096
    - ACRS / NRC staff concerns that staff should "exercise" AP600 analysis codes
- Planned Deliverables
  - Analysis Codes and Code Documentation
    - Source codes and executable
    - AP1000 analysis models
    - Most code documentation previously submitted as part of AP600 Design Certification
  - Users Guides and Manuals

# Approach for Code Review in Phase 2

- Basis for AP600 Acceptability
  - NUREG-1512 - AP600 FSER
- AP1000 Design
  - Similarities and differences to AP600
- Scaling of AP600 Tests to AP1000
  - Confirm AP1000 scalability where scaling was important for code acceptance
- AP1000 safety margins
  - Confirm adequate margins where margins were important for code acceptability

NRC will exercise codes as necessary to assess applicability of approved AP600 codes to AP1000

# Overview of Pre-Certification Review

- Phase 1 review identified significant issues to consider during pre-certification review
  - Identified major barriers to leveraging AP600 Certification to AP1000
- Phase 2 review to begin in February
  - Acceptability of AP600 Test Program
  - Acceptability of AP600 Analysis Codes
    - Determine the basis for their application to AP1000
  - AP600 analysis codes will be provided to the NRC as necessary for their review
- Phase 3 - Design Certification
  - Review of AP1000 Application under guidelines agreed upon during Phase 2

# AP1000 Plant Design Description Report Overview

# AP600 Major Uprate - Objectives

- Increase Plant Power Rating to Reduce Cost
  - Obtain a capital cost that can compete in U.S. market \$900-1000/KW for $n^{th}$ twin plant
- Retain AP600 Objectives and Design Detail
- Retain AP600 Licensing Basis
- Retain AP600 Risk Basis

# AP600 Major Uprate

- Design Approach
  - Increase the capability/capacity within “space constraints” of AP600
  - Meet regulatory requirements for Advanced Passive Plants
  - Retain credibility of “proven components”
  - Retain AP600 plant design (footprint)
  - Retain the basis for the cost estimate, construction schedule and modularization scheme

# Comparison of Selected Parameters

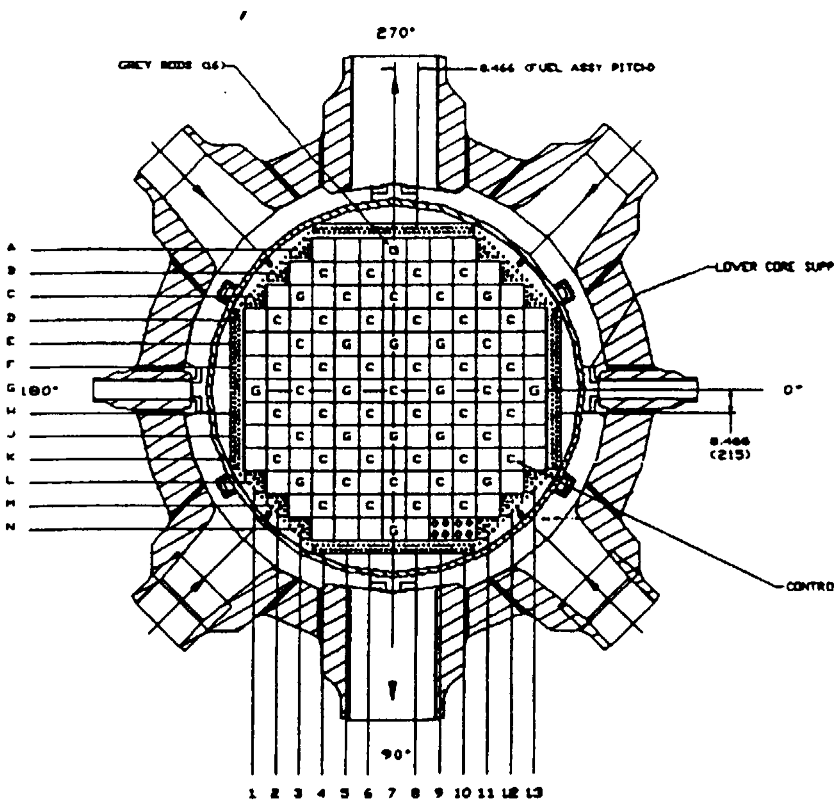
| PARAMETER | AP600 | AP1000 |
|---|---|---|
| Net Electric Output, MWe | 610 | 1090 |
| Reactor Power, MWt | 1933 | 3400 |
| Hot Leg Temperature, $^{o}F$ | 600 | 615 |
| Number of Fuel Assemblies | 145 | 157 |
| Type of Fuel Assembly | 17x17 | 17x17 |
| Active Fuel Length, ft | 12 | 14 |
| Linear Heat Rating, kw/ft | 4.10 | 5.71 |
| R/V I.D., inches | 157 | 157 |
| Steam Generator | $\Delta$75 | $\Delta$125 |
| Reactor Coolant Pump Flow, gpm | 51,000 | 75,000 |
| Pressurizer Volume, $ft^3$ | 1600 | 2100 |
| Core Makeup Tanks # / Volume, $ft^3$ | 2 / 2000 | 2 / 2500 |
| Containment Diameter / Height, ft | 130 / 190 | 130 / 215 |

# AP600 Major Uprate to 1000 MWe

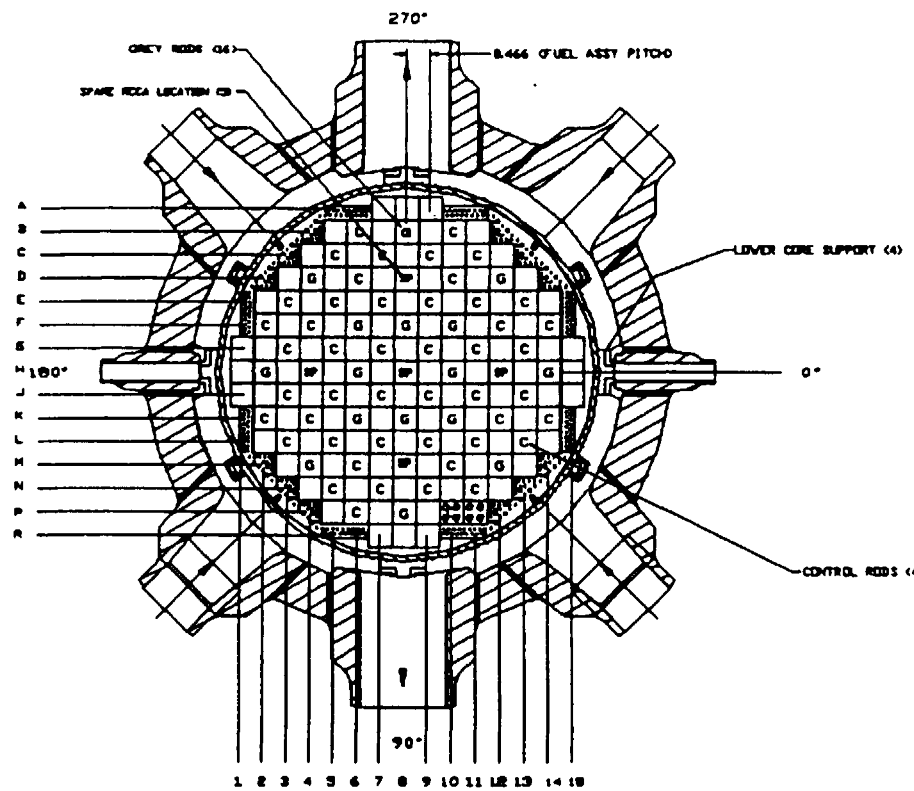
- Select proven core design
  - Doel 3, Tihange 4
    - 3000 MWt
    - 14 ft active fuel length; 17x17 fuel
    - 157 fuel assemblies
  - 3400 MWt option using core power density similar to operating 3-loop plants
    - North Anna, V.C. Summer, Vandellos II, ASCO
- Size key NSSS components
  - Reactor Vessel/Head - 3-Loop with reflector
  - Steam Generator - $\Delta$125 similar to ANO replacement
  - Reactor Coolant Pump - increase capacity
  - Pressurizer - increase volume

# Core Design

## AP600



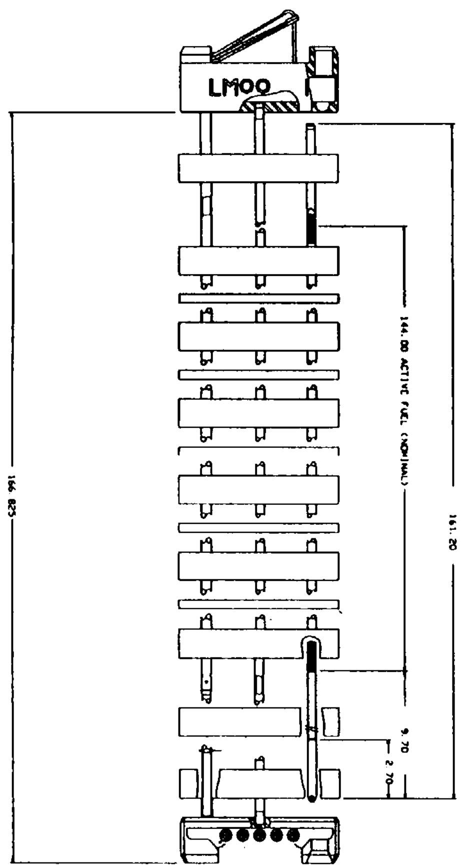

## AP1000



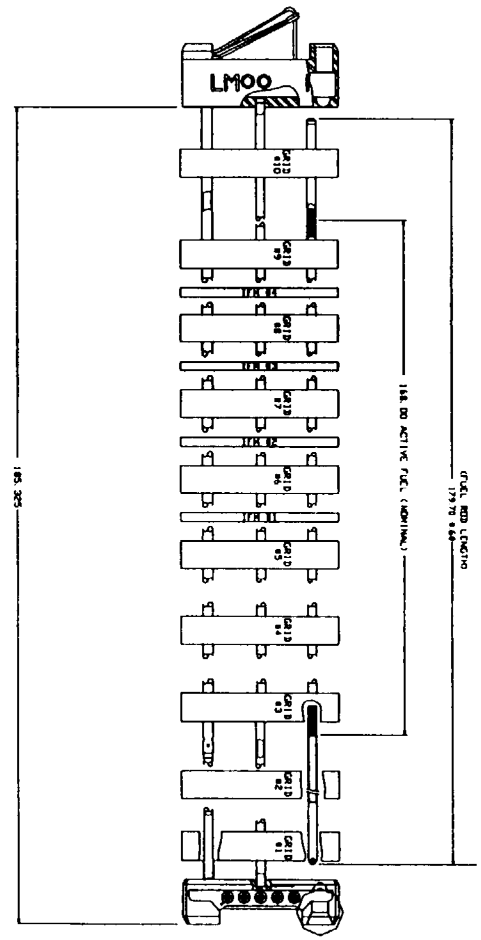

- Number of Fuel Assemblies Increased from 145 to 157
- Active fuel length increased from 12 ft to 14 ft

# Fuel Assembly

## AP600




## AP1000




- Active fuel length increased from 12 ft to 14 ft
- Overall dimension same as South Texas fuel

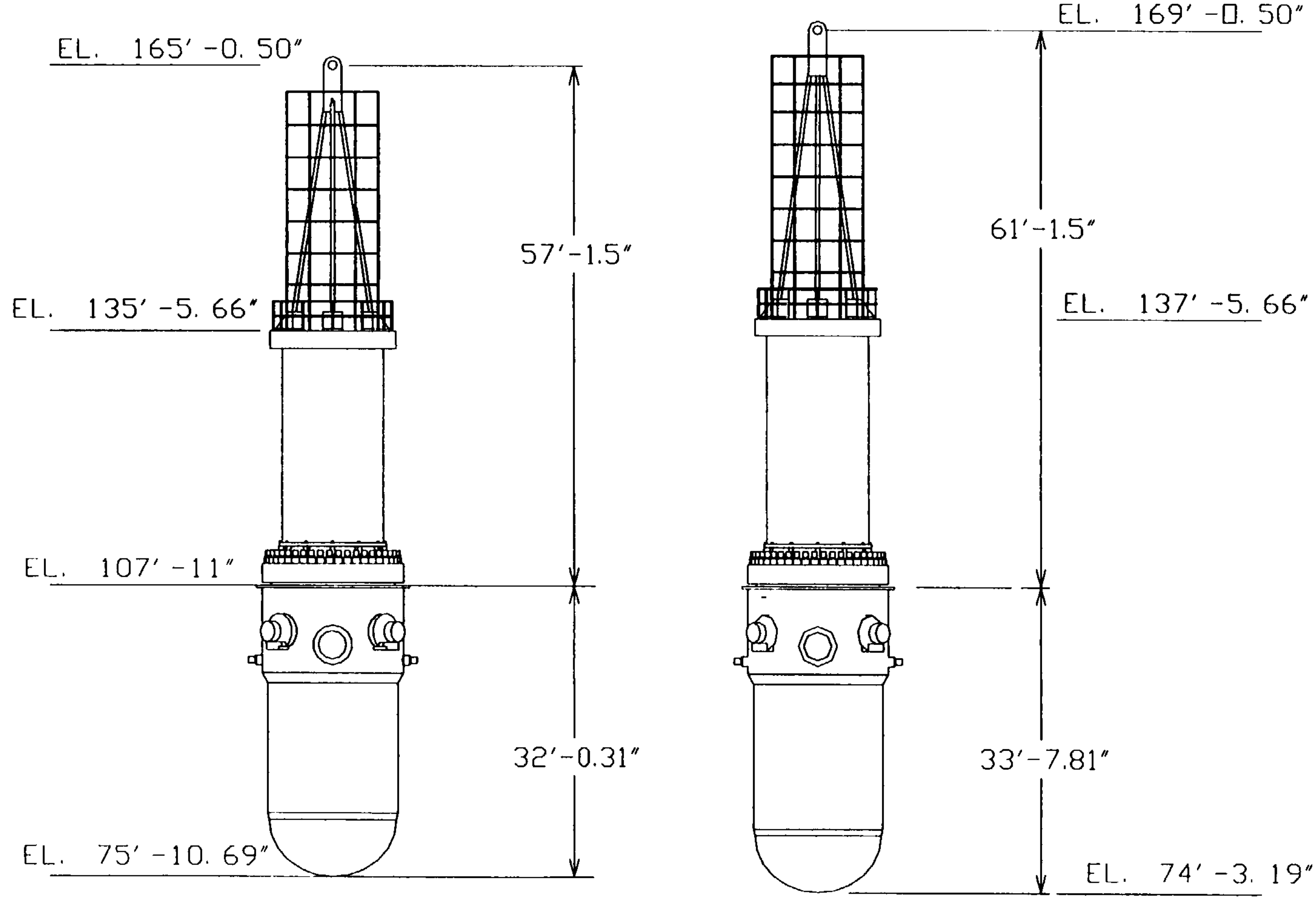
# Reactor Vessel Design Overview

- Reactor vessel
  - Maintains key AP600 design features
  - No bottom-mounted instrumentation
  - 60 year design life
  - Longer to accommodate longer fuel assemblies
- Lower internals
  - AP600-type internals
  - Lower core support plate thickness increased to accommodate heavier fuel
- Integrated Head Package
  - Modified to accommodate longer fuel
  - Additional control rods

# Reactor Vessel

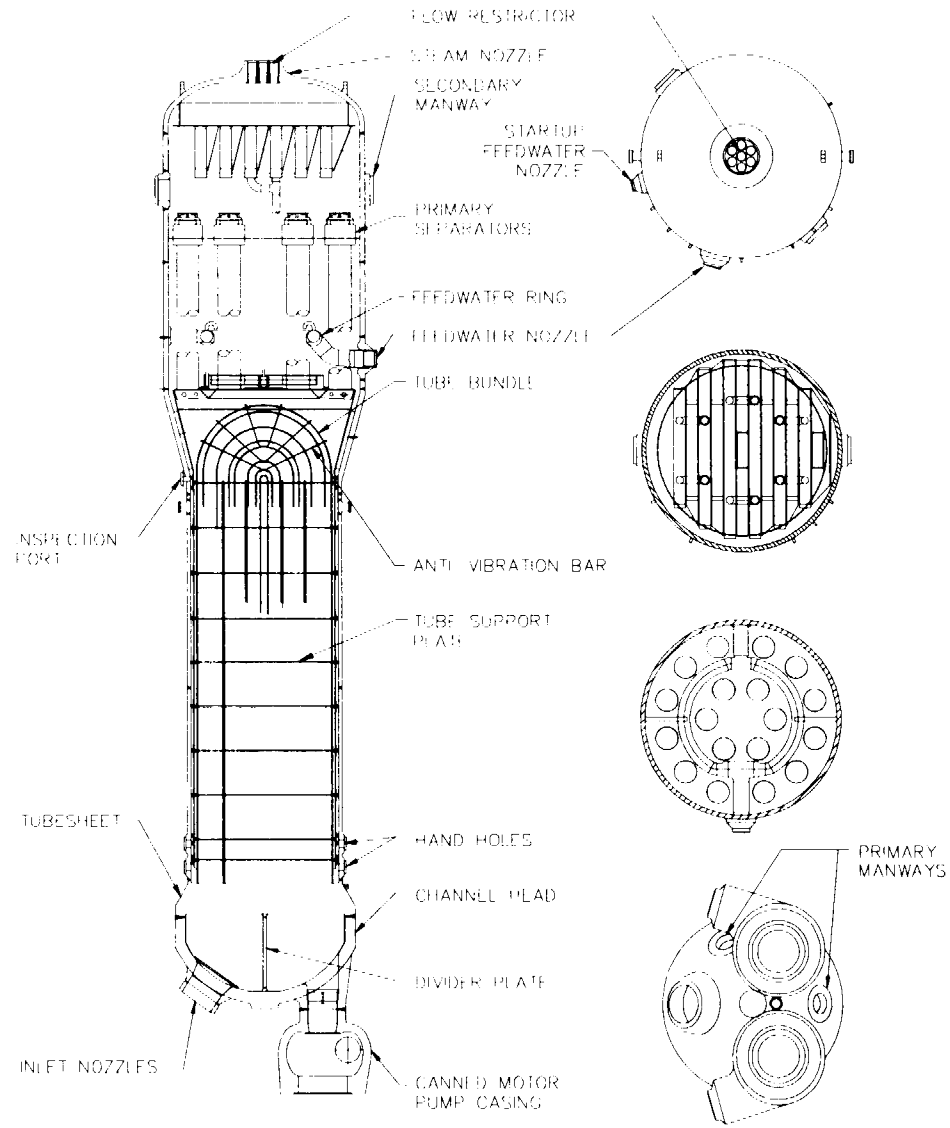
## with Integrated Head Package

AP600 AP1000



# Steam Generator

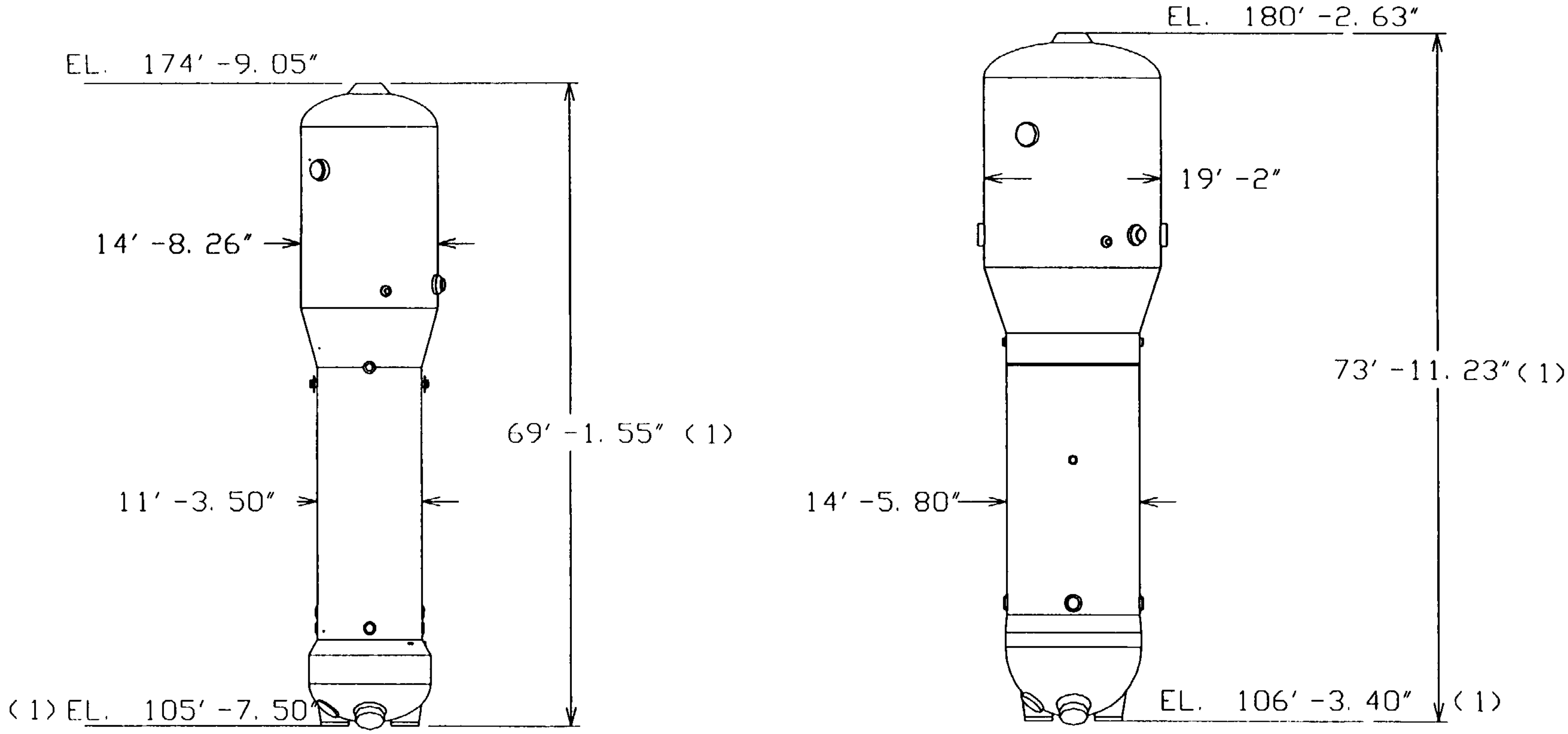
- Δ125 Steam Generator
  - Based on W / CE Designs
    - Δ75 - Standard Replacement SG for Model F - AP600
    - Δ94 - South Texas Replacement SG
    - ANO (Arkansas) Replacement SG
      - 1500 MWt per SG
      - Inconel 690 thermally treated tubes
  - Inconel 690 TT tubes



# Steam Generator

## AP600

## AP1000

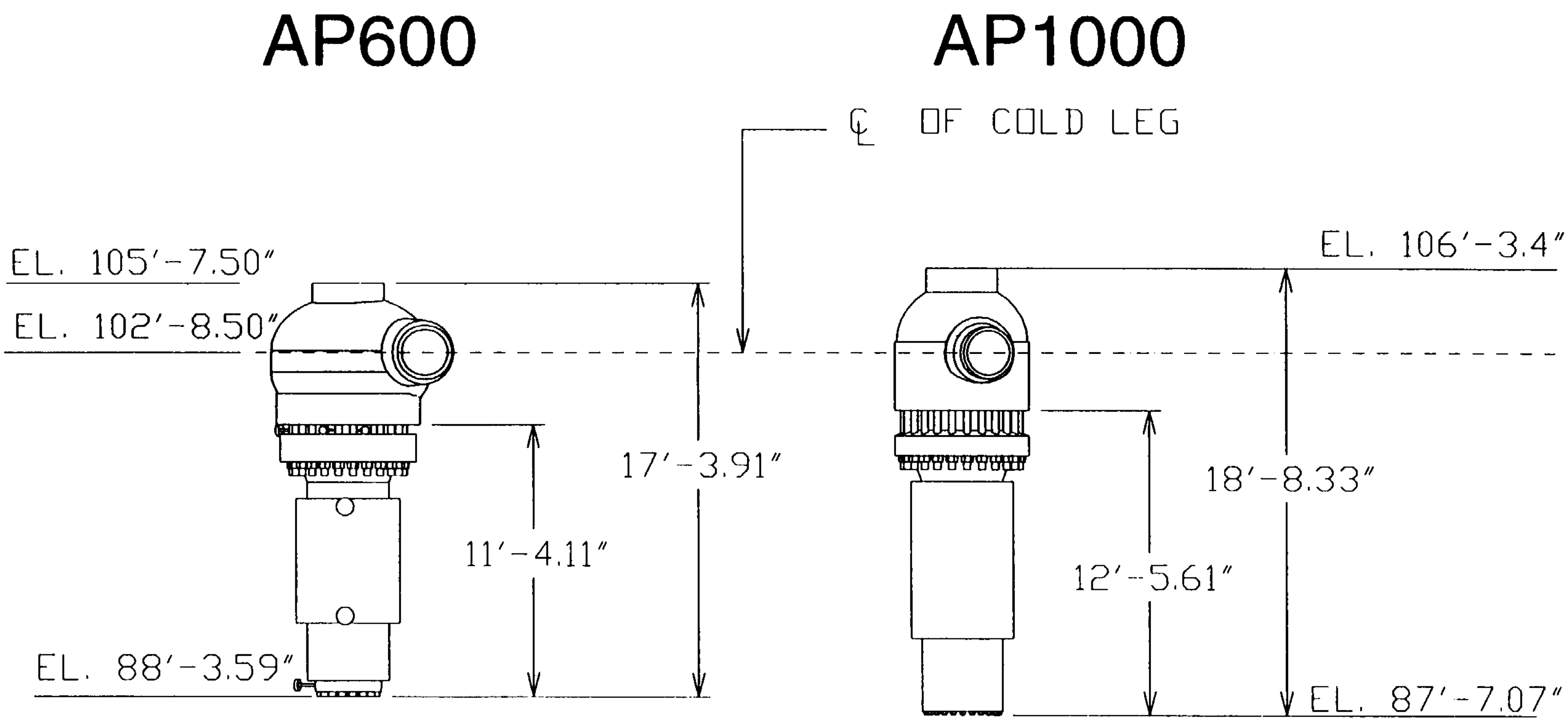



(1) - S/G OUTLET NOZZLE TO RCP CASING WELD

# Reactor Coolant Pump

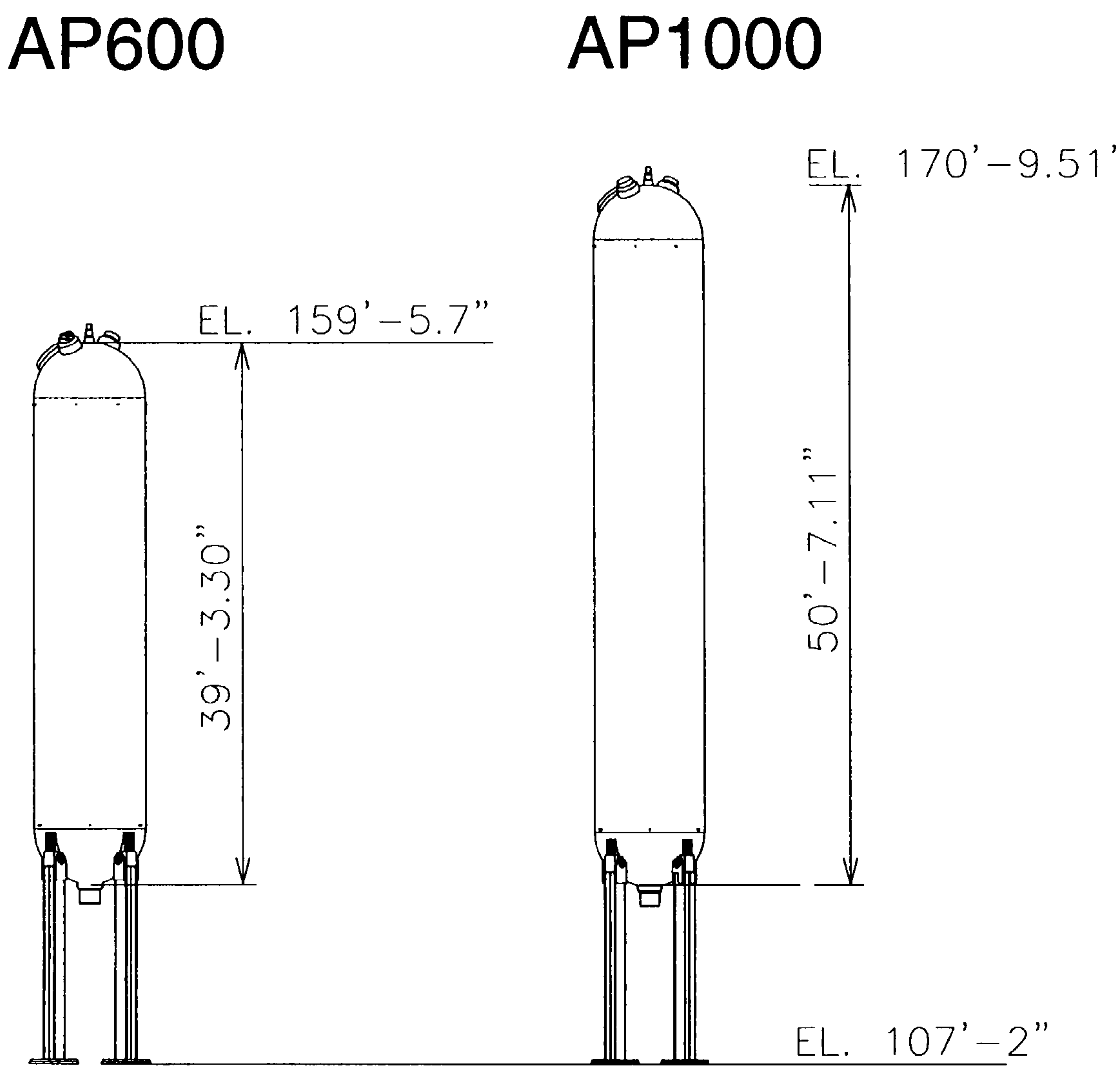
- AP600 RCP based on proven motor design
- Increase capacity for AP1000
  - AP1000 higher power density core requires longer flow coast down - more pump inertia
  - Pump flow requirements increased to accommodate higher core power
- Impacts to pump design minimized
  - Use motor rating at hot coolant condition
  - Variable speed controller added to reduce motor power in cold coolant conditions
  - Use high-efficiency hydraulics - scaled from Tsuruga 3/4
  - Canned motor similar to AP600 size

# Reactor Coolant Pump




| Parameter | AP600 | AP1000 |
|---|---|---|
| Design Flow, gpm | 51,000 | 75,000 |
| Design Head, ft | 240 | 350 |
| Rotating Inertia, $lb\text{-}ft^2$ | 5,000 | 15,000 |
| Motor Rating, Hp | 3200 | 6000 |

# Pressurizer



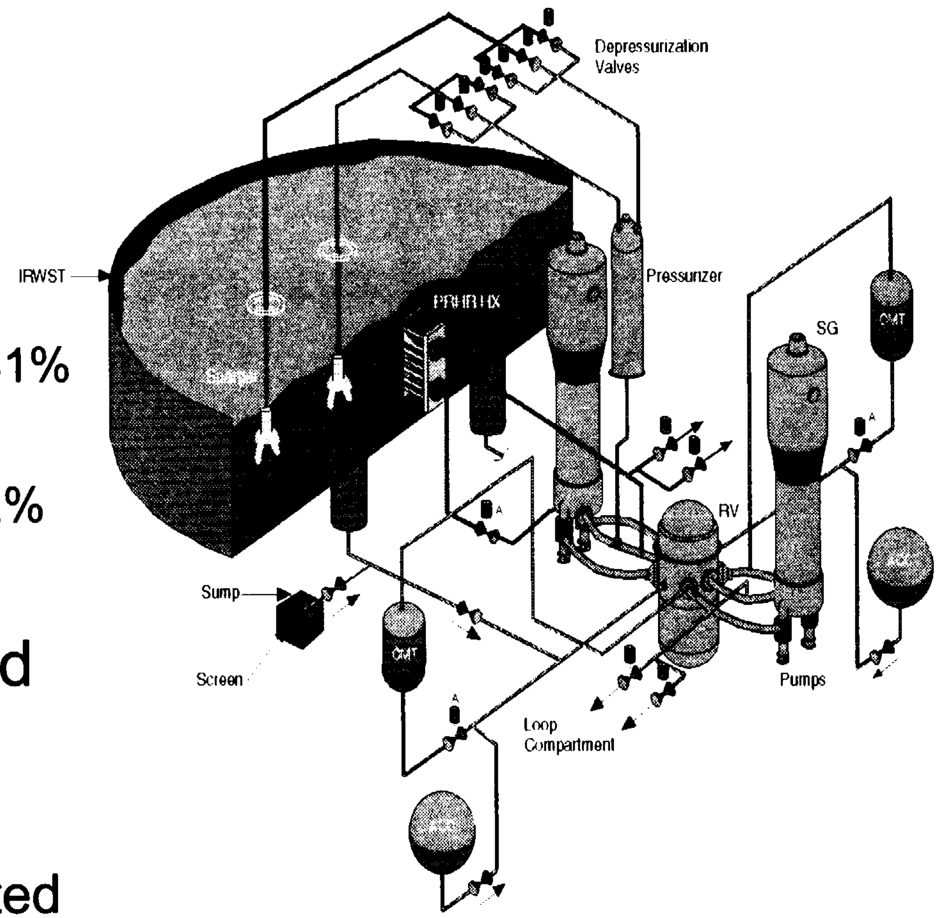

- Pressurizer volume increased from 1600 $ft^3$ to 2100 $ft^3$

# Passive Safety Systems Resized for AP1000

- AP1000 Design Approach
  - Maintain safety margins
    - Consider both deterministic and probabilistic criteria
      - Meet deterministic safety criteria
      - Maintain PRA success criteria
        - Level 1 and Level 2
  - Maintain AP600 configuration / arrangements
    - Design changes only to address increased core power

# AP1000 Passive Core Cooling System

- System Configuration Retained
- Capacities Increased to Accommodate Higher Power
    - CMT Increased 25%
    - IRWST Injection Increased 84%
    - Sump Recirculation Increased 131%
    - ADS 4 Increased 89%
    - PRHR HX Capacity Increased 72%

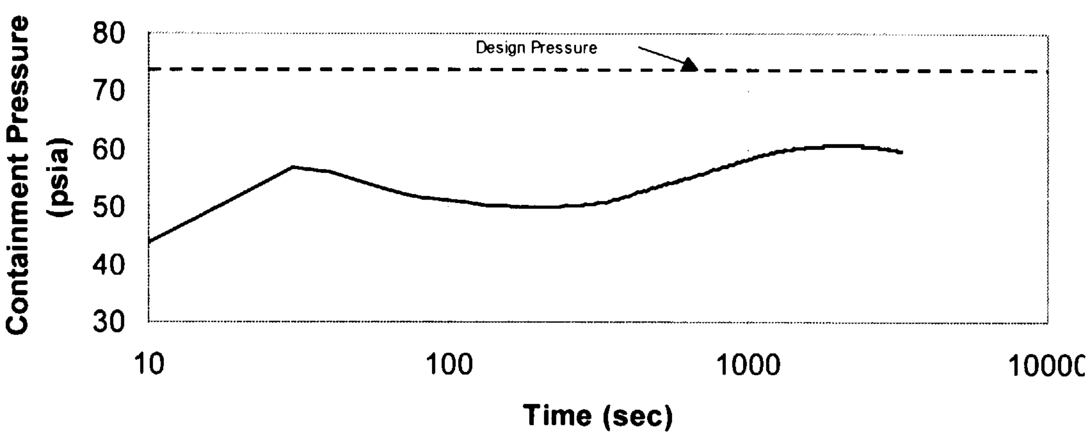


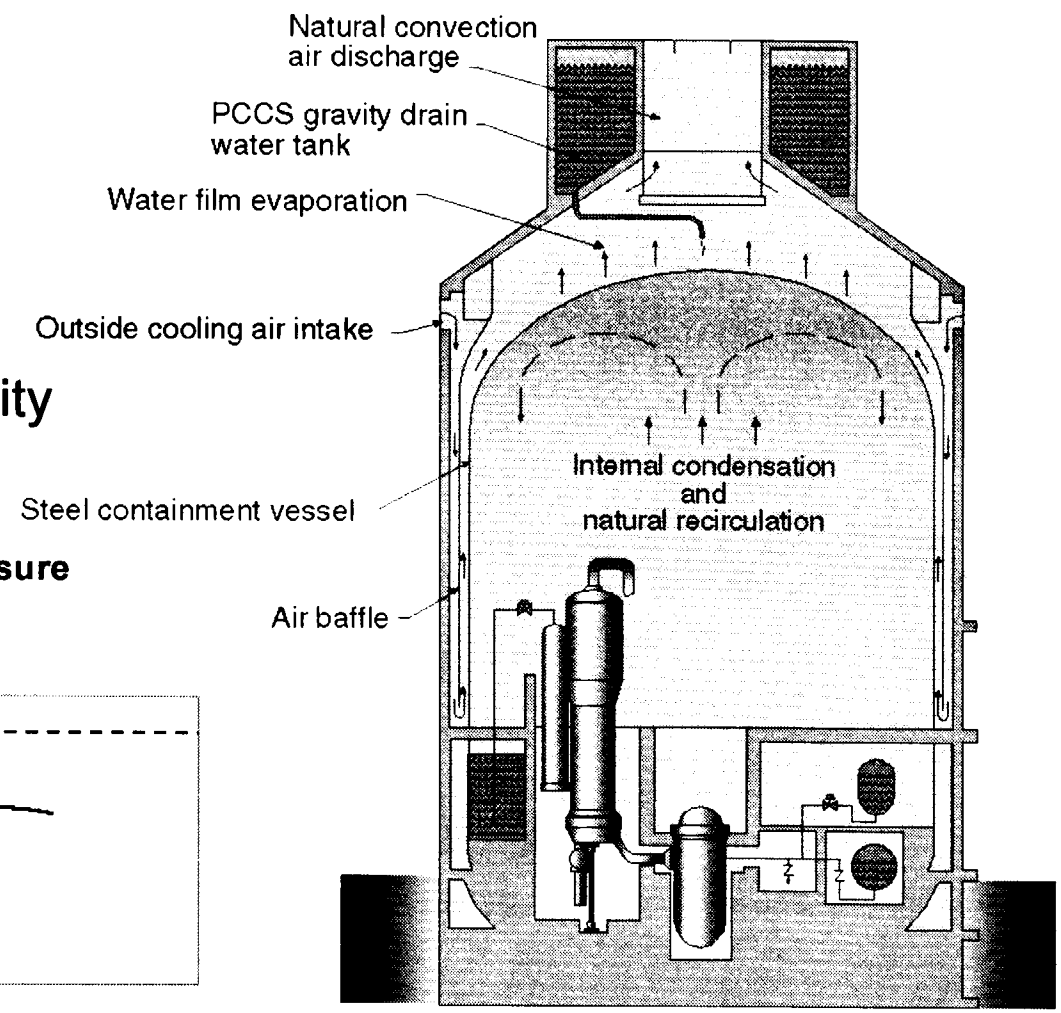

- System Performance Assessed
    - No core uncovery for SBLOCA
        - DVI line break
    - Large margin to PCT limit expected

# AP1000 Passive Containment Cooling

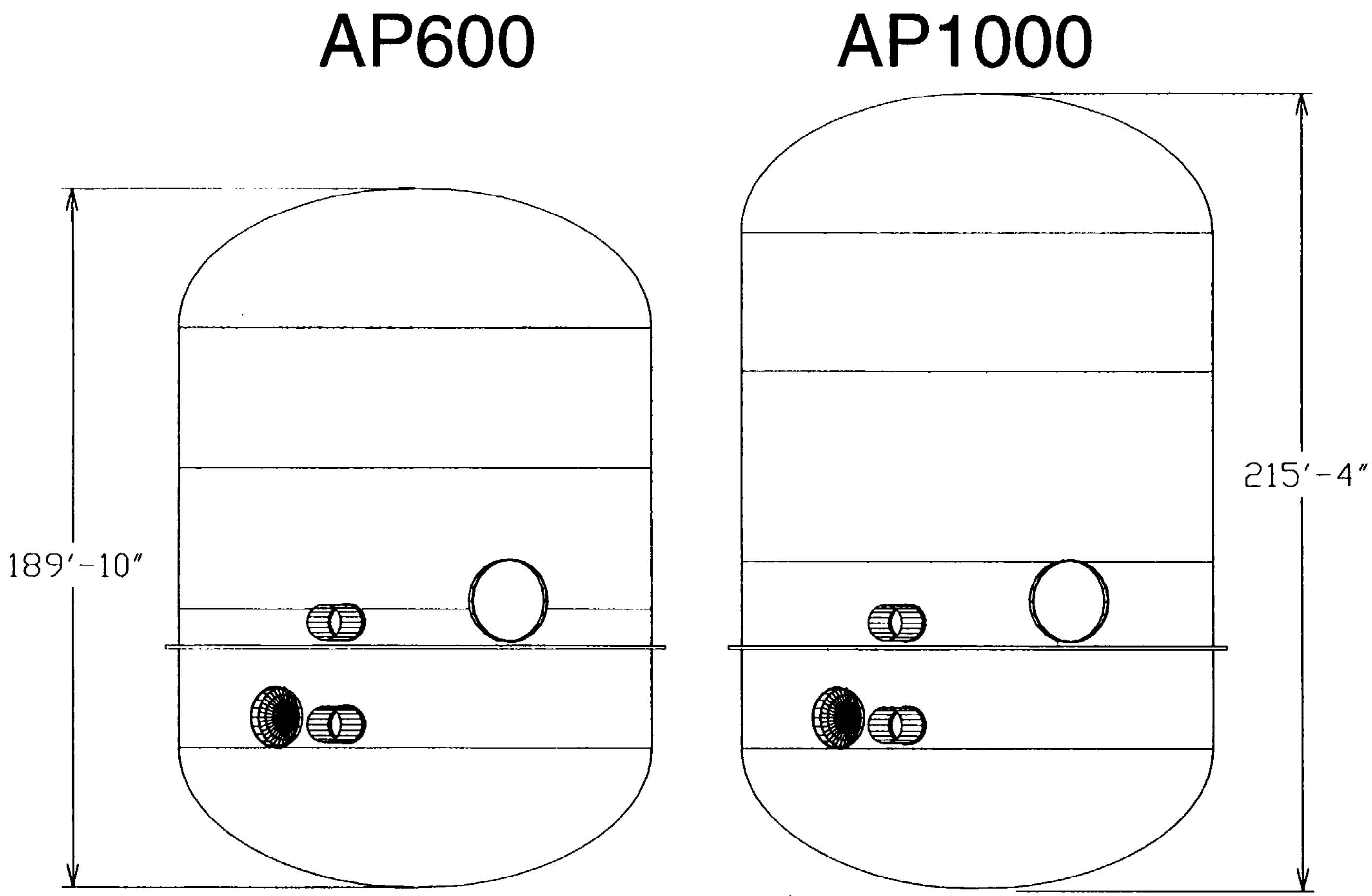
- Containment
  - Height increased 25 feet
  - Volume increased 20%
  - Design pressure increased
- PCS Capacity Increased
  - Higher flow rate / tank capacity

**AP1000 DECL LOCA Containment Pressure Response**



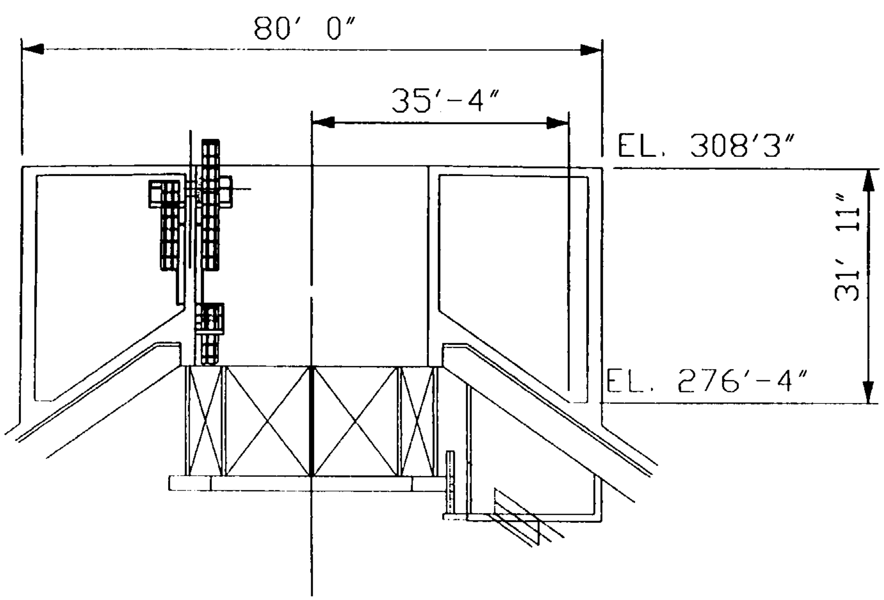
# Containment Vessel

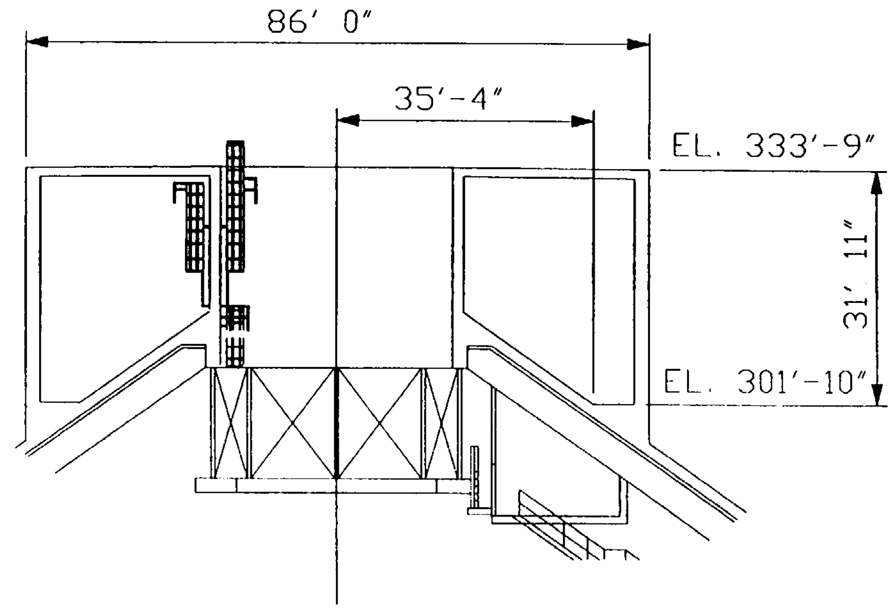



| Parameter | AP600 | AP1000 |
|---|---|---|
| Shell Thickness | 1 5/8" | 1 ¾" |
| Total Free Volume, $ft^3$ | $1.7 \times 10^6$ | $2.07 \times 10^6$ |
| Design Pressure, psig | 45 | 59 |
| Material | A537 Class 2 | SA738 Grade B |

# PCS Water Storage Tank

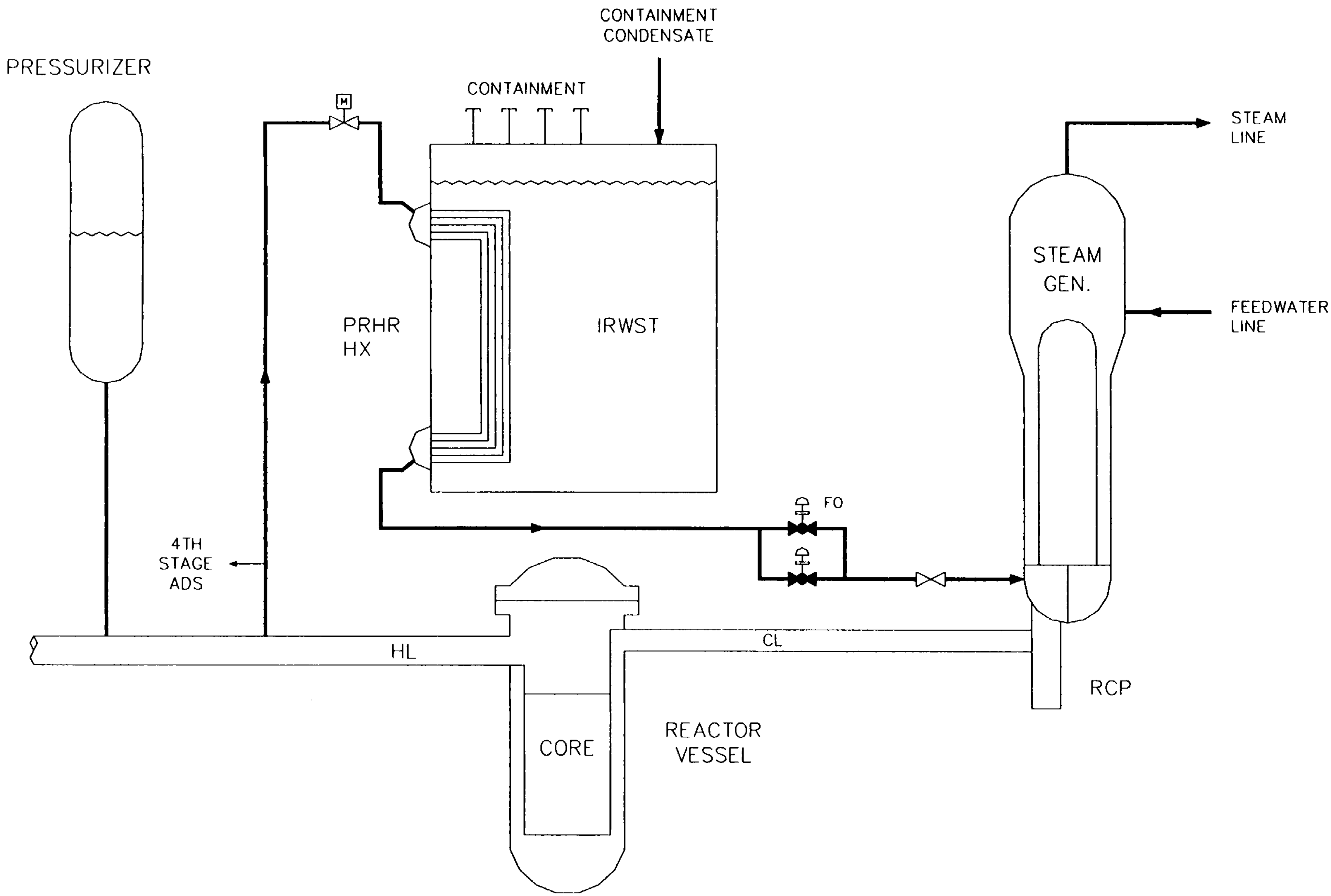
AP600 | AP1000



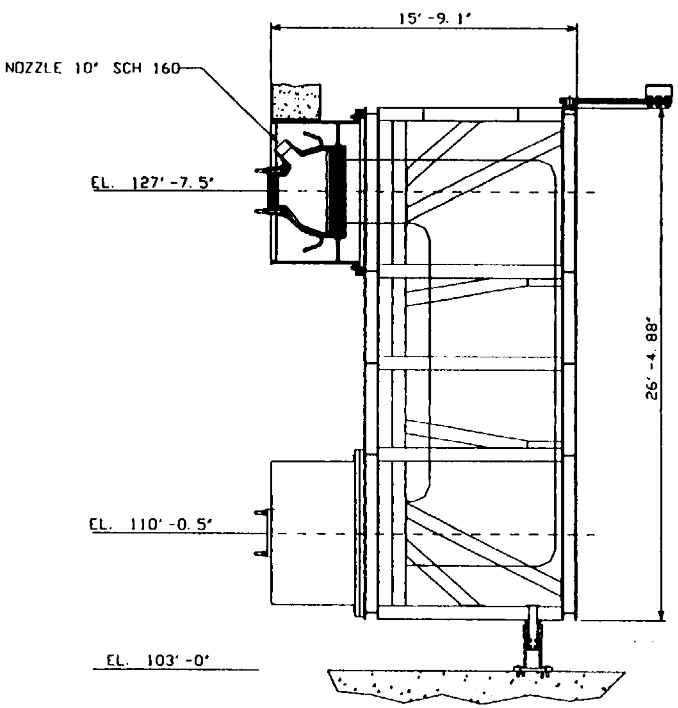

- Passive Containment Cooling Water Storage Tank volume increased from 519,000 to 800,000 gallons

# Passive Decay Heat Removal

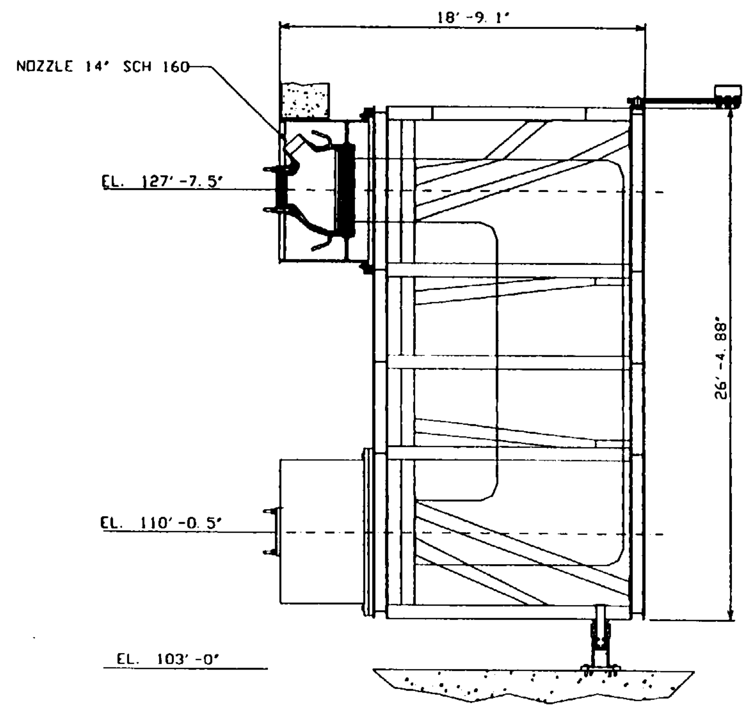


# Passive RHR Heat Exchanger

AP600

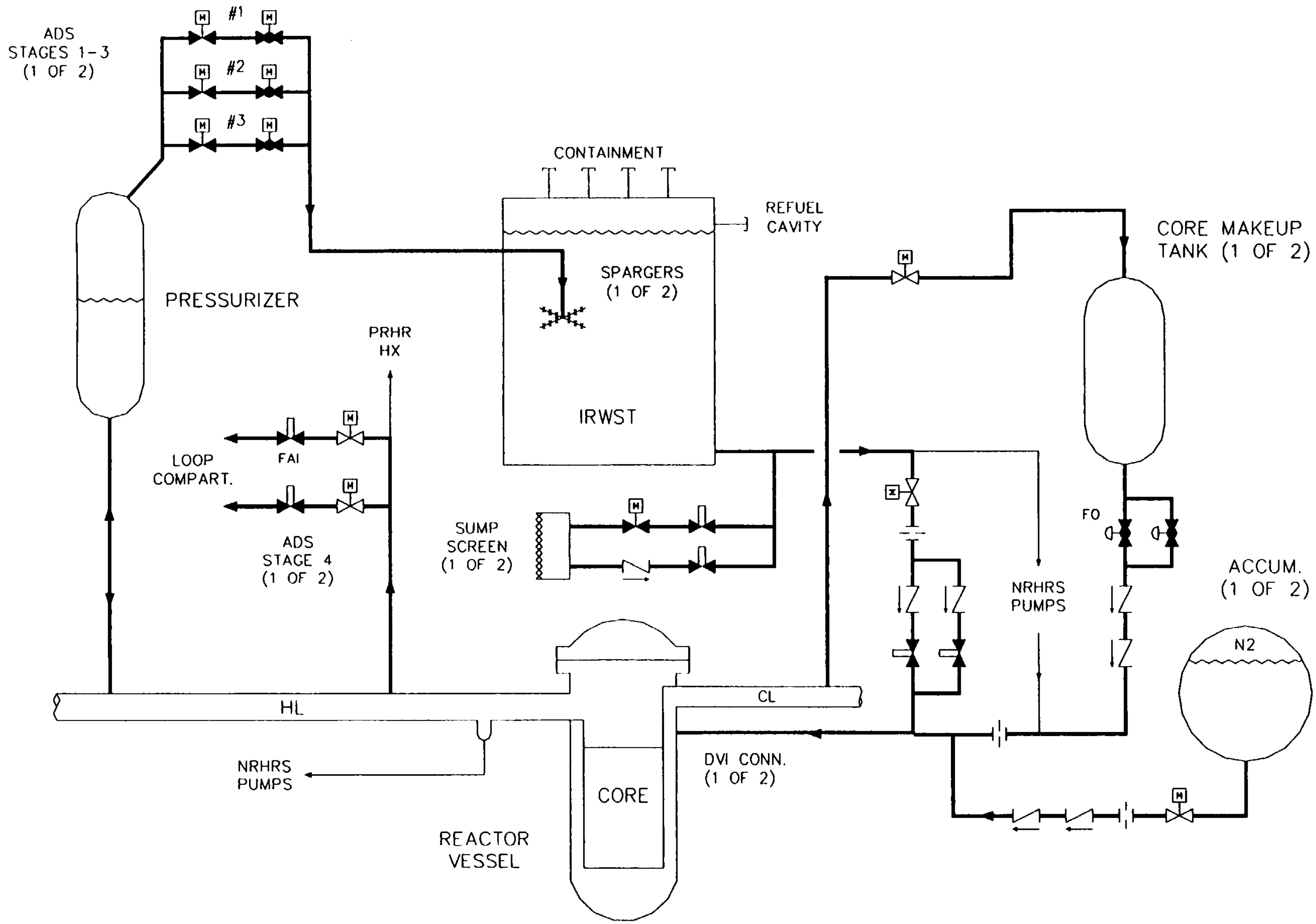



AP1000



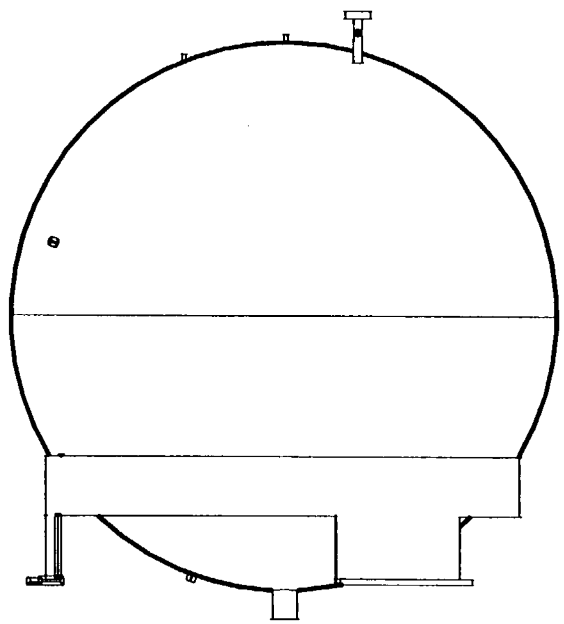

- PRHR Heat Transfer Capacity Increased 72%

# AP1000 Passive Safety Injection

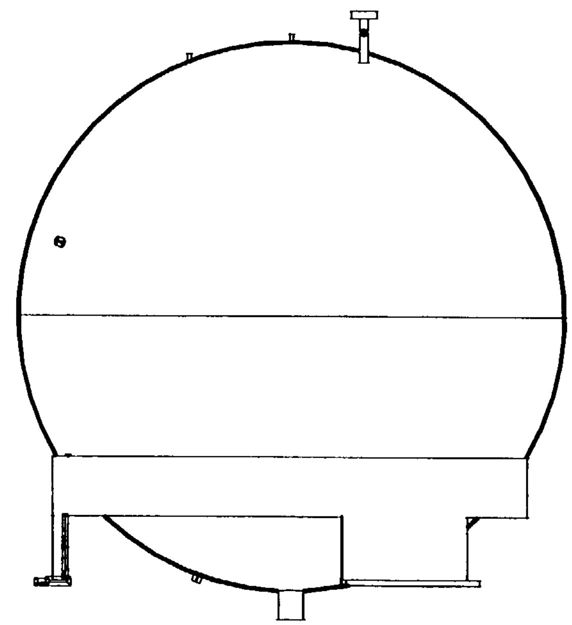


# Accumulators

AP600

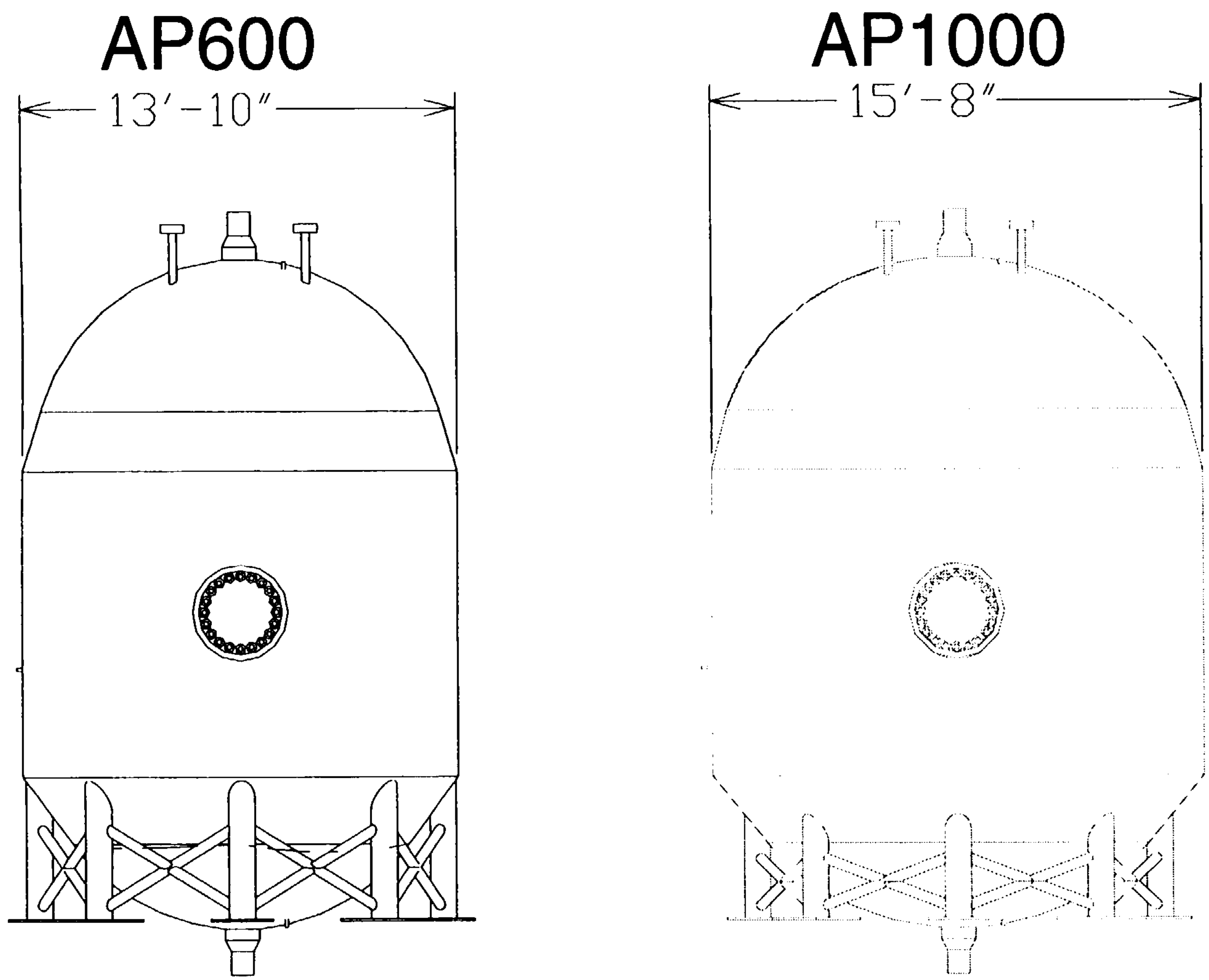


AP1000



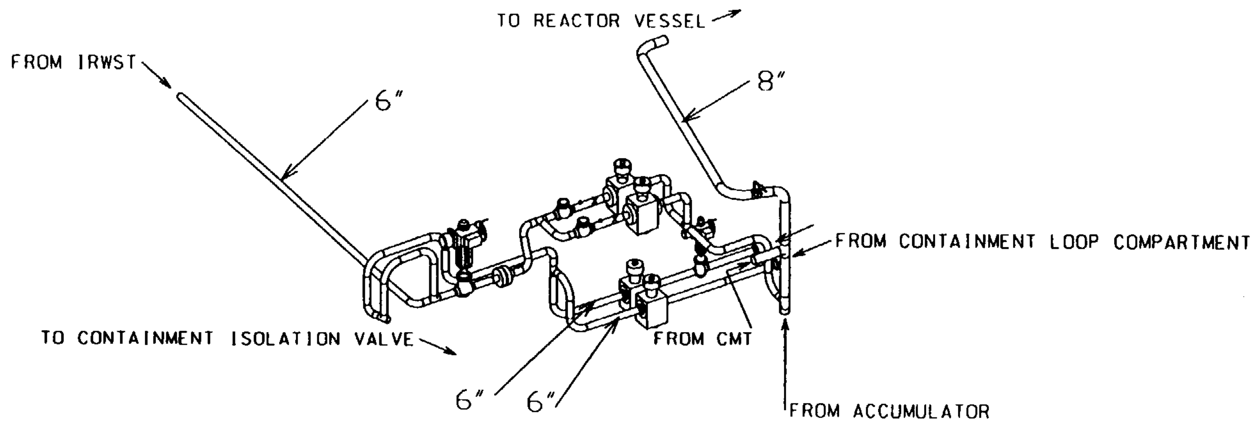
- Accumulator volume is 2000 $ft^3$ for both plant designs

# Core Makeup Tanks

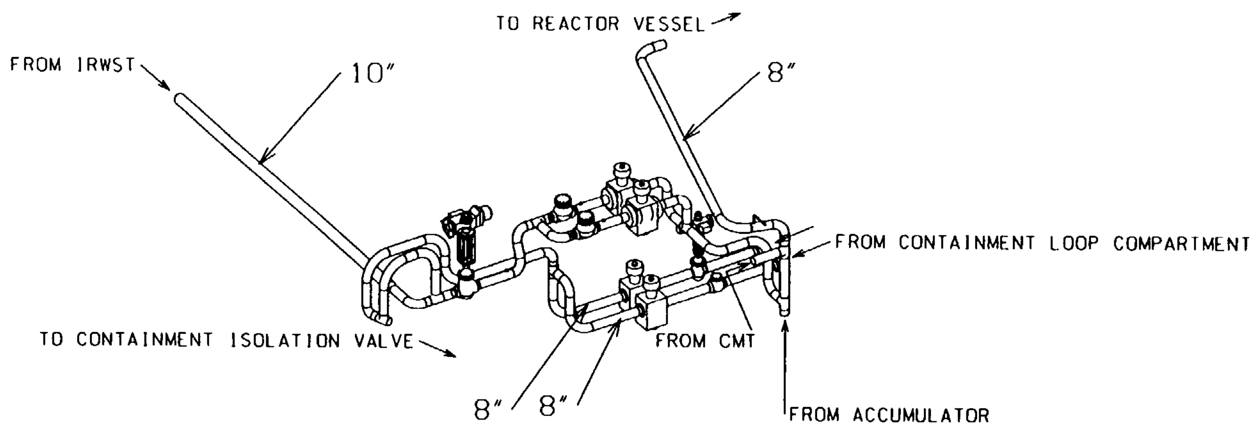



- Core Makeup Tank volume and flow rate is increased 25%
  - 2000 to 2500ft$^3$
  - Maintains AP600 margins for multiple failure events

# Comparison of IRWST Injection/DVI Line

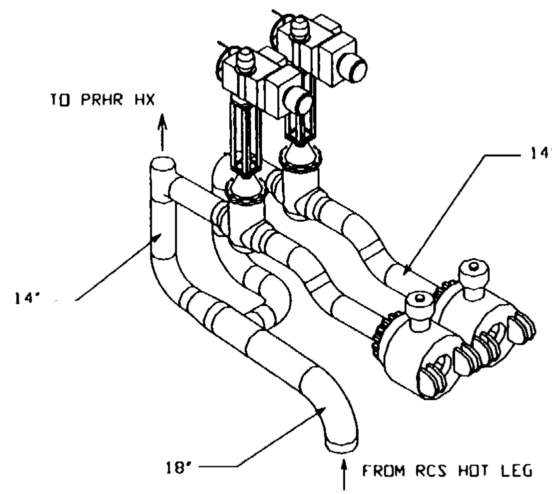



DVIA-AP600

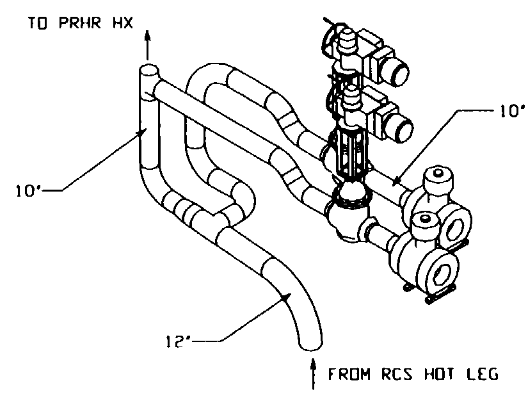



DVIA-1000

# Comparison of 4th Stage ADS




AP1000

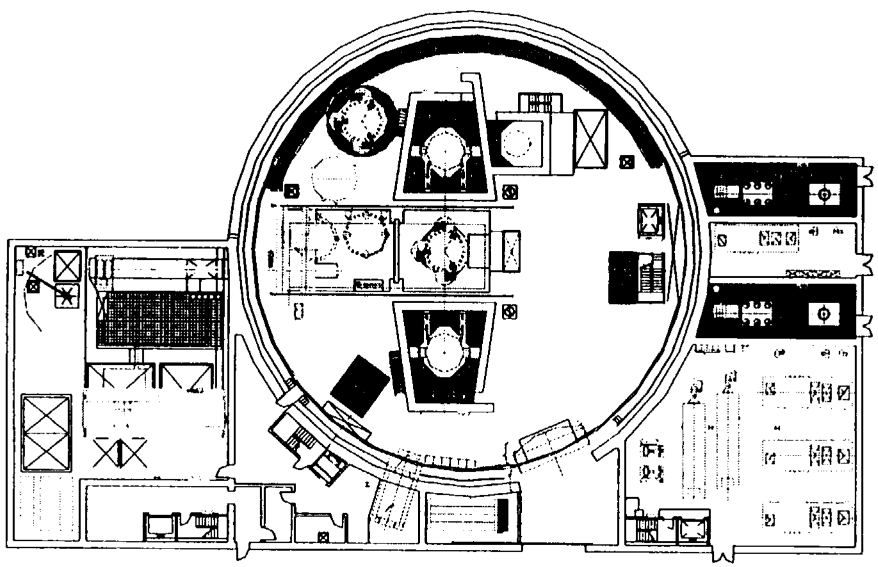



AP600

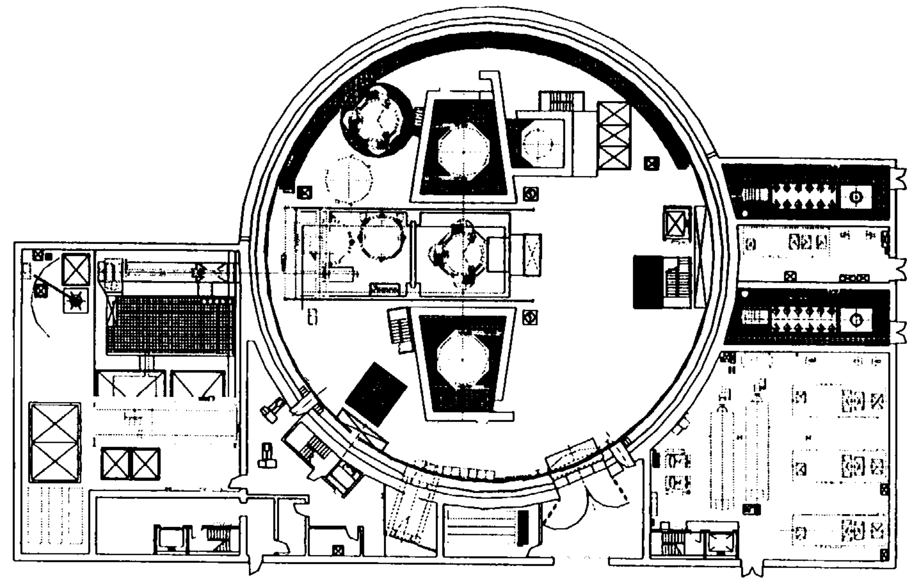
# AP1000 General Arrangement

## Plan at Elevation 135'

AP600



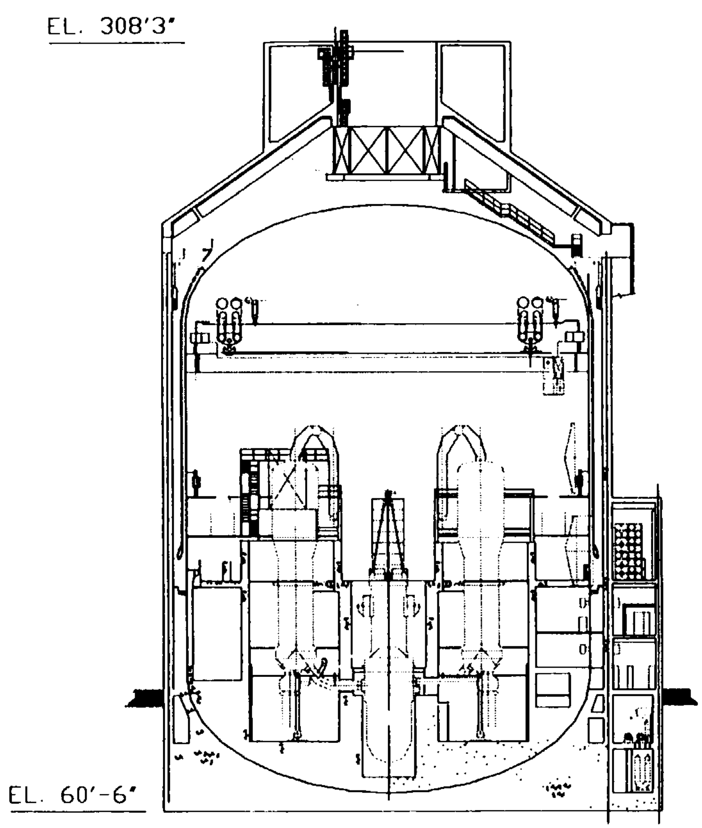
AP1000



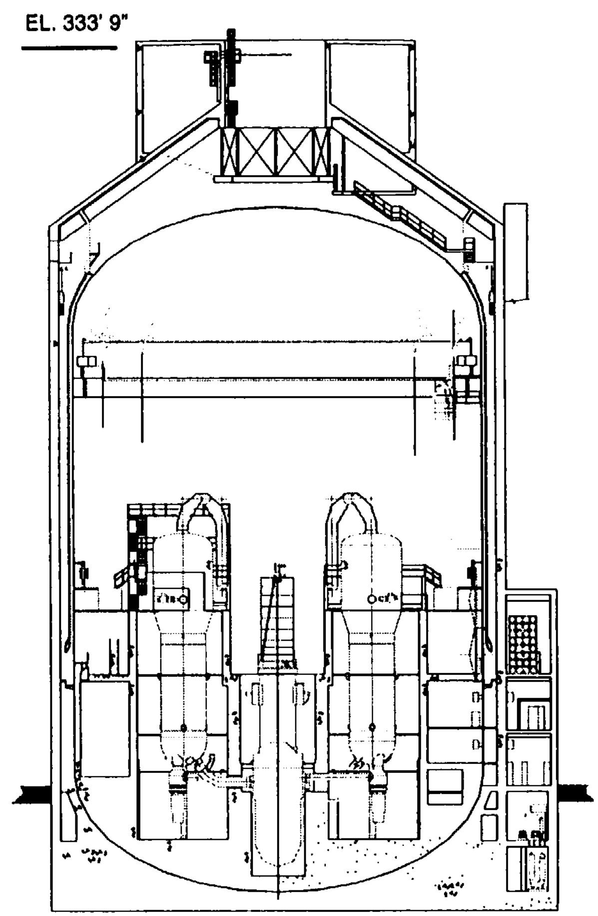
# AP1000 General Arrangement

## Containment Section View

AP600




AP1000



# Preliminary AP1000 Transient Analyses Using LOFTRAN Codes

Uriel Bachrach
Senior Engineer
Containment and Radiological Analysis
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# Events Analyzed

- Non LOCA Events
  - Loss of forced reactor coolant flow
  - Loss of AC Power to the plant auxiliaries
  - Loss of Normal Feedwater Flow
  - Feedline Rupture
- Steam Generator Tube Rupture

# Non LOCA and SGTR Analyses

Support and verify the following:

- Demonstrate Acceptable DNB Margin
  - Reactor coolant pump coast down
- Demonstrate RCS Heat Removal
  - Passive RHR Heat Exchanger
  - Steam Generator Inventory
- Pressurizer Performance
  - Margin to overfill
- Interaction Between Passive Systems

# Complete Loss RCS Flow

- Same assumptions and methods as AP600
  - Revised Thermal Design Procedure
  - Rod Drop Times ➔ Longer
    - Longer Fuel
    - Higher RCS Flow
  - Pump Coastdown ➔ Longer
    - Pump inertia increased by a factor of 3 over AP600 / EP1000
- **Acceptance Criteria**
  - RCS and SG pressures < 110% of Nominal
  - DNBR within acceptable limits

# Complete Loss RCS Flow
## Sequence of Events

Preliminary analysis show DNBR margin is similar for both plants

| | AP1000 | AP600 |
|---|---|---|
| **DNBR Limit (typical cell)** | **1.24** | **1.24** |
| **Minimum DNBR** | **1.447** | **1.484** |
| **DNBR Margin** | **13.6%** | **15.8%** |
| **Mass Flow (lbm/hr-ft$^2$)** | **$1.11 \times 10^6$** | **$0.78 \times 10^6$** |

# Complete Loss RCS Flow
## DNBR Correlation

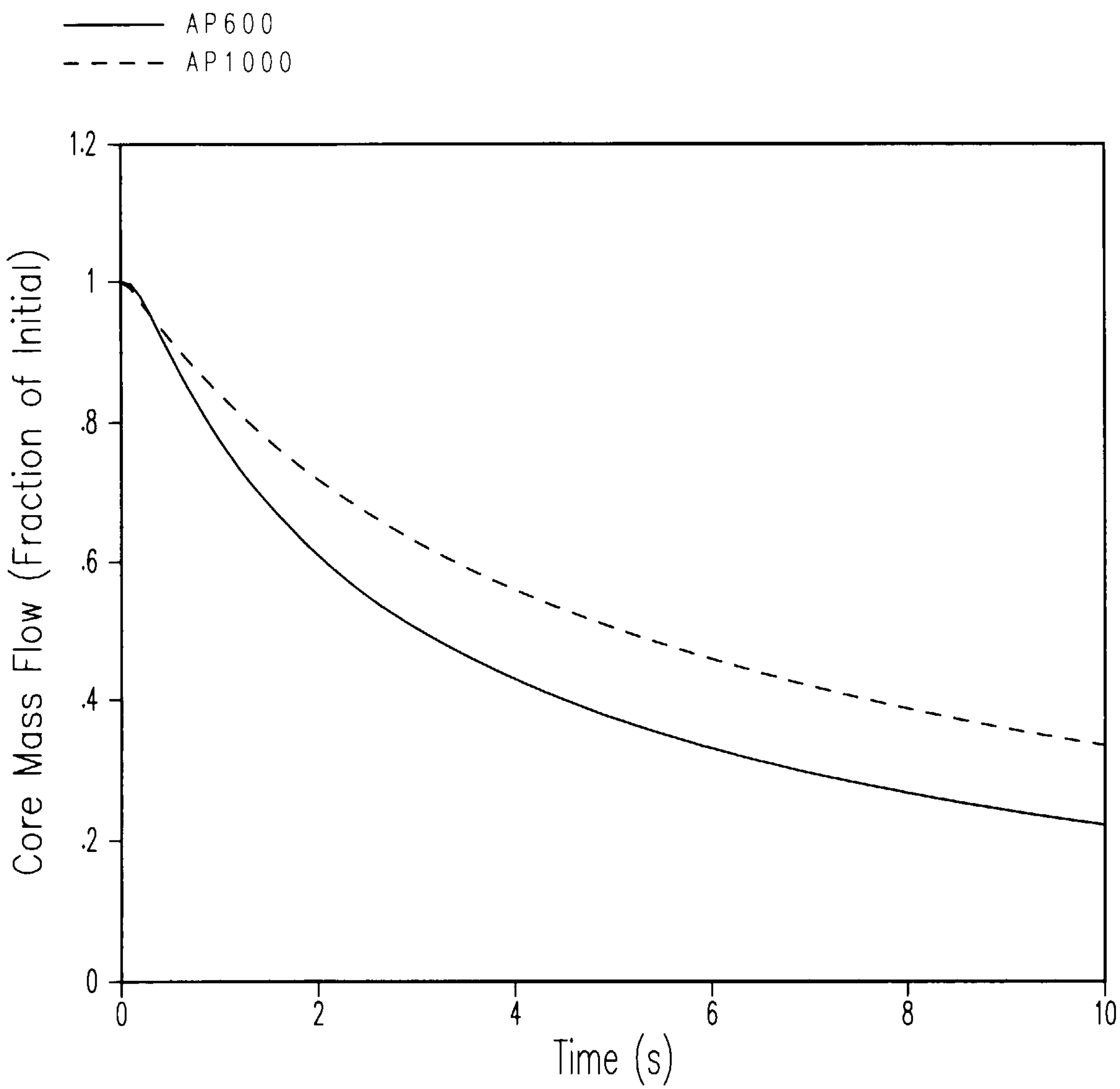
- AP600 mass velocity below limit of WRB-2 correlation ($<0.9 \times 10^6$ lbm/ft$^2$-hr)
  - DNB testing conducted
  - Multiplier developed to extend WRB-2 to lower flows
- AP1000 mass velocity above limit of WRB-2 correlation
  - Higher initial reactor coolant flow
  - Increased reactor coolant pump inertia
  - WRB-2 correlation can be applied with no penalty

# Complete Loss RCS Flow

## DNBR Correlation

- Revised Thermal Design Procedure (RTDP) used in conjunction with WRB-2 to calculate DNBR
- RTDP Quality limit of 25% exceeded for AP1000
- Existing test data available to extend RTDP application of WRB-2 for higher quality
  - Tests used to develop WRB-2 performed for quality up to 35%, but not used in formulating correlation
  - Extension of correlation planned prior to Design Certification of AP1000

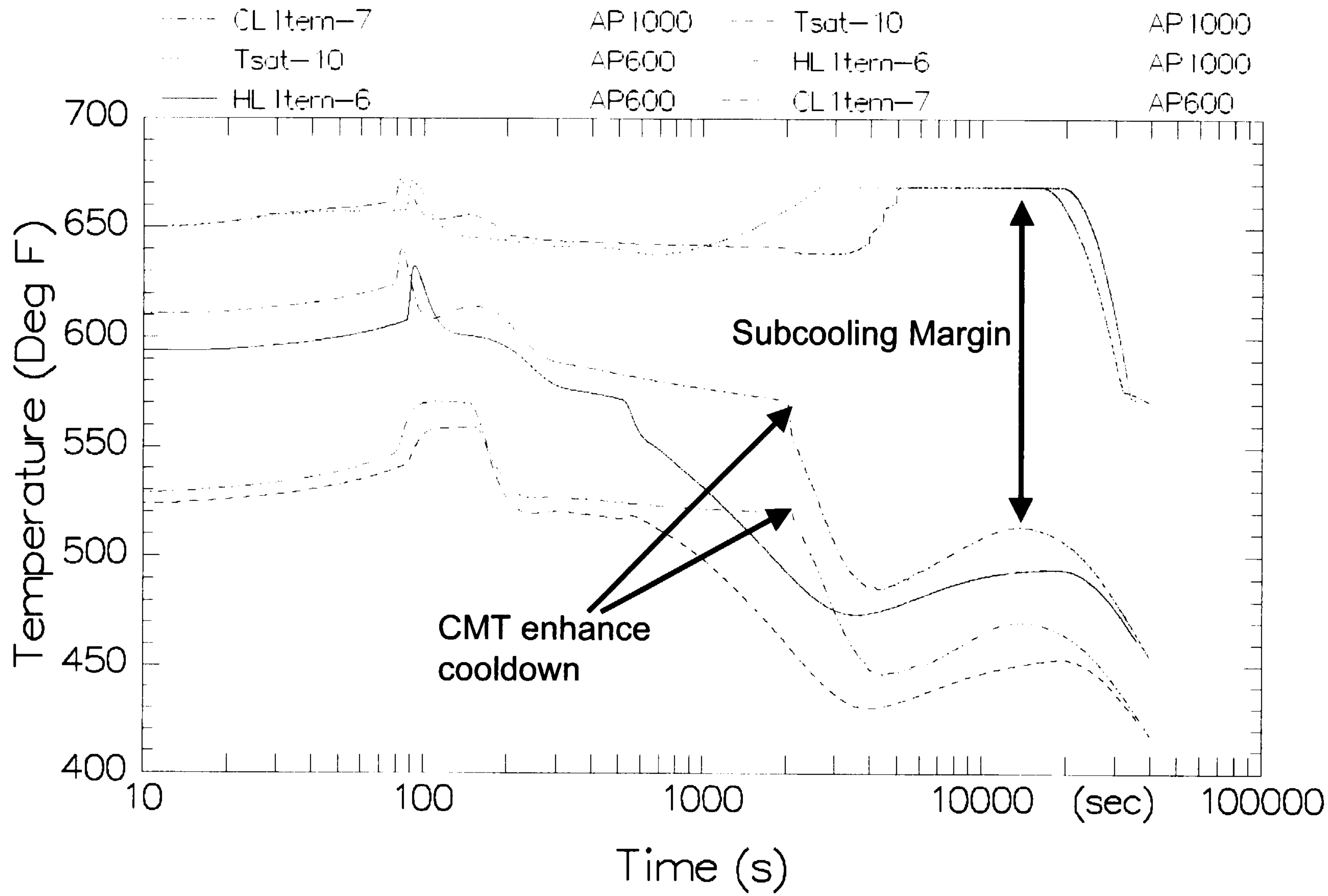
# Complete Loss RCS Flow
## Transient



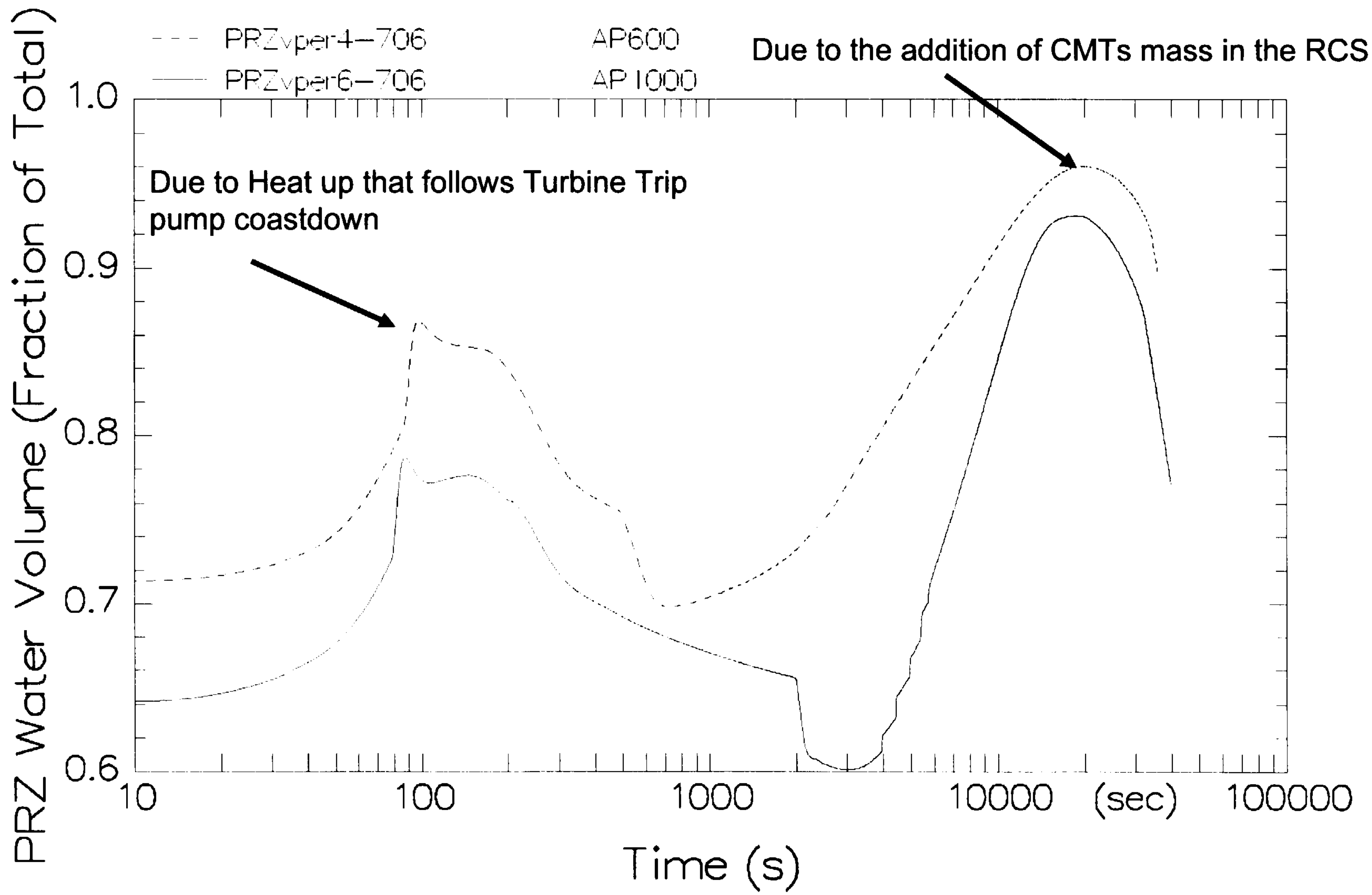
# Loss of AC Power

- Same assumptions and methods as AP600
- Acceptance Criteria
  - RCS and SG pressures < 110% of Nominal
  - No Fuel Failure
  - No Pressurizer Overfilling

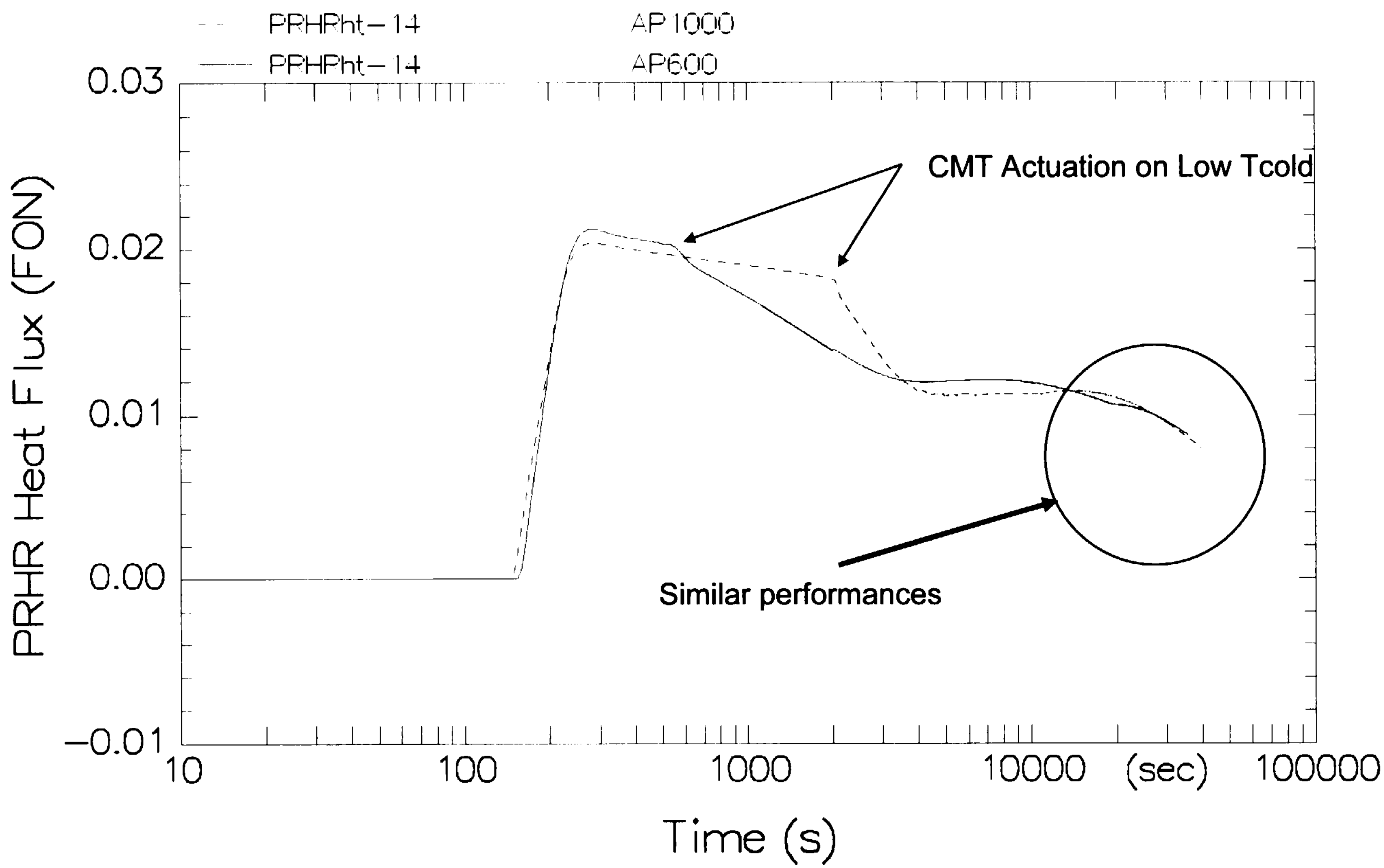
# Loss of AC Power - Transient



# Loss of AC Power - Transient



# Loss of AC Power - Transient



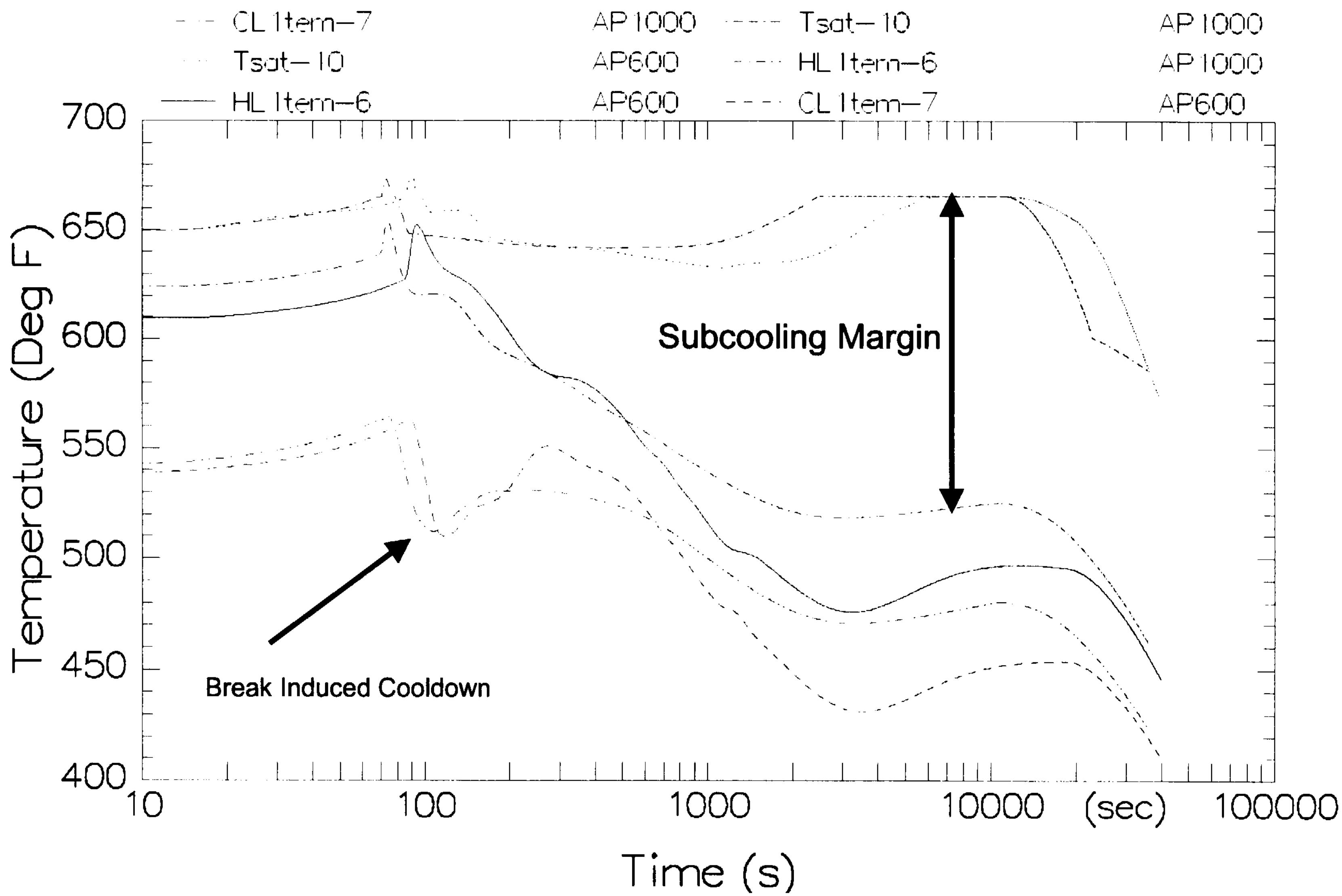
# Loss of Normal Feedwater

- Same assumptions and methods as AP600
- Transient similar to Loss of AC Power
- Acceptance Criteria
  - RCS and SG pressures < 110% of Nominal
  - No Fuel Failure
  - No Pressurizer Overfilling
- Results and phenomena similar to Loss of AC Power

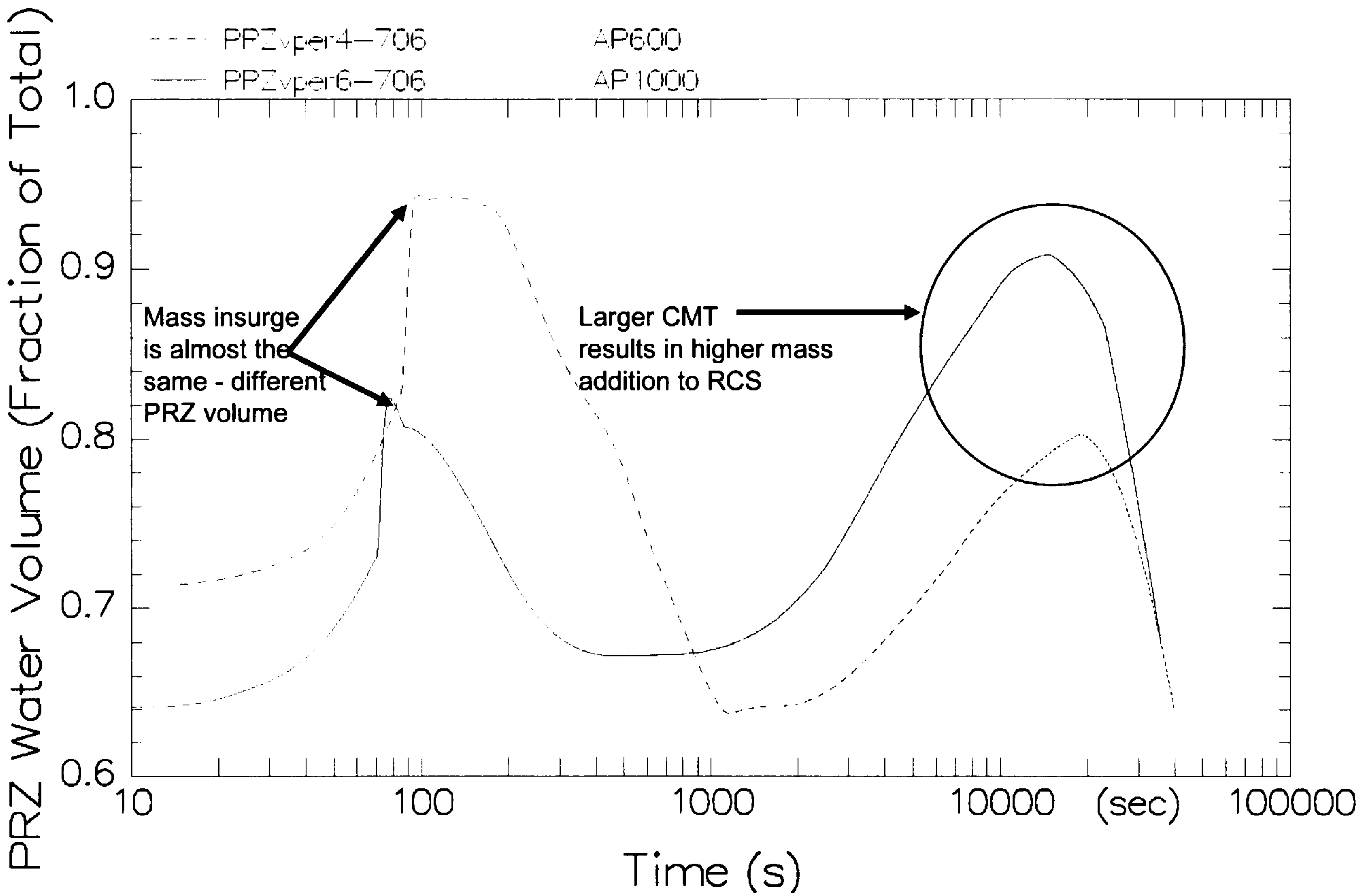
# Feedline Rupture

- Same assumptions and methods as AP600
- Acceptance Criteria
  - Feedline Break is a Condition IV event
    - Heat Transfer Capability (SG + PRHR) must assure
      - RCS and SG pressures < 110% of Nominal
      - Core Cooling

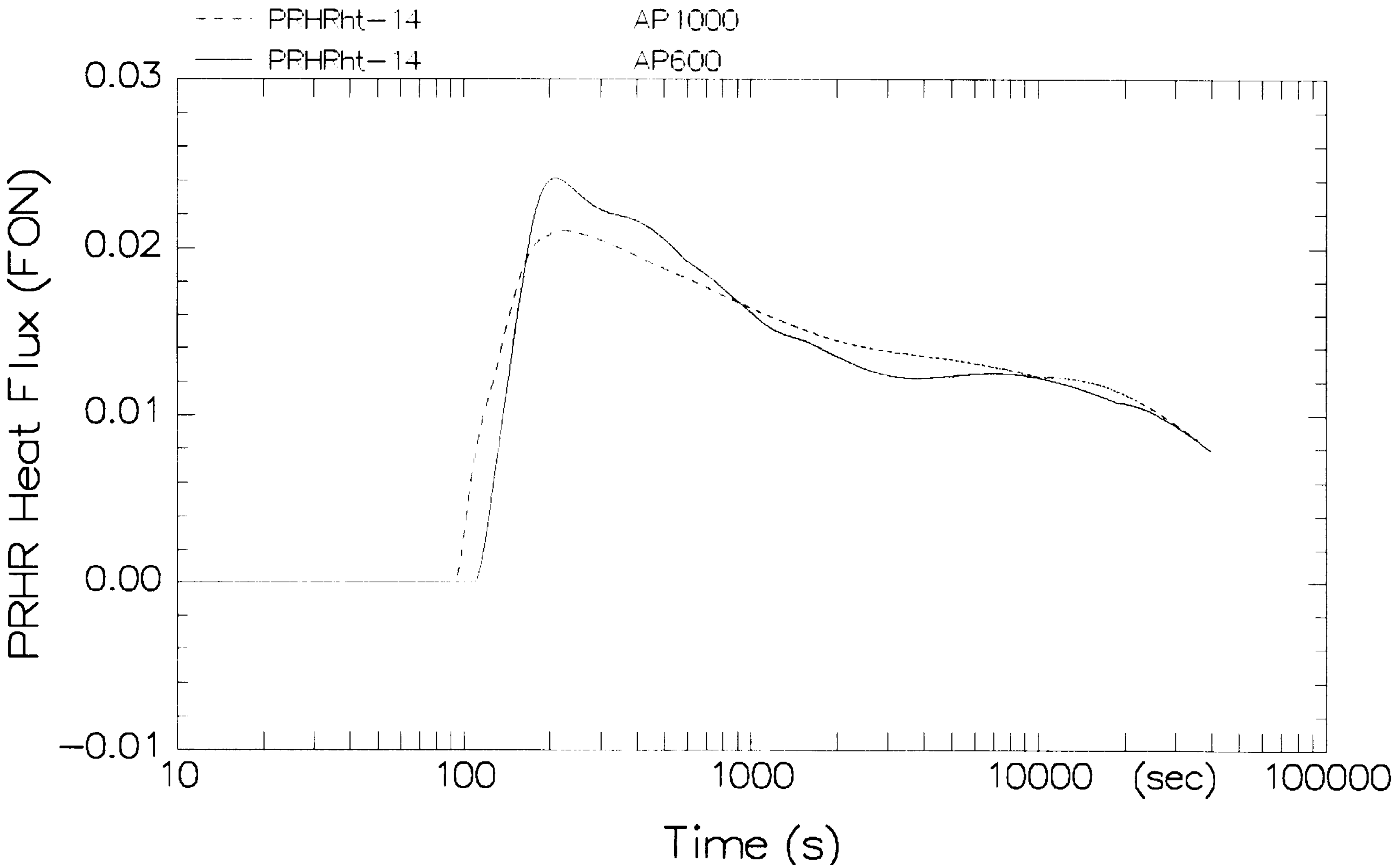
# Feedline Rupture - Comparison



# Feedline Rupture - Comparison



# Feedline Rupture - Comparison



# Transient Analysis Conclusions

- The transients analyzed show that the AP1000 plant response is very similar to AP600
- Large pressurizer steam volume and steam generator inventory provides margin for initial portion of the transients analyzed (before PRHR actuation)
- PRHR heat transfer increase assures the residual heat removal function and provides RCS cooldown and depressurization similar to AP600
- CMTs provides RCS boration following the RCS cooldown
- Safety margins are equivalent to AP600

# Steam Generator Tube Rupture

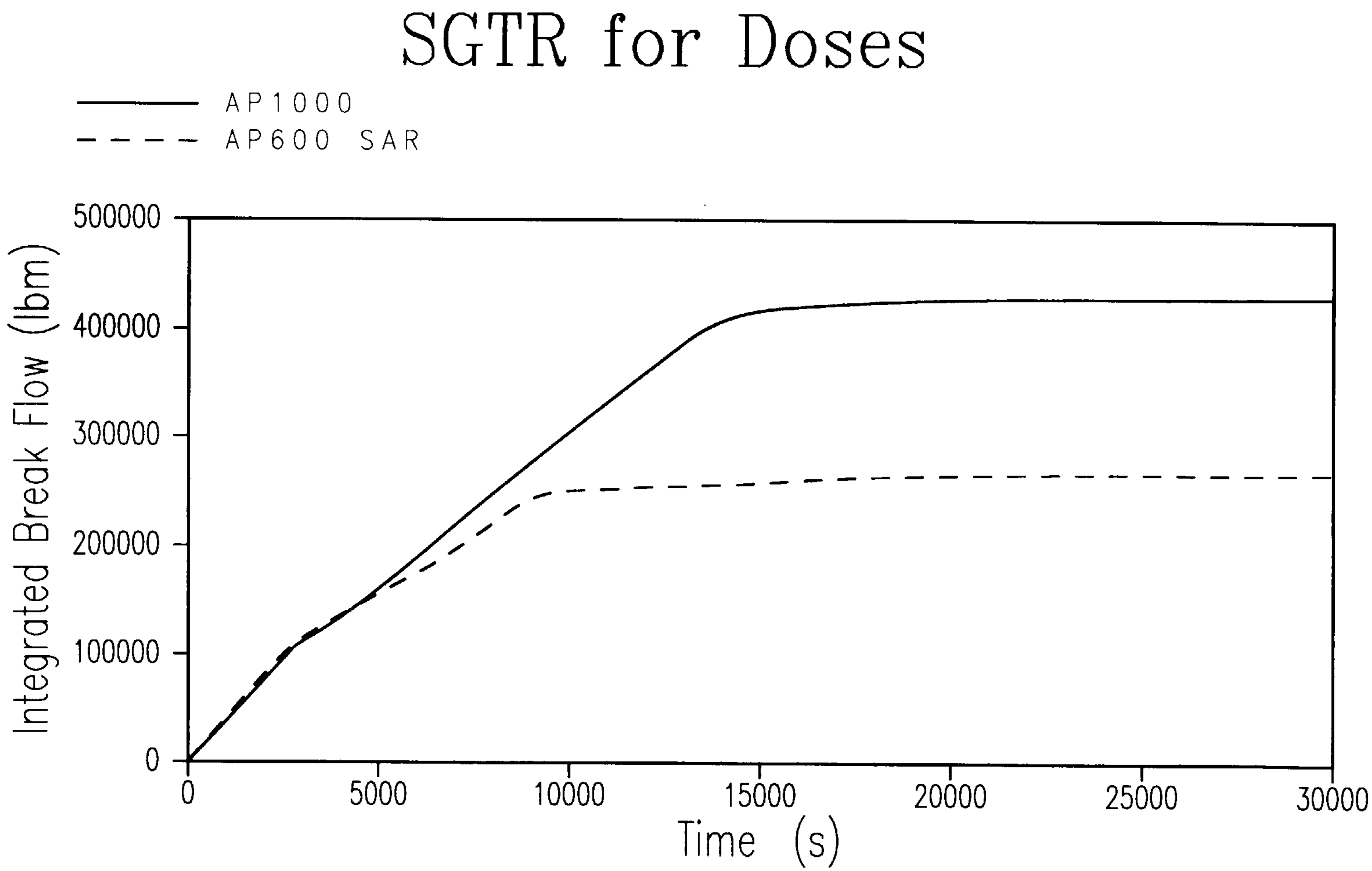
- The purpose of the SGTR analysis performed is to demonstrate the ability of the passive safety systems to mitigate the consequences
  - Offsite doses within acceptable limits

# Steam Generator Tube Rupture

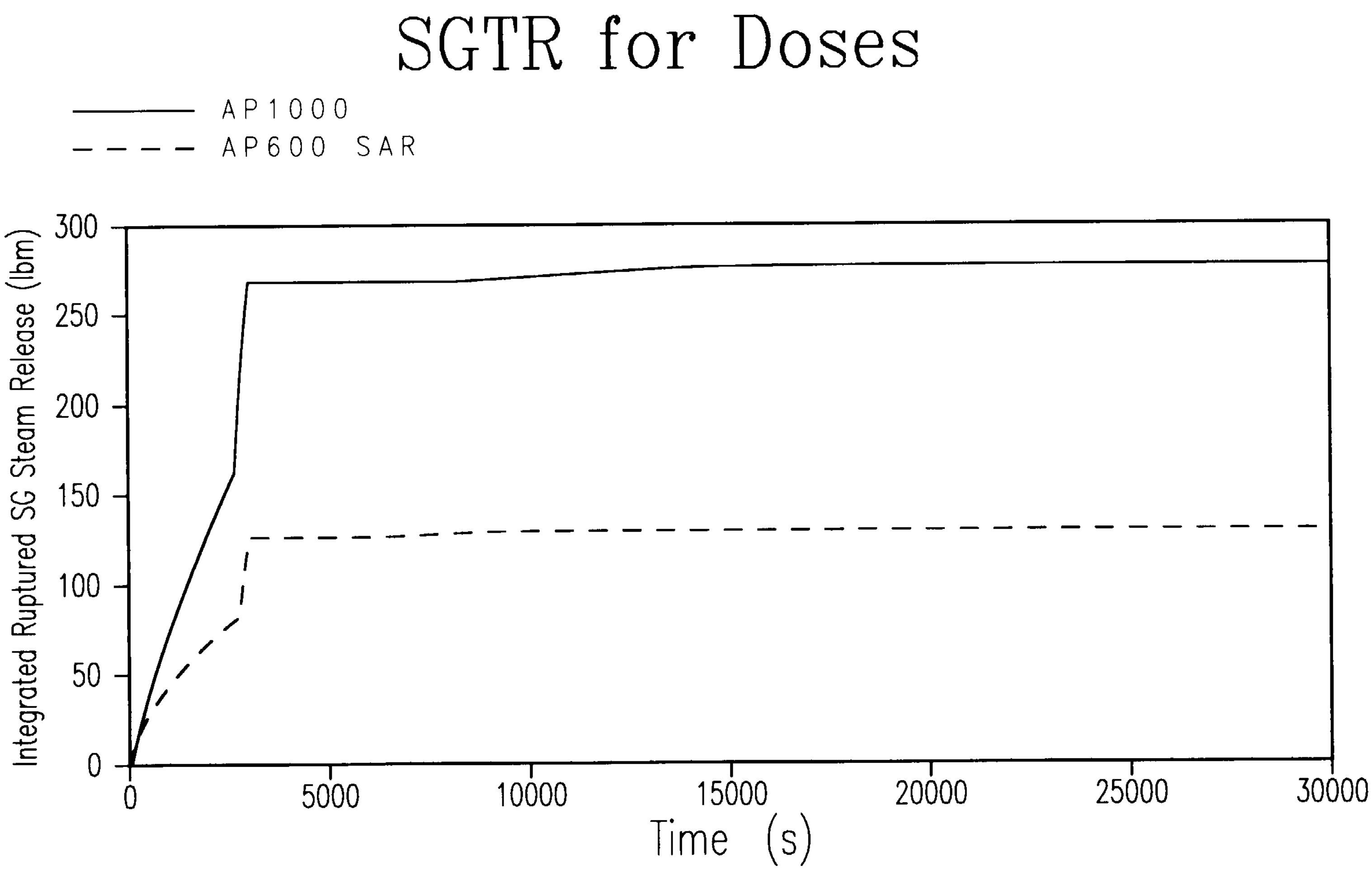
- Response similar to AP600
  - Passive systems terminate break flow
- Increased releases resulting from higher power
  - Consistent with results of uprating operating plants

| Plant | Time Break Flow Flashing Stops | Total Flashed Break Flow After Trip | Total Ruptured SG Steam Releases After Trip | Total Break Flow |
|---|---|---|---|---|
| AP1000 | 3407 sec | 7351.0 | 324600 lbm | 427300 lbm |
| AP600 | 3216 sec | 5052.4 lbm | 144800 lbm | 264900 lbm |

# SGTR - Transient



# SGTR - Transient



# Steam Generator Tube Rupture

- Off-site doses are well within established limits
  - Increase by approximately a factor of 1.65 due to increased break flow and releases (and higher initial noble gas activity in coolant)

| | AP600 Calculated TEDE Dose (rem) | AP1000 Estimated TEDE Dose (rem) | AP600 Reported TEDE Dose (rem) | TEDE Dose Limit (rem) |
|---|---|---|---|---|
| **Accident-initiated iodine spike** | | | | |
| Site boundary | 0.54 | 0.9 | 1.5 | 2.5 |
| Low population zone | 0.08 | 0.13 | 0.3 | 2.5 |
| **Pre-accident iodine spike** | | | | |
| Site boundary | 0.85 | 1.4 | 3.0 | 25 |
| Low population zone | 0.13 | 0.21 | 0.45 | 25 |

# SGTR Analysis Conclusions

- The transient analyzed shows that the AP1000 plant response is similar to AP600
- Higher power results in expected increase in releases
- Safety margins are maintained

# LOFTRAN

- LOFTRAN approved by NRC for licensing basis analysis in 1983
- LOFTRAN nodes “hardwired” in a PWR configuration with pre-set protection system
    - User input controls everything else
        - Geometric data
        - Plant conditions
        - Protection system setpoints
- LOFTRAN is used for 2,3 and 4 loop operating plants
    - Flexibility of user controlled modeling allows analyses of plants with significantly different sizes and power levels

# LOFTRAN

- Modified LOFTRAN code (LOFTTR2) approved by NRC for licensing basis SGTR analysis in 1987 (WCAP-10698)
  - New SGTR break flow model
  - Updated secondary representation
  - Operator action, PORV, SI and AFW controls

# LOFTRAN

- LOFTRAN codes modified for AP600 (described in WCAP-14234)
  - Additional protection system controls
  - PRHR and CMT models
    - Preset connections to RCS
    - User controls everything else
      - ◆ Geometric data
      - ◆ Conditions
      - ◆ Actuation setpoints
      - ◆ Correlations

# LOFTRAN

- AP600 analyses of non-LOCA and SGTR performed with modified LOFTRAN codes accepted by NRC (NUREG-1512)
- CMT model did not need adjustments to match test data
- PRHR correlations set based on PRHR tests
  - Verified against ROSA tests in blind calculations

# LOFTRAN

- AP1000 configuration easily modeled with AP600 LOFTRAN version
  - Similar to using standard LOFTRAN for 2, 3 and 4 loop operating plants at different power levels etc.

# LOFTRAN

- Documentation to be provided to NRC for running AP600 versions of LOFTRAN codes
  - Description of input/output variables in standard LOFTRAN
  - Description of input/output variables added for standard LOFTTR2
  - Description of input/output variables added in AP600 LOFTRAN versions
  - Preliminary LOFTRAN base input listing developed for AP1000
  - Input listings for sample transients

# AP1000 SBLOCA Scoping Analysis w/NOTRUMP-AP600

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# Objectives

- Provide an overview of the preliminary SBLOCA analyses results
- Provide a synopsis of the applicable documentation associated with the NOTRUMP version approved for AP600 application
- Discuss the code transmittal effort and associated documentation

# AP1000 SBLOCA Overview

- Same assumptions utilized as for AP600
  - 10 CFR Appendix K based analyses
  - NOTRUMP code validated against AP600 tests
- Acceptance Criteria
  - Peak Clad Temperature < 2200 ºF
- Additional Passive Plant Considerations
  - Results should exhibit similar behavior as AP600
  - Large margins over operating plants

# AP1000 SBLOCA Overview

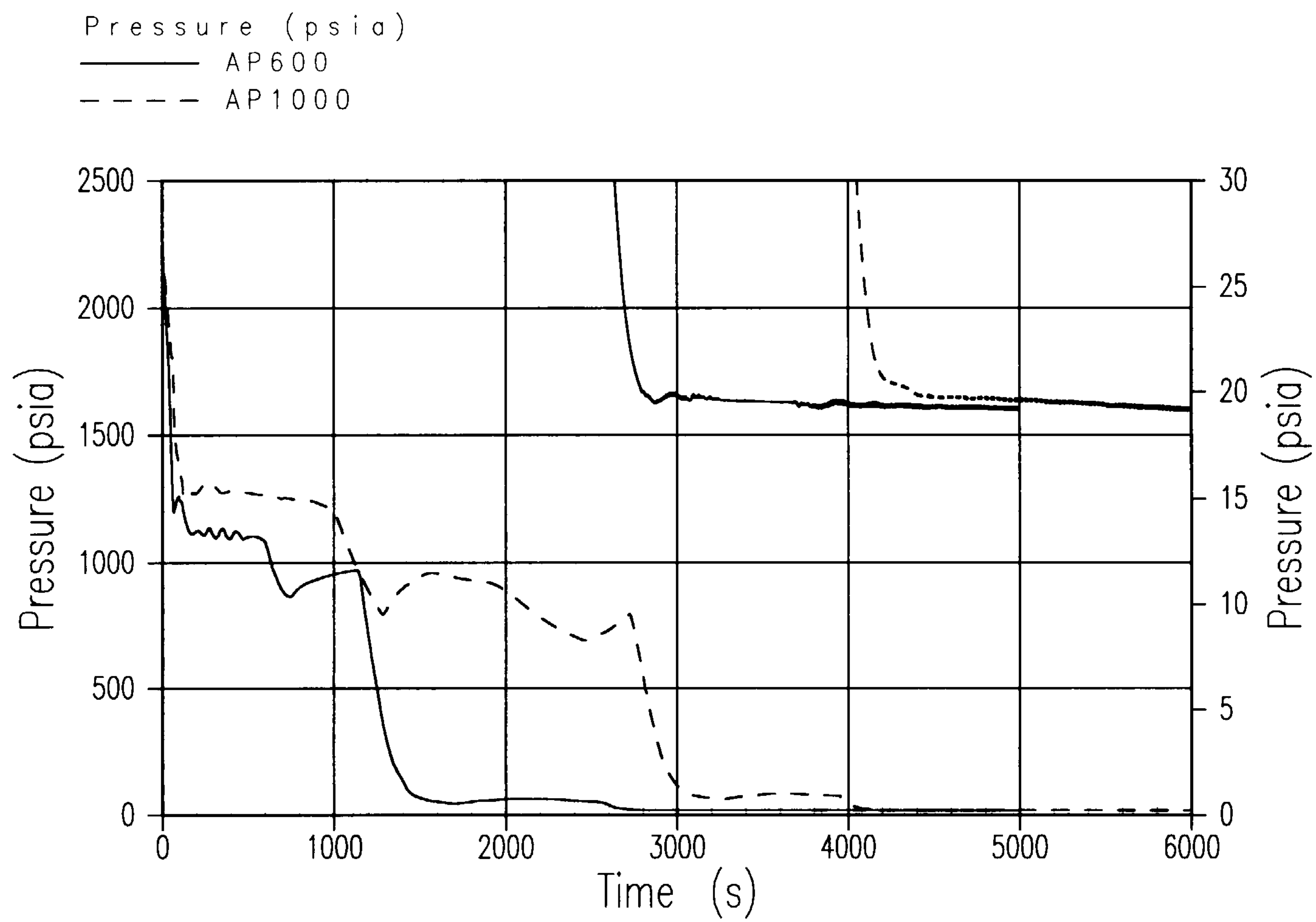
- AP600 plant model modified to reflect design changes
  - Geometrical changes to reflect component sizing
  - Initial conditions changed
  - Core nodalization changed to represent 14 foot core
- Lack of momentum flux model in NOTRUMP addressed differently
  - AP600 model utilized IRWST level penalty approach
  - AP1000 model utilizes ADS-4 flow path resistance Increase during the non-critical flow period
    - Results demonstrated to be comparable
    - ADS-4 resistance increase based on AP600 detailed momentum flux model assessments
      - ◆ AP1000 model resistance increase expected to be smaller due to design modifications

# AP1000 SBLOCA Results Overview

- Several SBLOCA analyses were performed to compare the AP600 and AP1000 plant performance
  - 2-Inch Cold Leg Break
    - Reference case
  - Double-Ended DVI Line Break (4-Inch Vessel Orifice)
    - Most limiting accident scenario due to loss of a PXS train
  - Double-Ended DVI Line Break At Elevated Containment Pressure
    - Demonstrate impact on IRWST injection characteristics
  - Inadvertent Actuation Of The Automatic Depressurization System (a.k.a. Inadvertent ADS)
    - Places greatest demand on plant ADS performance

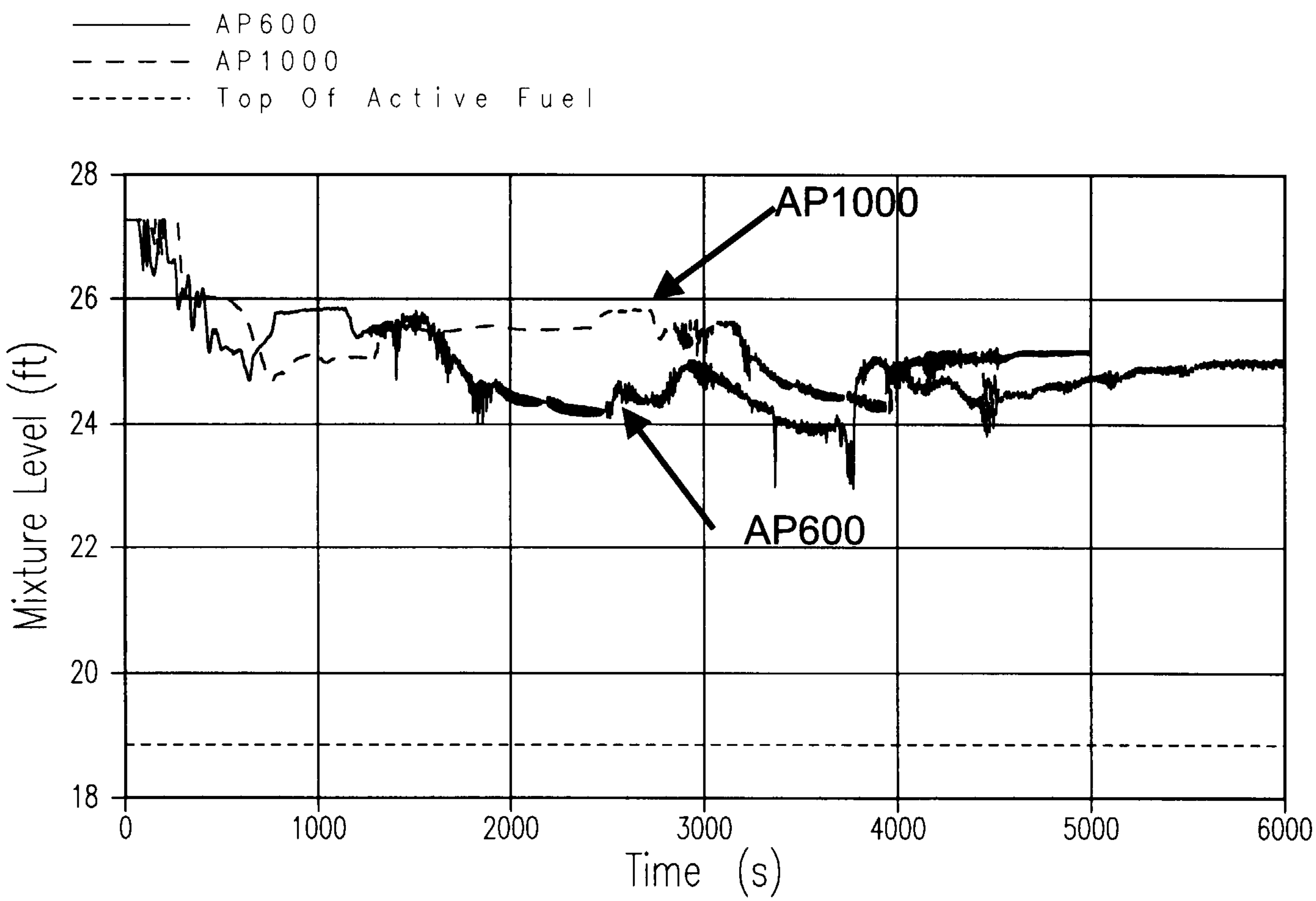
# AP1000 SBLOCA Results Overview

## *2-Inch Cold Leg Break - RCS Pressure*



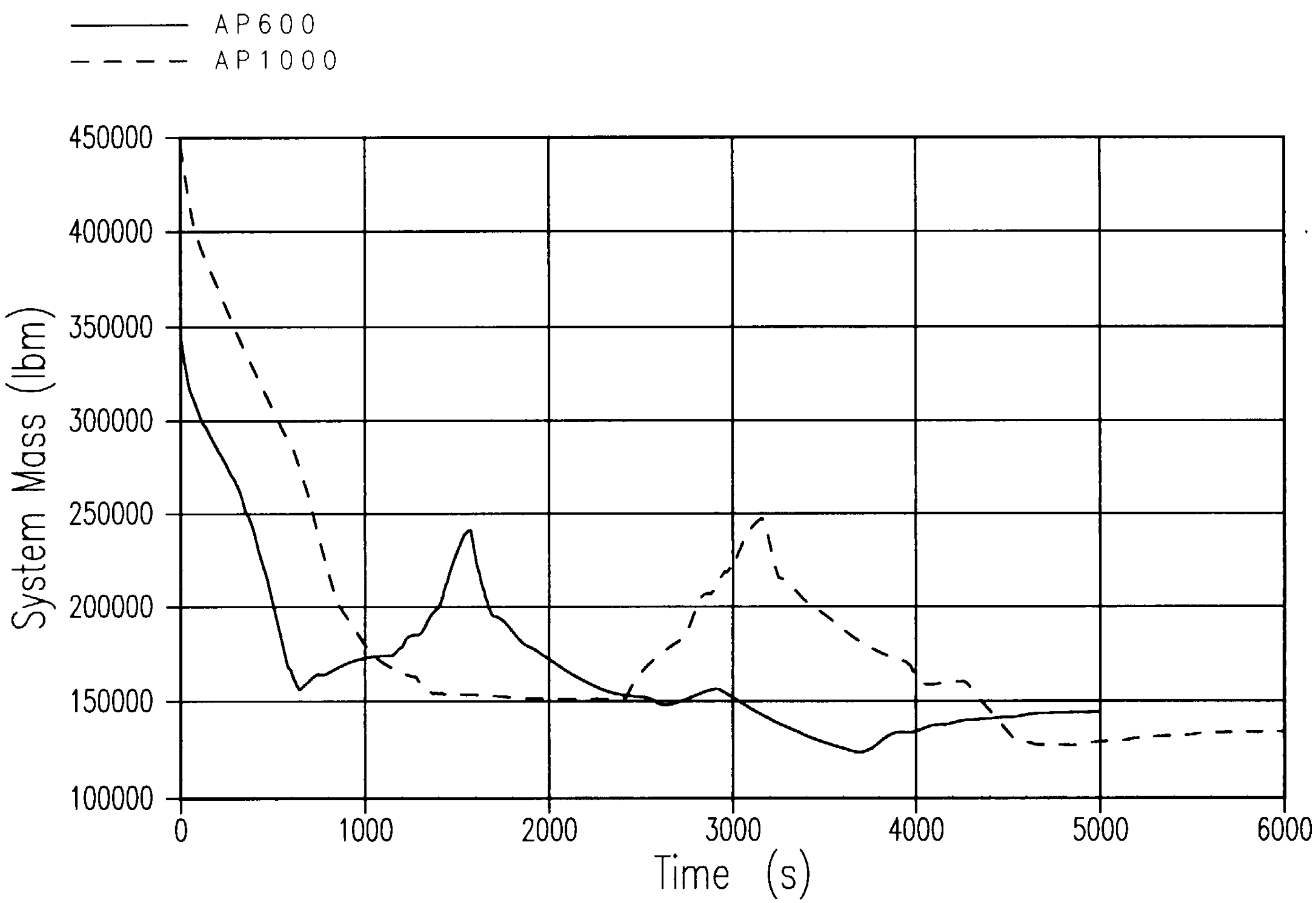
# AP1000 SBLOCA Results Overview

***2-Inch Cold Leg Break - Core/Upper Plenum Mixture Level***



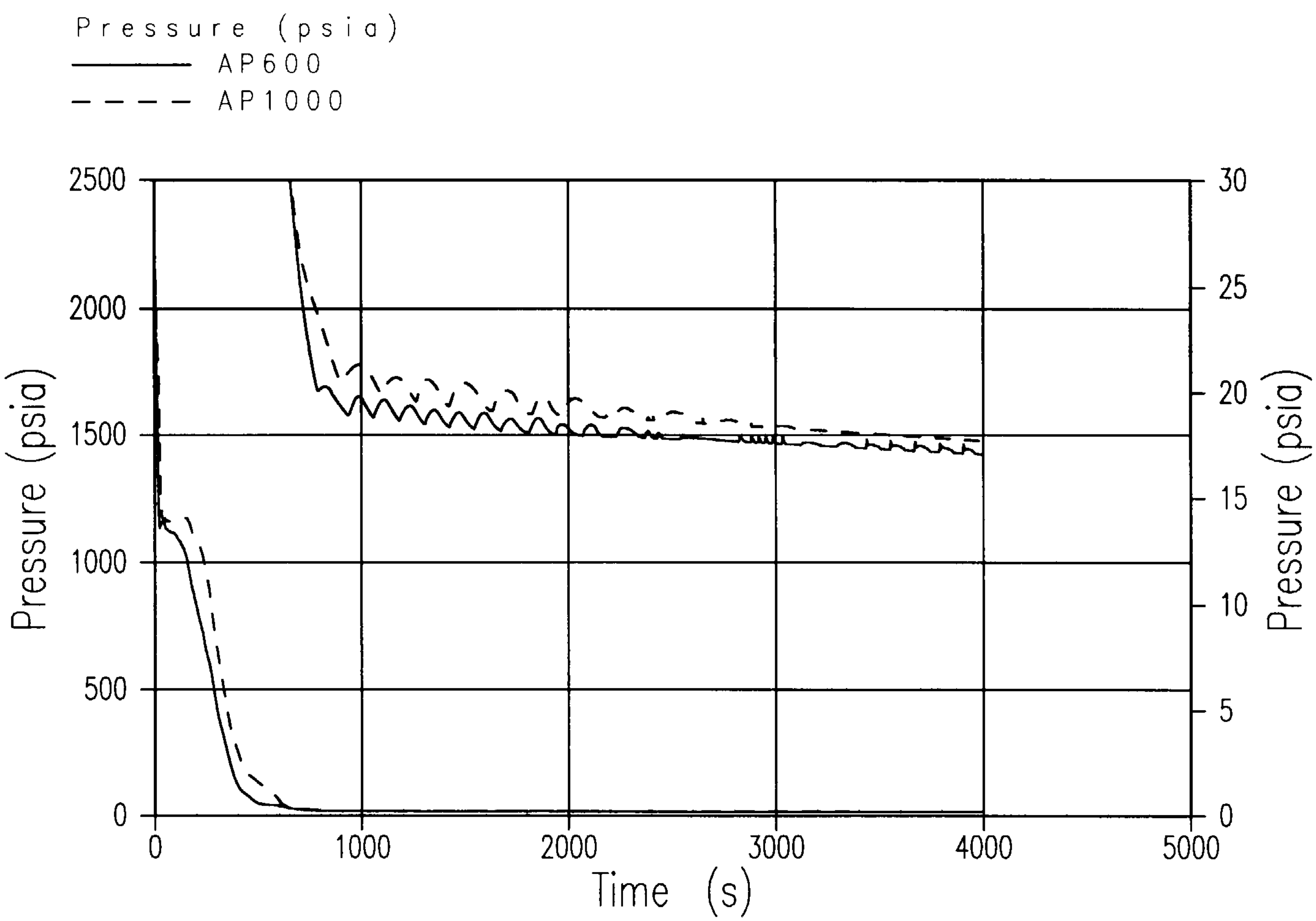
# AP1000 SBLOCA Results Overview

***2-Inch Cold Leg Break - RCS Inventory***



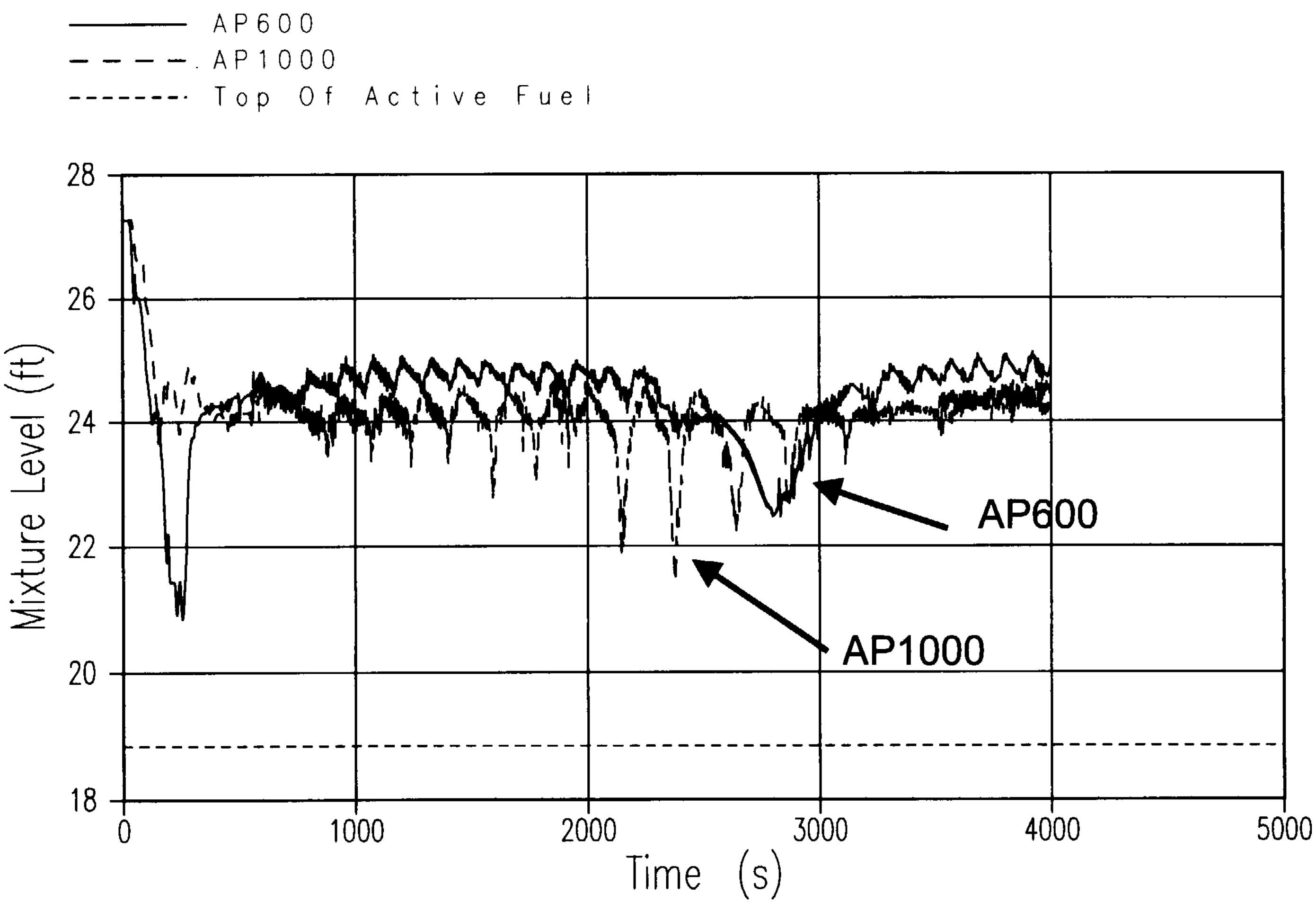
# AP1000 SBLOCA Results Overview

## *DE-DVI (Base) - RCS Pressure*



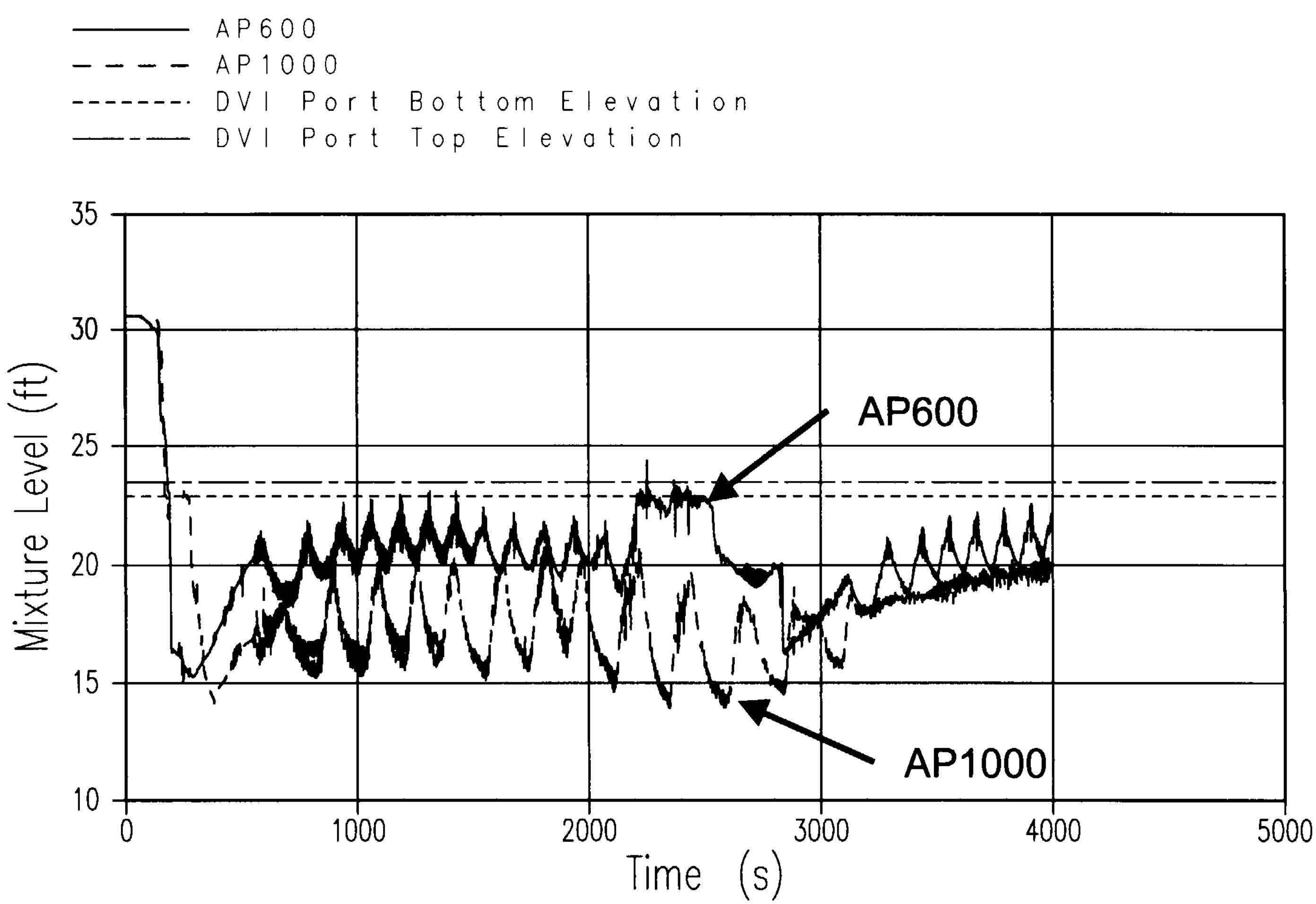
# AP1000 SBLOCA Results Overview

## *DE-DVI (Base) - Core/Upper Plenum Mixture Level*



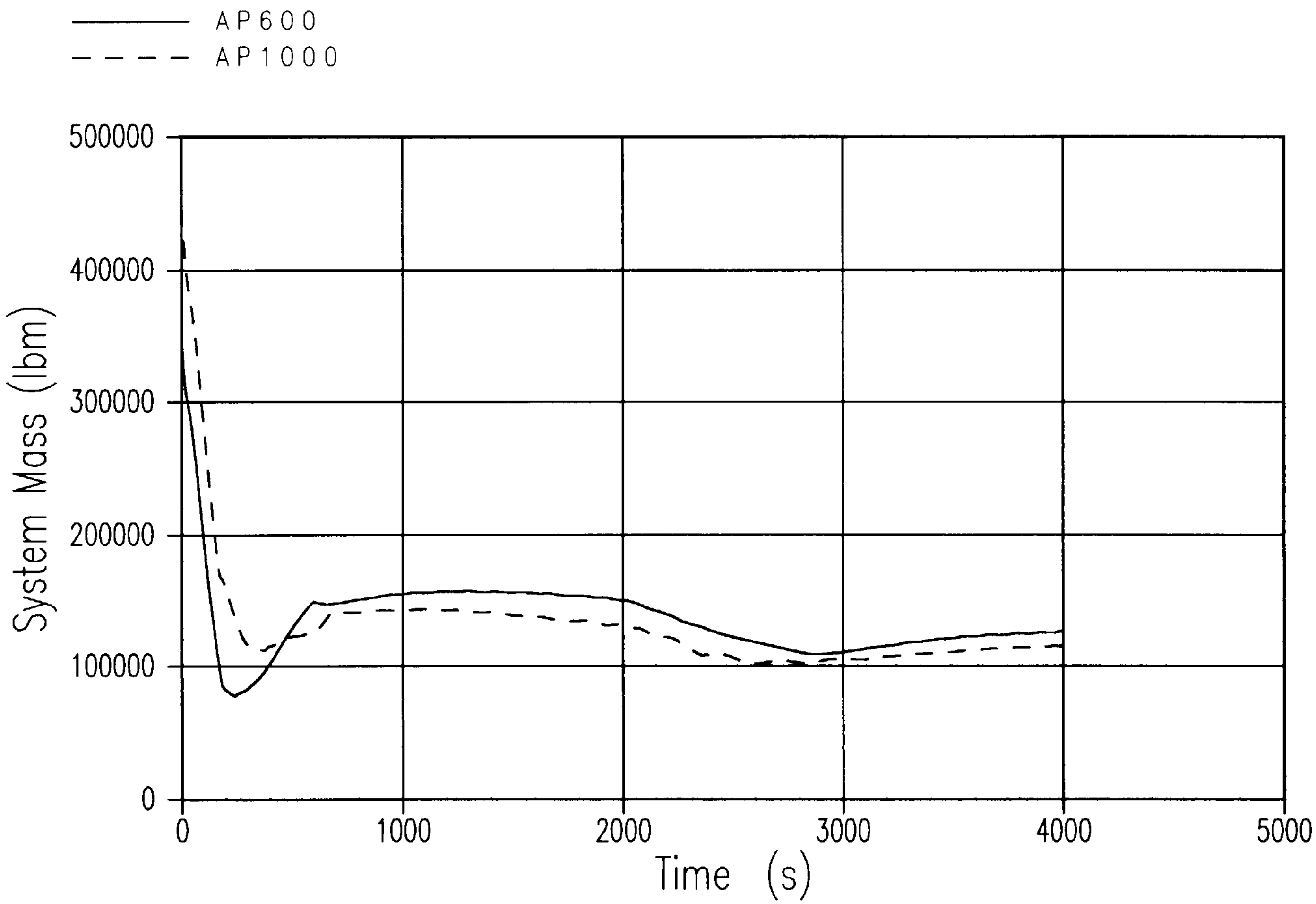
# AP1000 SBLOCA Results Overview

## *DE-DVI (Base) - Downcomer Mixture Level*



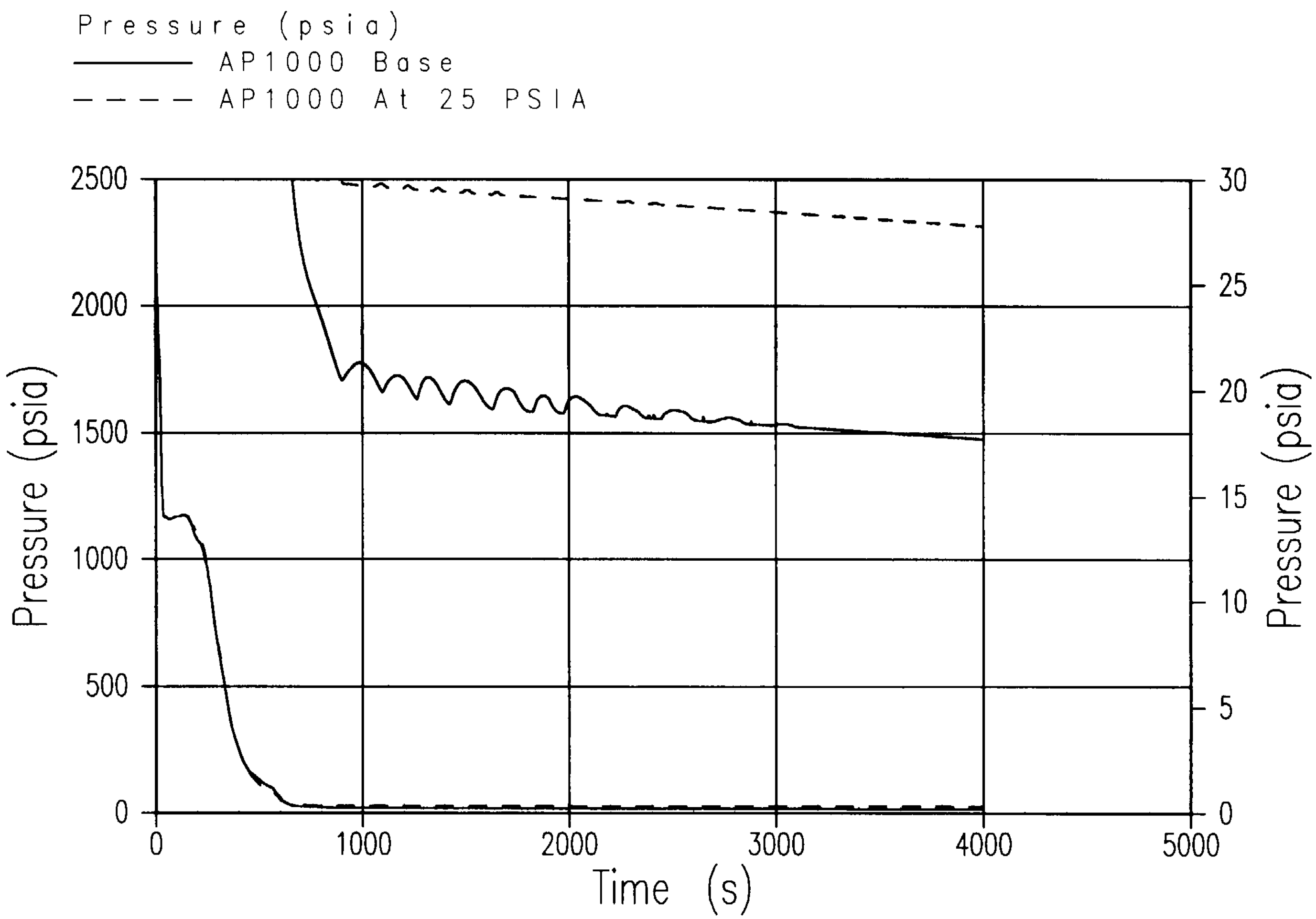
# AP1000 SBLOCA Results Overview

***DE-DVI (Base) - RCS Inventory***



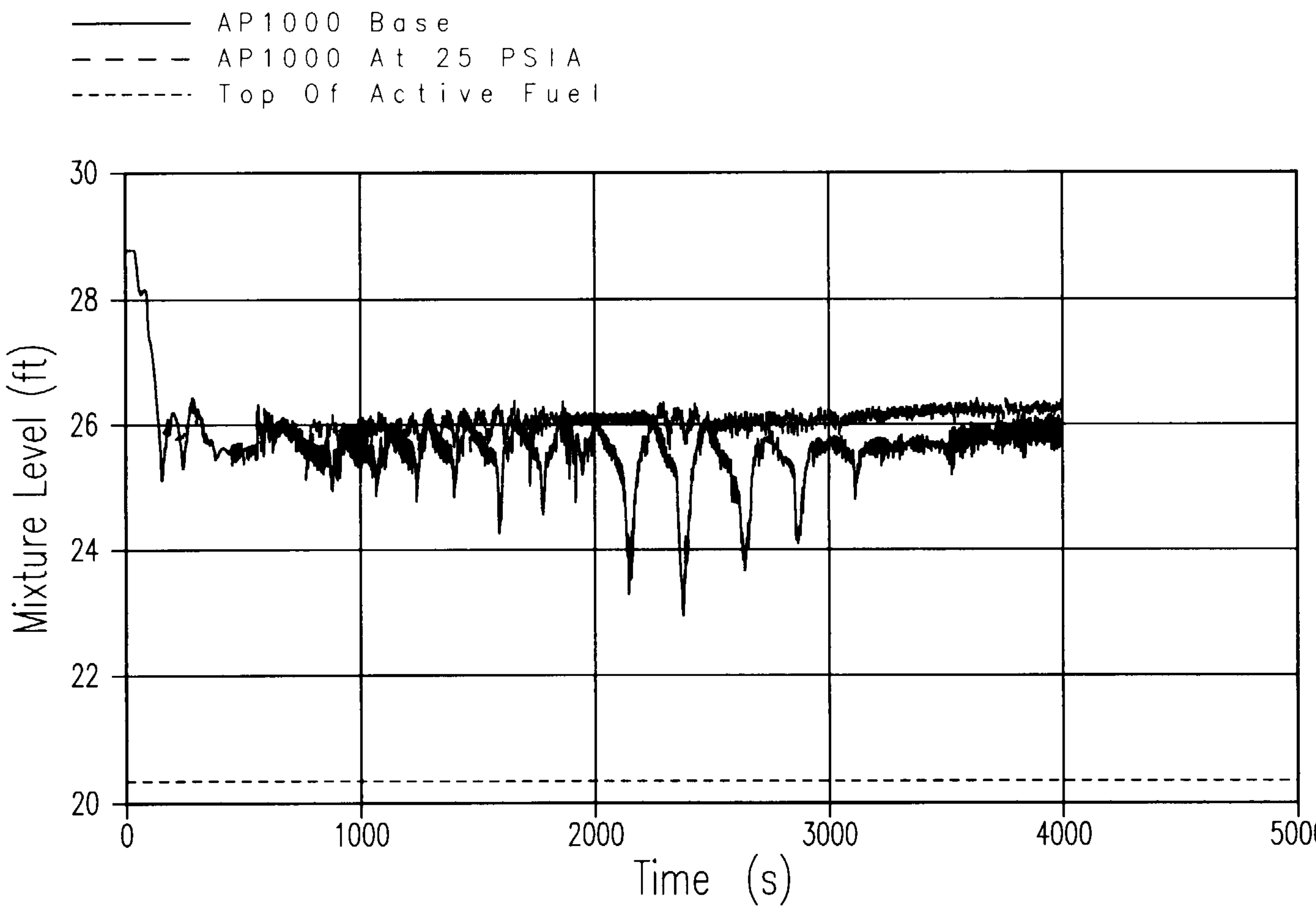
# AP1000 SBLOCA Results Overview

## *DE-DVI (Elevated Pressure) - RCS Pressure*



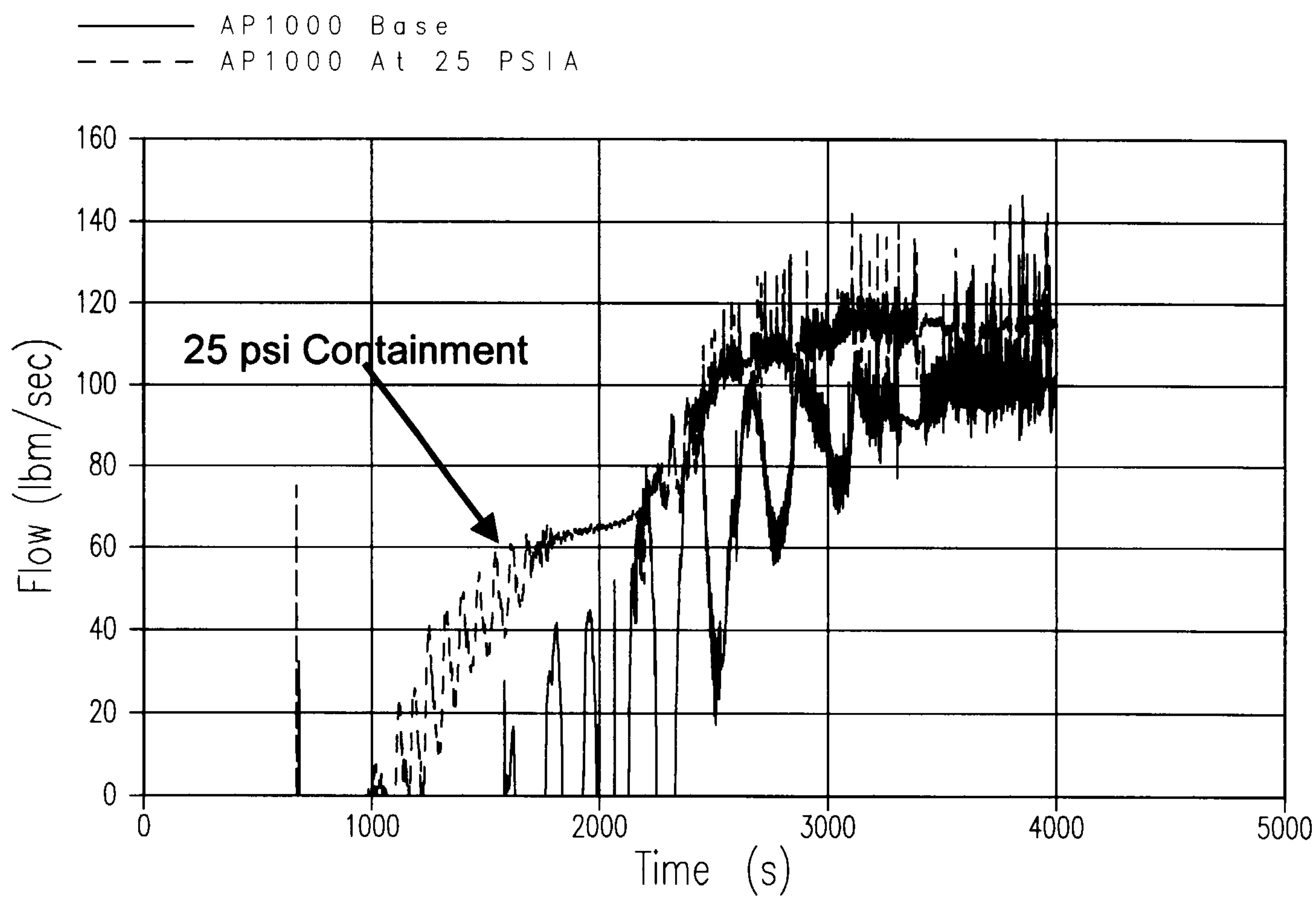
# AP1000 SBLOCA Results Overview

## *DE-DVI (Elevated Pressure) - Core/Upper Plenum Mixture Level*



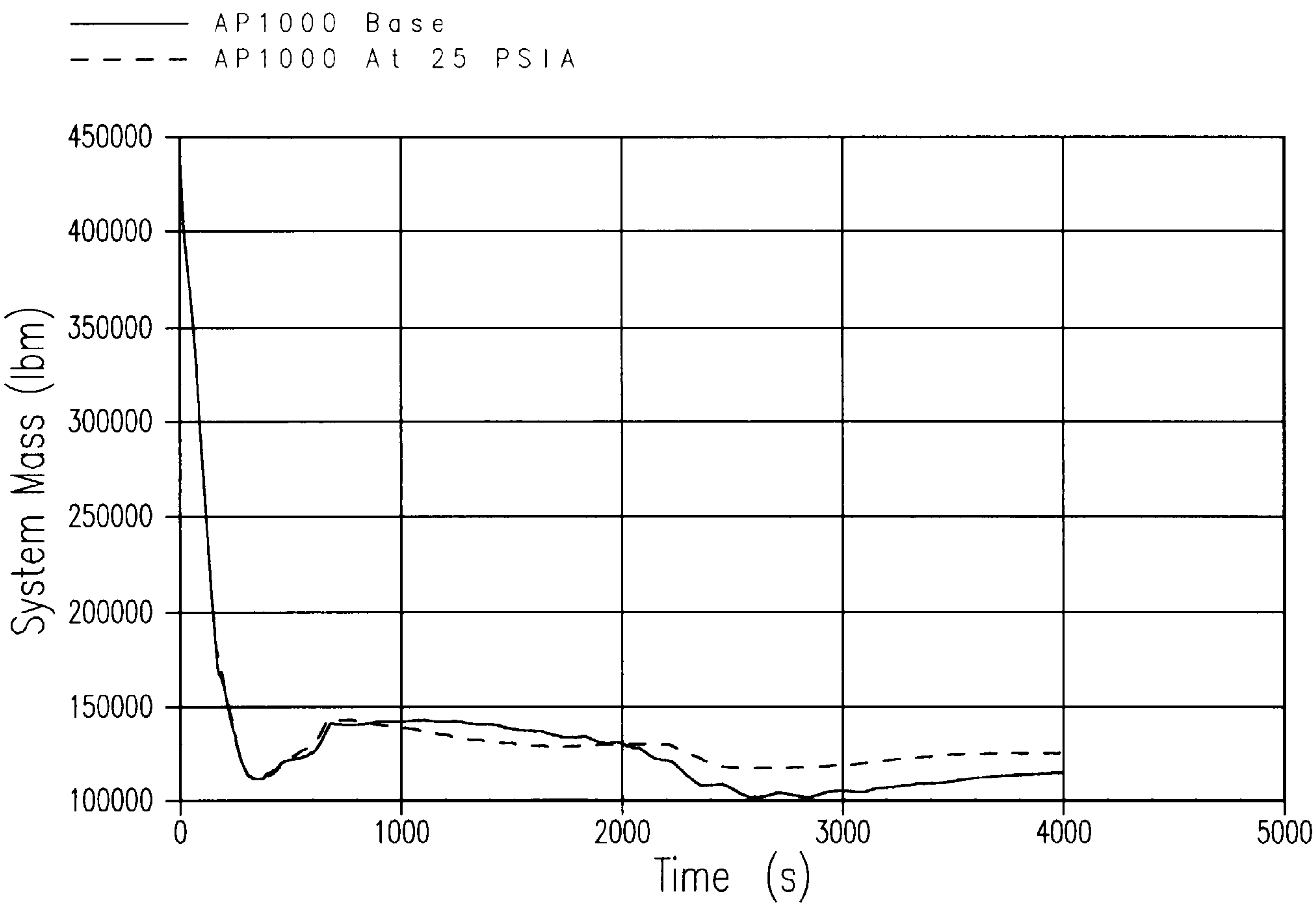
# AP1000 SBLOCA Results Overview

***DE-DVI (Elevated Pressure) - Intact IRWST Injection***



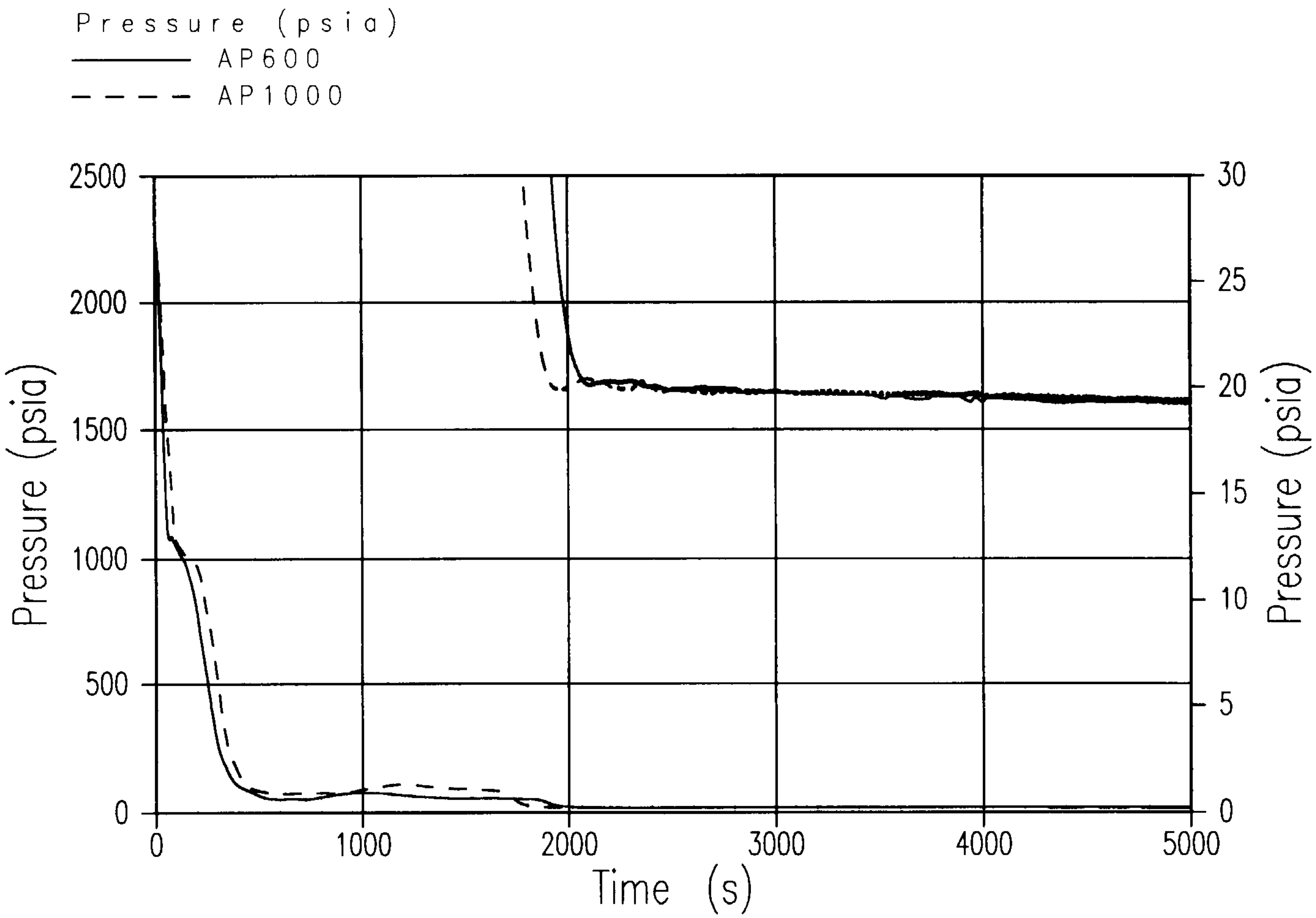
# AP1000 SBLOCA Results Overview

## *DE-DVI (Elevated Pressure) - RCS Inventory*



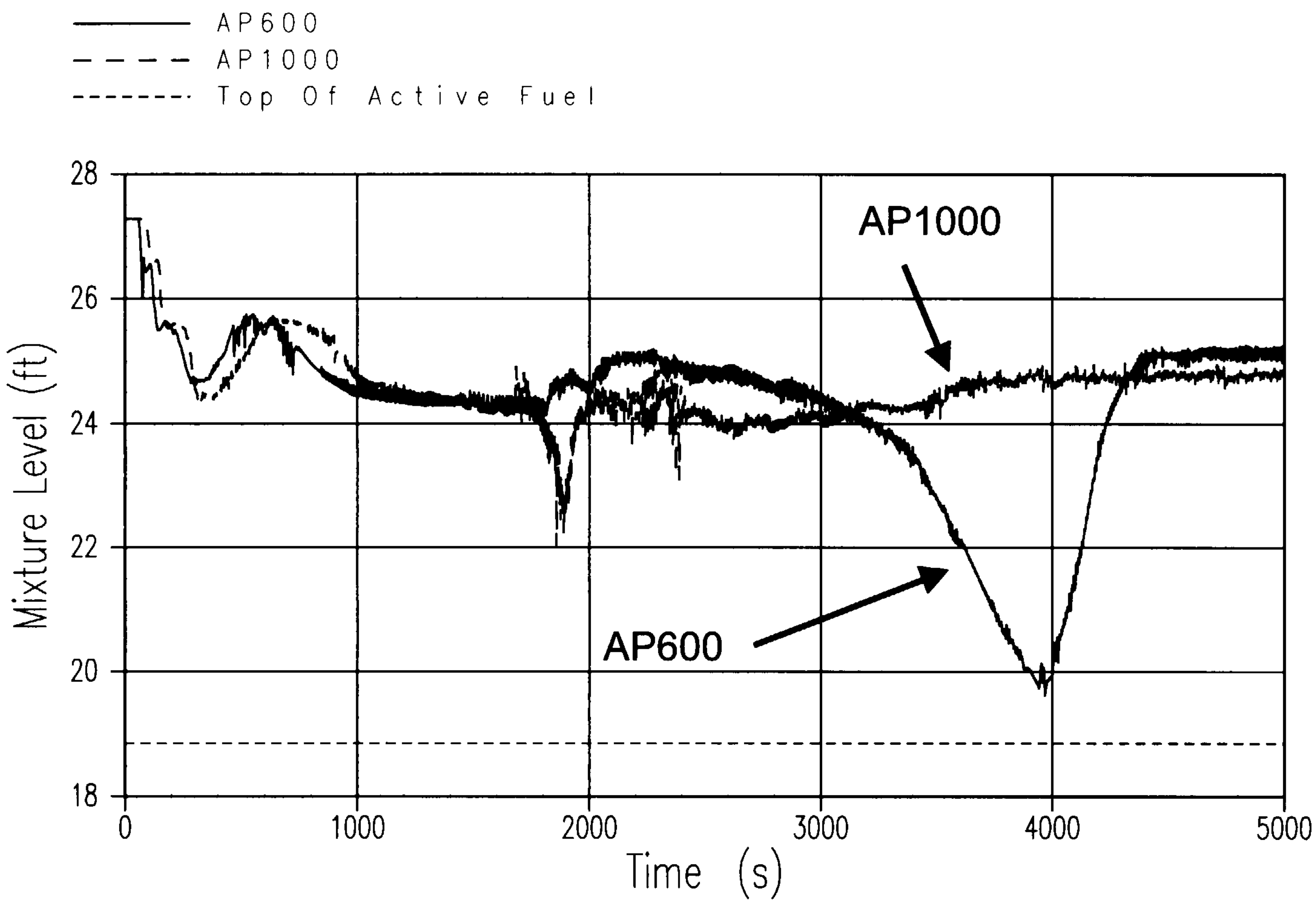
# AP1000 SBLOCA Results Overview

## *Inadvertent ADS - RCS Pressure*



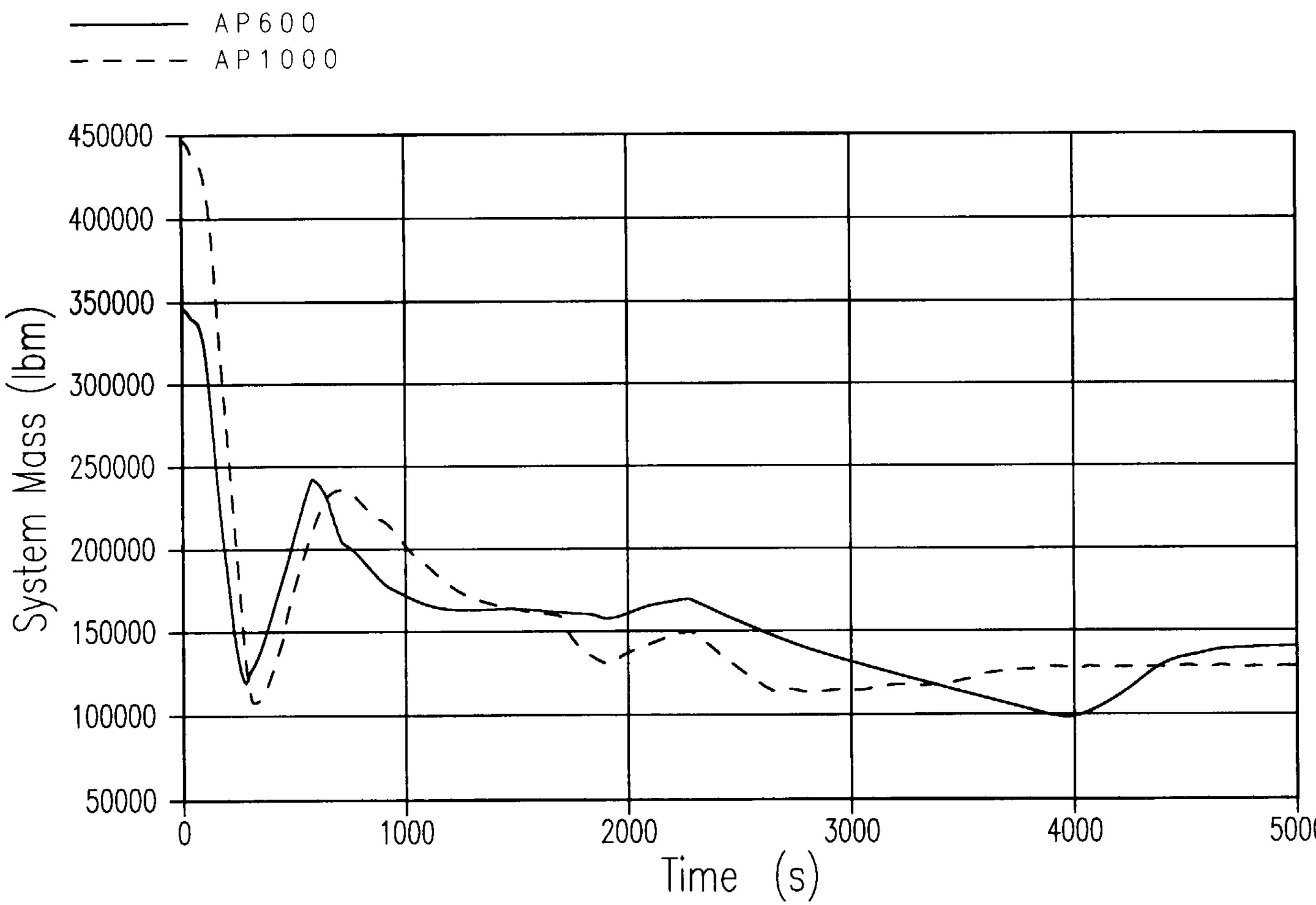
# AP1000 SBLOCA Results Overview

***Inadvertent ADS - Core/Upper Plenum Mixture Level***



# AP1000 SBLOCA Results Overview

***Inadvertent ADS - RCS Inventory***



# AP1000 SBLOCA Conclusions

- Scoping AP1000 transient results indicate comparable margin to AP600
  - AP1000 plant physical size results in breaks acting like smaller breaks when compared to AP600
  - No core uncovery observed
  - No new phenomena observed

# AP1000 NOTRUMP Documentation

- NOTRUMP approved by NRC for licensing basis SBLOCA in 1985
  - Meyer, P. E., "NOTRUMP - A Nodal Transient Small-Break and General Network Code," WCAP-10079-P-A, (Proprietary) and WCAP-10080-A (Non-proprietary), August 1985.
  - Lee, N., Rupprecht, S. D., Schwarz, W. R., and Tauche, W. D., "Westinghouse Small-Break ECCS Evaluation Model Using the NOTRUMP Code," WCAP-10054-P-A (Proprietary) and WCAP-10081-A (Non-proprietary), August 1985.

# AP1000 NOTRUMP Documentation

- AP600 SBLOCA Evaluation Model Licensing Basis
  - Kemper, R. M., "Applicability of the NOTRUMP Computer Code to AP600 SSAR Small-Break LOCA Analyses," WCAP-14206 (Proprietary) and WCAP-14207 (Non-Proprietary), November 1994.
  - Kemper, R. M., "AP600 Accident Analyses – Evaluation Models," WCAP-14601, Revision 2 (Proprietary), June 1998.
  - Fittante, R. L. et al., "NOTRUMP Final Validation Report for AP600," WCAP-14807, Revision 5, (Proprietary), August 1998.
    - Includes SBOCA PIRT, NOTRUMP code modifications employed for AP600 and model validation

# AP1000 NOTRUMP Transmittal

- Documentation to be provided to NRC for running AP1000 NOTRUMP code
  - Source code and executable associated with NOTRUMP-AP600 for HP-UX 10.20
  - Description of input/output variables for AP1000 plant model
  - NOTRUMP steady-state and transient modeling methodology for AP1000
  - NOTRUMP steady-state and transient input decks for the AP1000 plant

# WCOBRA/TRAC Preliminary Safety Assessment of AP1000 LOCA Events

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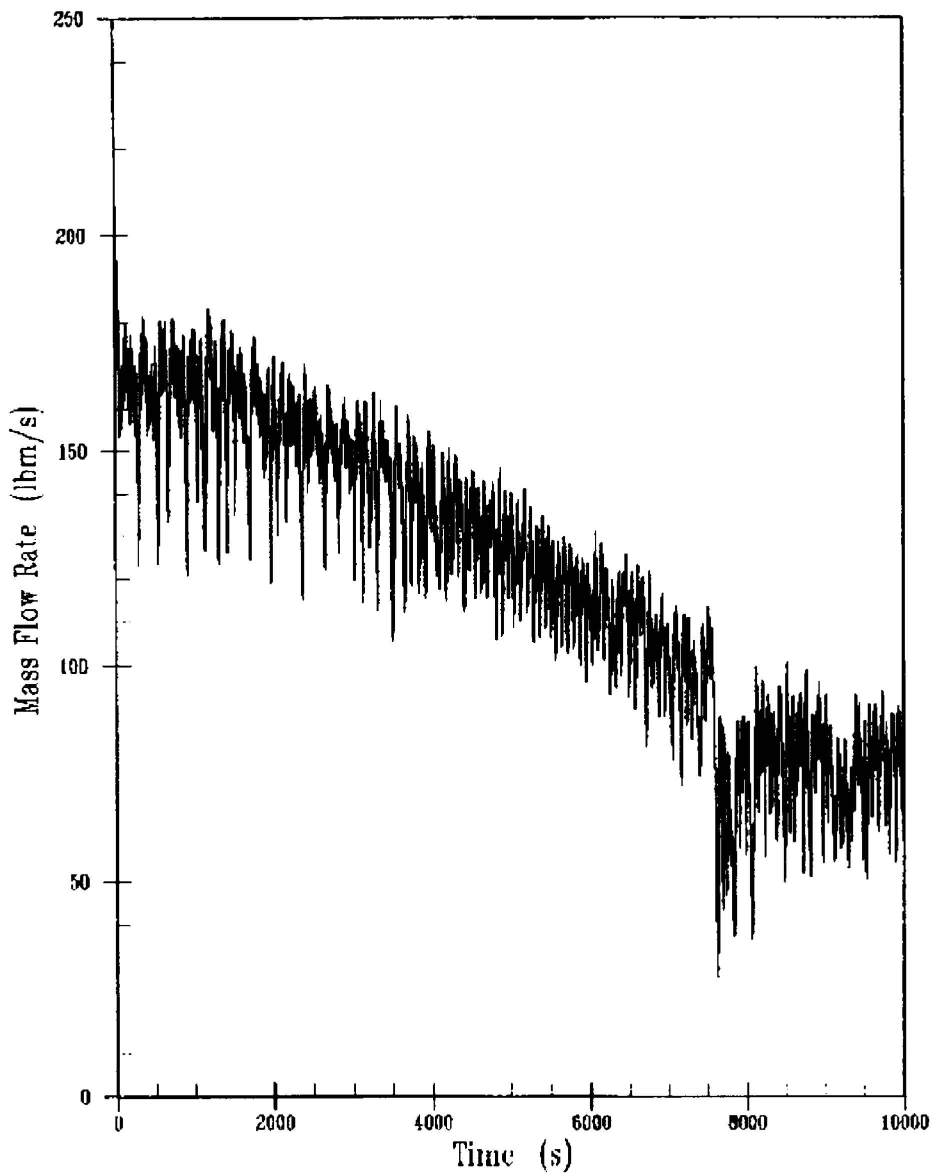
# Long-Term Cooling Analyses

- The purpose of long-term cooling analyses is to demonstrate the long-term stable performance of passive safety systems post-LOCA
  - WCOBRA/TRAC Model Validated against OSU Long-Term Cooling Tests for AP600 (WCAP-14776)
    - To demonstrate stable IRWST injection
    - To demonstrate stable containment recirculation flow
    - To demonstrate core cooling is maintained indefinitely
- AP1000 preliminary analysis completed
  - Similar performance to AP600
  - 10CFR50.46 Acceptance Criteria are satisfied

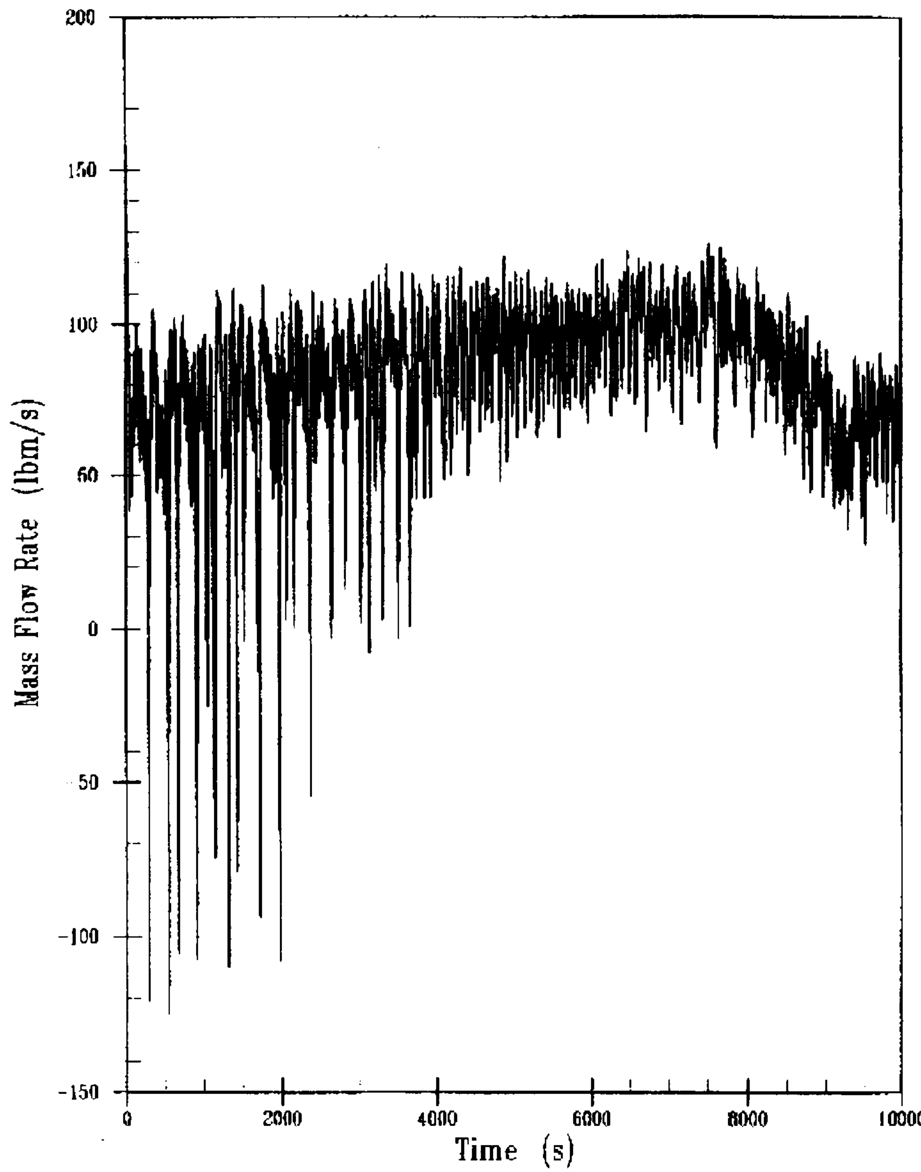
# AP1000 long-term core cooling

- The limiting AP600 SSAR case (DEDVI break, with its early switchover to containment recirculation) is analyzed for AP1000 in WCAP-15612:
  - increased ADS Stage 4 valve and line sizes
  - increased DVI piping sizes
  - increased core power and active fuel length
- WCOBRA/TRAC is executed continuously during the long-term cooling phase from the beginning of IRWST injection
- A "window mode" case is performed with WCOBRA/ TRAC at the switchover to containment recirculation

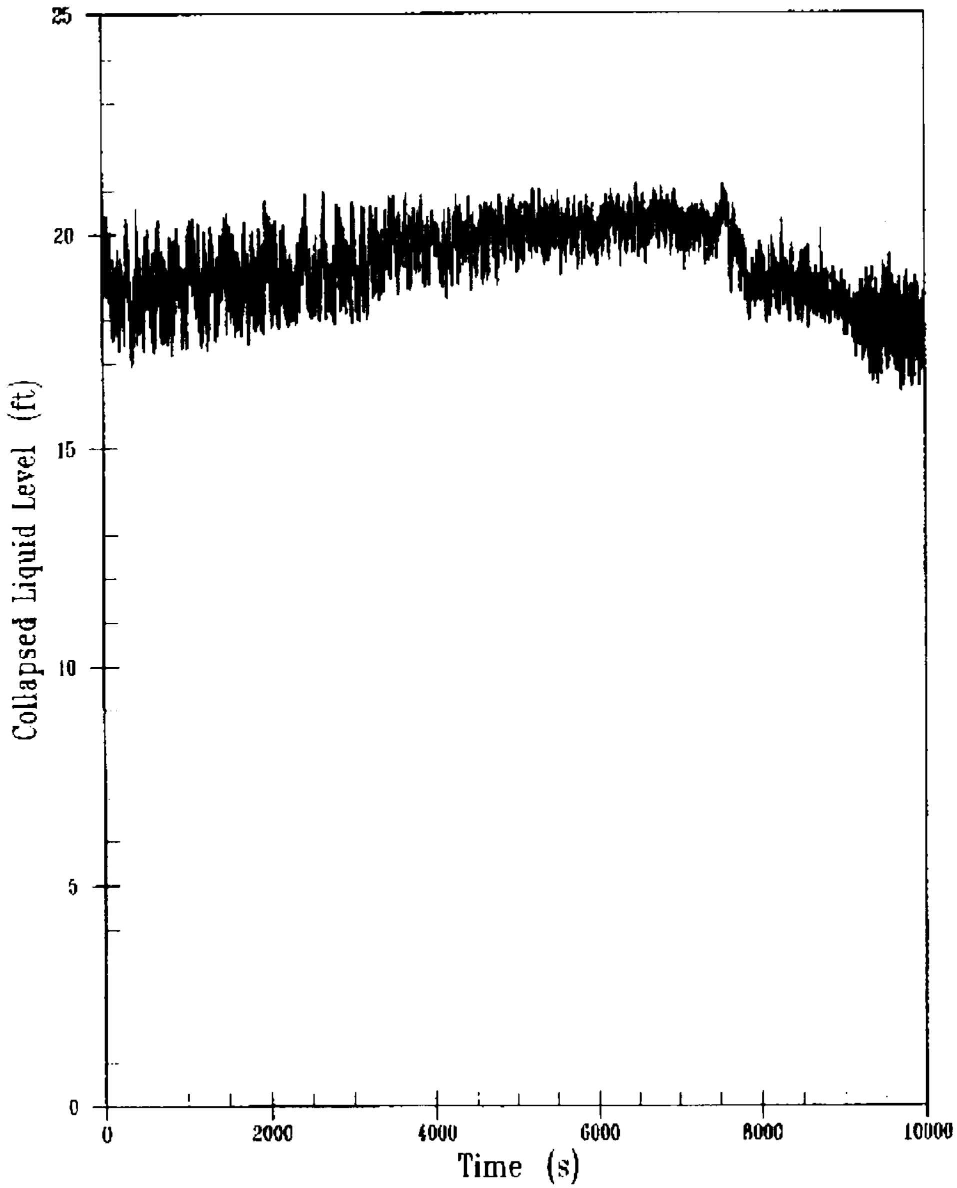
# DVI-B Mixture Flow Rate



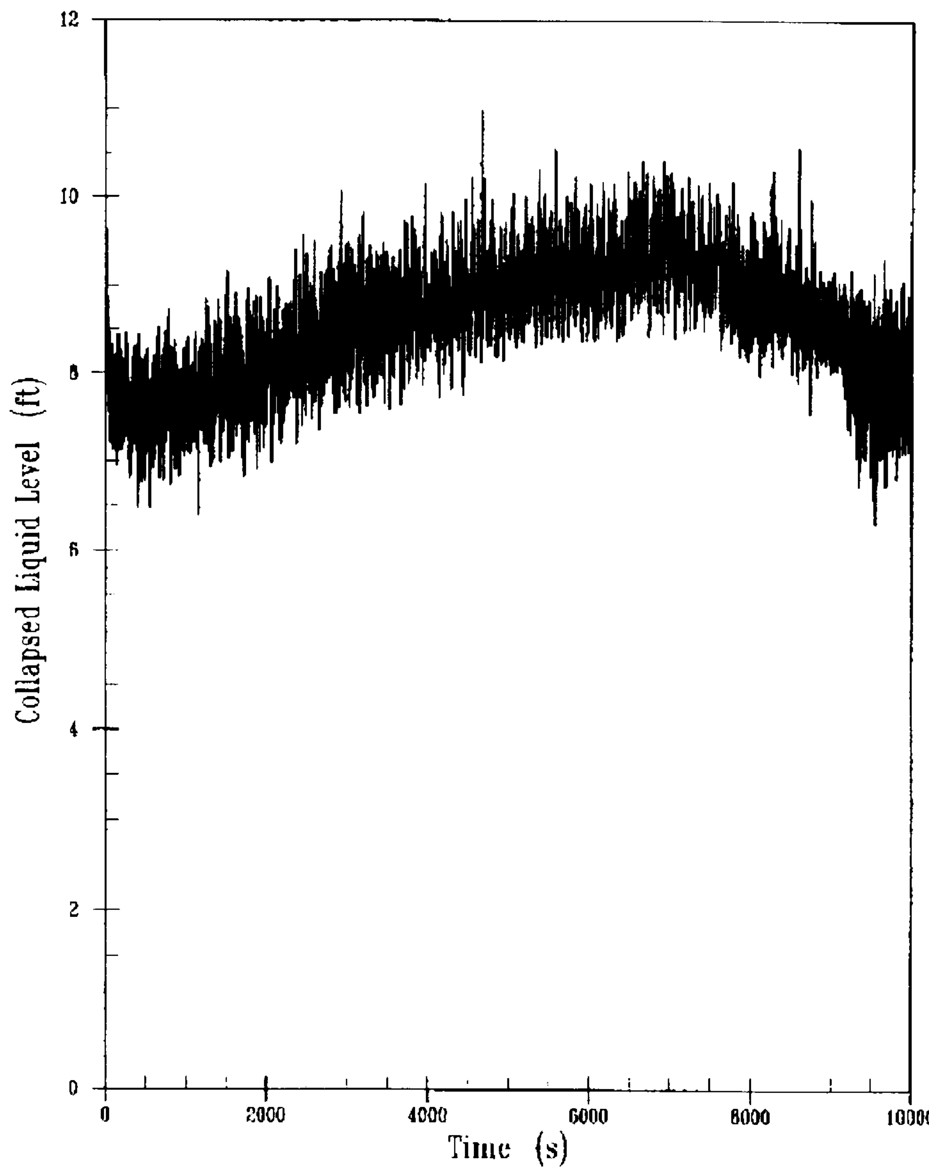
# DVI-A Mixture Flow Rate



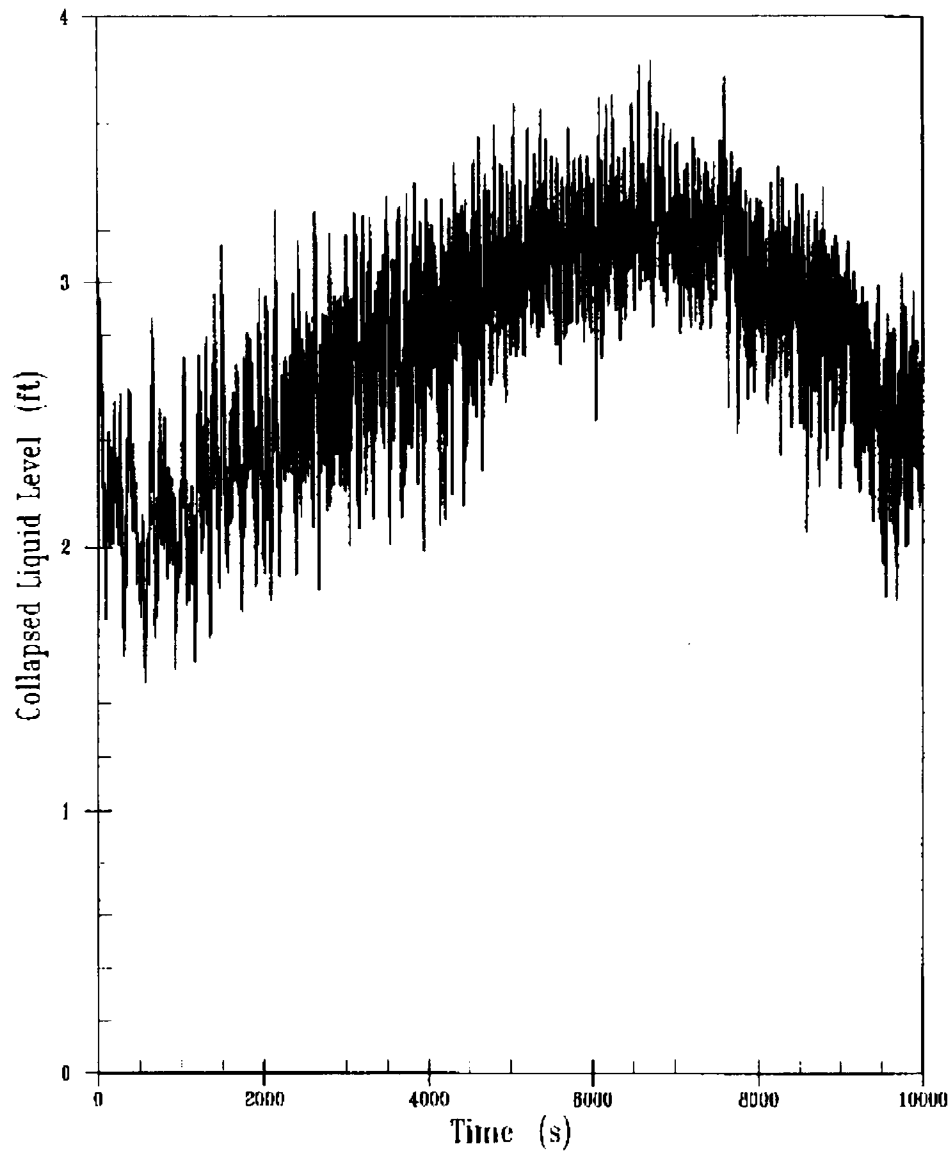
# Collapsed Level of Liquid in Downcomer



# Collapsed Level of Liquid Over the Heated Length of Fuel



# Collapsed Liquid Level in the Upper Plenum



# Long-Term Cooling Conclusions

- No new phenomena relative to the AP600 SSAR cases are predicted for AP1000

- Equivalent predictions of long-term core cooling for a DEDVI break are predicted by WCOBRA/TRAC in a continuous calculation and a window mode analysis

- The WCOBRA/TRAC long-term cooling methodology approved for AP600 analyses may also be applied to AP1000 analyses

# Approval History of WCOBRA/TRAC

- In 1996, the WCOBRA/TRAC Code Qualification Document (WCAP-12945) and the large break LOCA best-estimate analysis methodology were approved for Westinghouse 3-loop and 4-loop plants

- AP600 approvals were obtained in NUREG-1512
  - for large break LOCA analysis
  - for post-LOCA long-term cooling analysis

# WCOBRA/TRAC Items in Phase 2

- Source/executable of the AP code version, WCOBRA/TRAC Mod7A Rev4AP
- AP1000 DEDVI break long-term cooling analysis initial and restart input decks
- NRC already possesses the following pertinent and approved documents:
  - WCOBRA/TRAC CQD
  - WCAP-14776, Rev 4 (OSU Test simulations)
  - WCAP-14171, Rev 2 (AP600 LBLOCA report)
  - WCAP-14601, Rev 2 (AP600 Accident analysis models)
- WCOBRA/TRAC Code User's Manual

# AP1000 Large Break LOCA Analysis

- Will use a simplified version of the conventional plant best-estimate methodology (as approved for AP600 in WCAP-14171)
- No validation was necessary against any of the AP600 tests because the accumulators are the only passive safety system that affects large break LOCA ECCS performance
- Therefore, AP1000 results should exhibit similar behaviors to the AP600 SSAR results; they are not affected by any scaling issues that may arise for the passive safety systems in the AP600 test facilities
- PCT Acceptance Criterion remains PCT< 2200F

# AP1000 Large Break LOCA Analysis

- AP600 Exhibits Large Safety Margin
  - 500F in PCT margin to the regulatory limit with the approved best-estimate methodology
  - 95% PCT value, including the statistical uncertainty

- AP1000 LBLOCA Assessment
  - Higher core linear power will result in a higher calculated PCT than AP600
  - The increases are estimated as 120F for the blowdown peak value and 300F for the reflood peak value
  - Therefore, AP1000 will retain margin to the regulatory limit
  - In Phase 3 the AP1000 Design Basis LBLOCA Analysis will be performed in accordance with NUREG-1512 restrictions
  - There is no need to consider LBLOCA in Phase 2 of the AP1000 review

# AP1000 Containment Scoping Analyses using WGOTHIC 4.2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# Introduction

- Purpose of the containment scoping analyses:
  - Estimate the required increase in the containment height for AP1000
  - Estimate the margin to the containment design pressure for the DECL LOCA and MSLB events using the same bounding methodology that was used for AP600

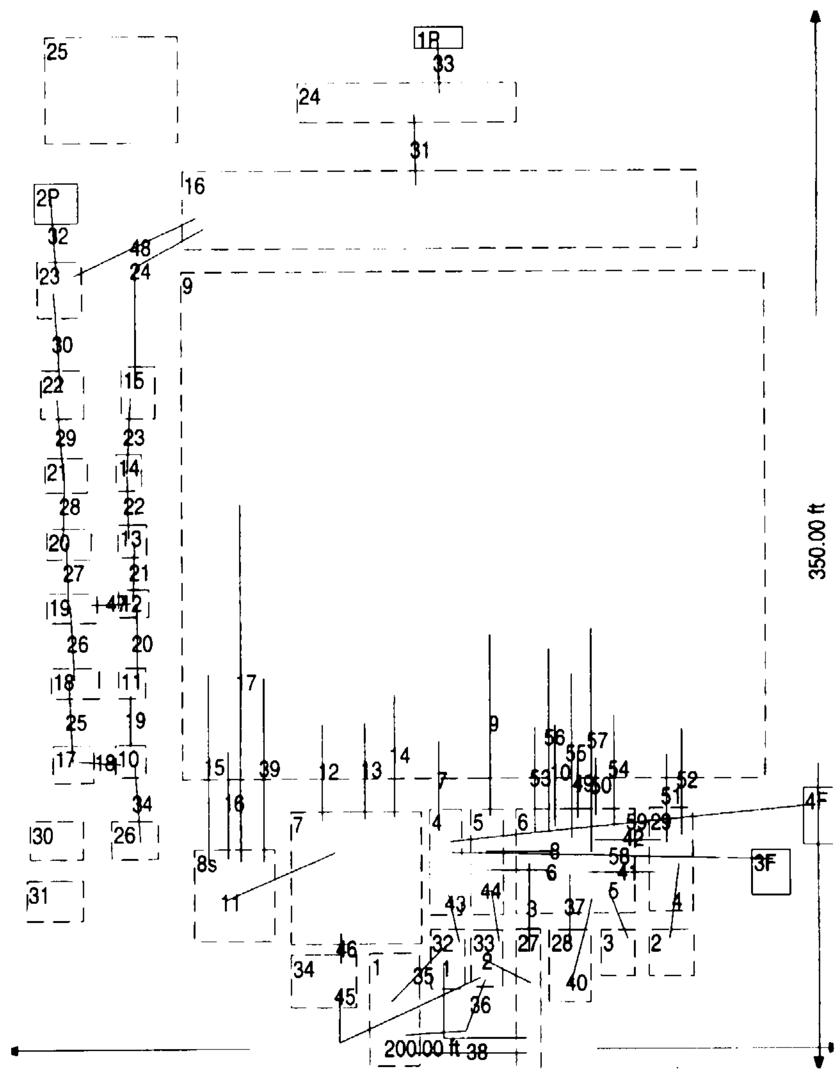
- Analysis Acceptance Criteria
  - The calculated peak pressure must be less than the AP1000 containment design pressure

# Containment Scoping Analyses

- The AP600 containment model noding structure was revised to use a single lumped parameter volume above the operating deck to represent the dome.
- The number of climes for PCS heat and mass transfer was reduced from 8 to 2, 1 wet and 1 dry.
- Confirmed same response for AP600 LOCA and MSLB transient events
- A preliminary model of the AP1000 containment was constructed using this revised noding structure
  - Increased shell height and surface area
  - Increased the corresponding dome and PCS volumes
  - Changed the PCS water flow rate vs. time

# Containment Scoping Analyses

## AP1000 Containment Model Noding Diagram

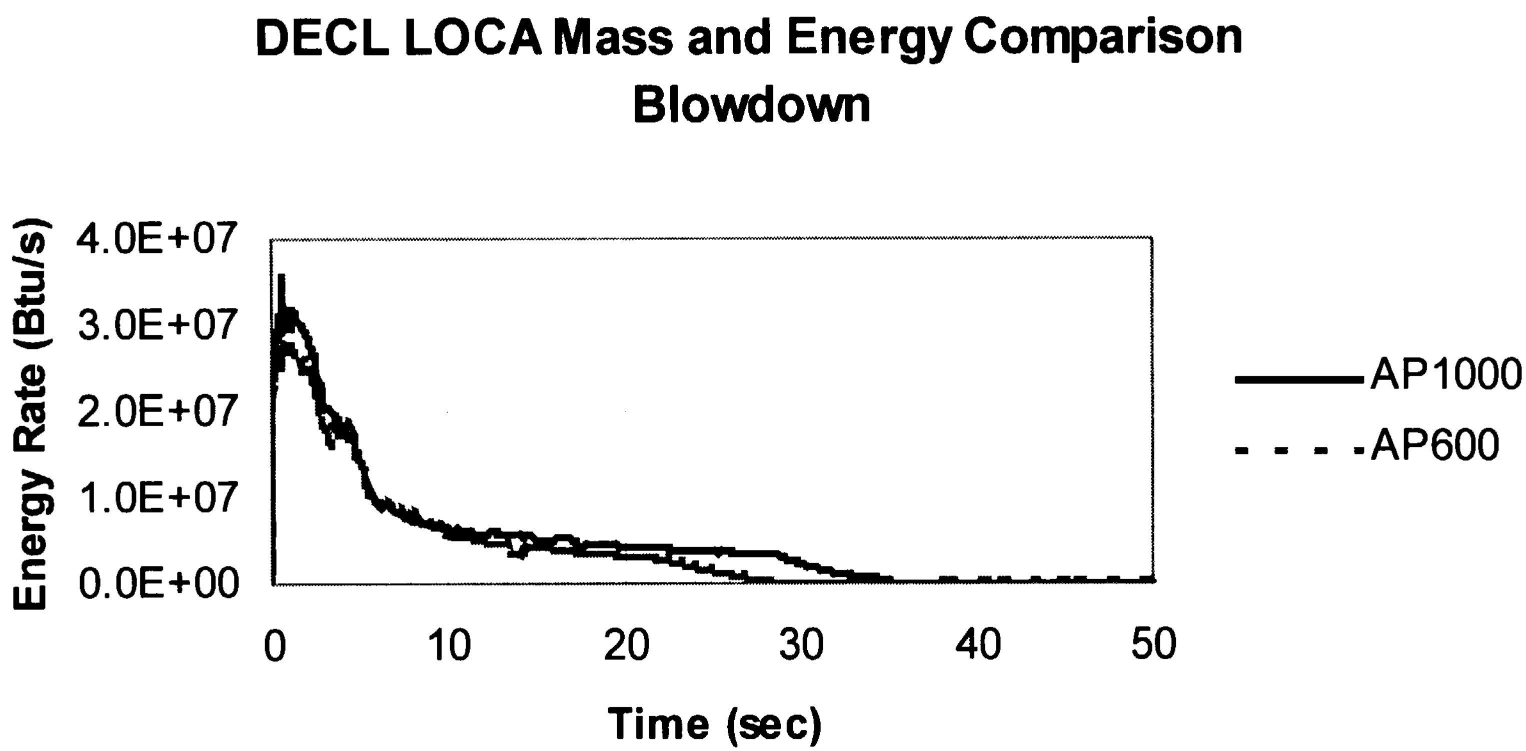


# Containment Scoping Analyses

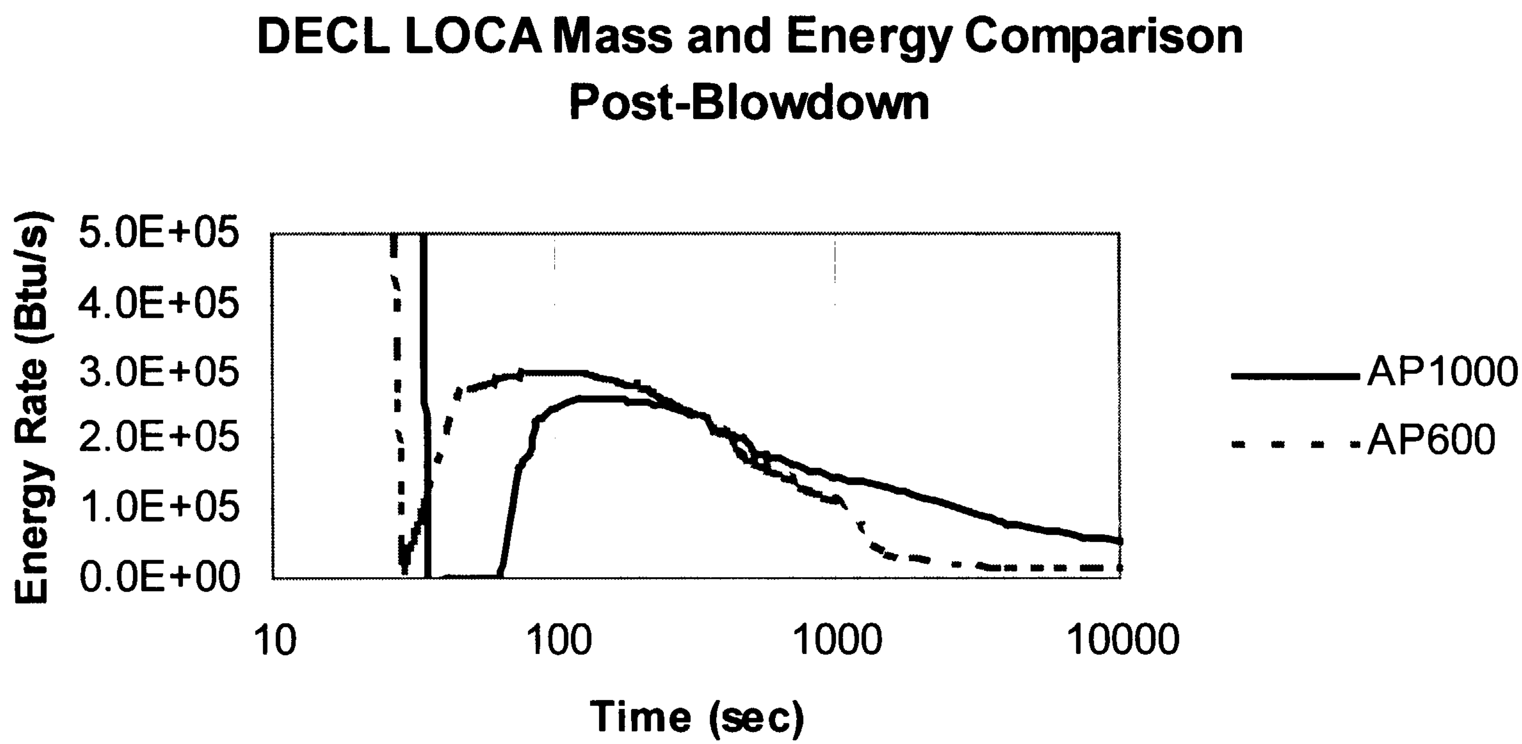
- A preliminary RCS model of the AP1000 was constructed using the existing AP600 SATAN model to calculate the DECL LOCA blowdown M&E release
  - Increased pressurizer, SG, and CMT volumes
  - Increased power level
  - Changed initial temperatures

- New post-blowdown DECL LOCA mass and energy releases were calculated using a conservative, but more realistic time for the SG secondary energy release (5 hours vs. 1 hour)
  - ADS-4 and passive RHR essentially isolate the SGs from the RCS
  - Results from mechanistic models indicate the SGs retain energy for several hours after event initiation

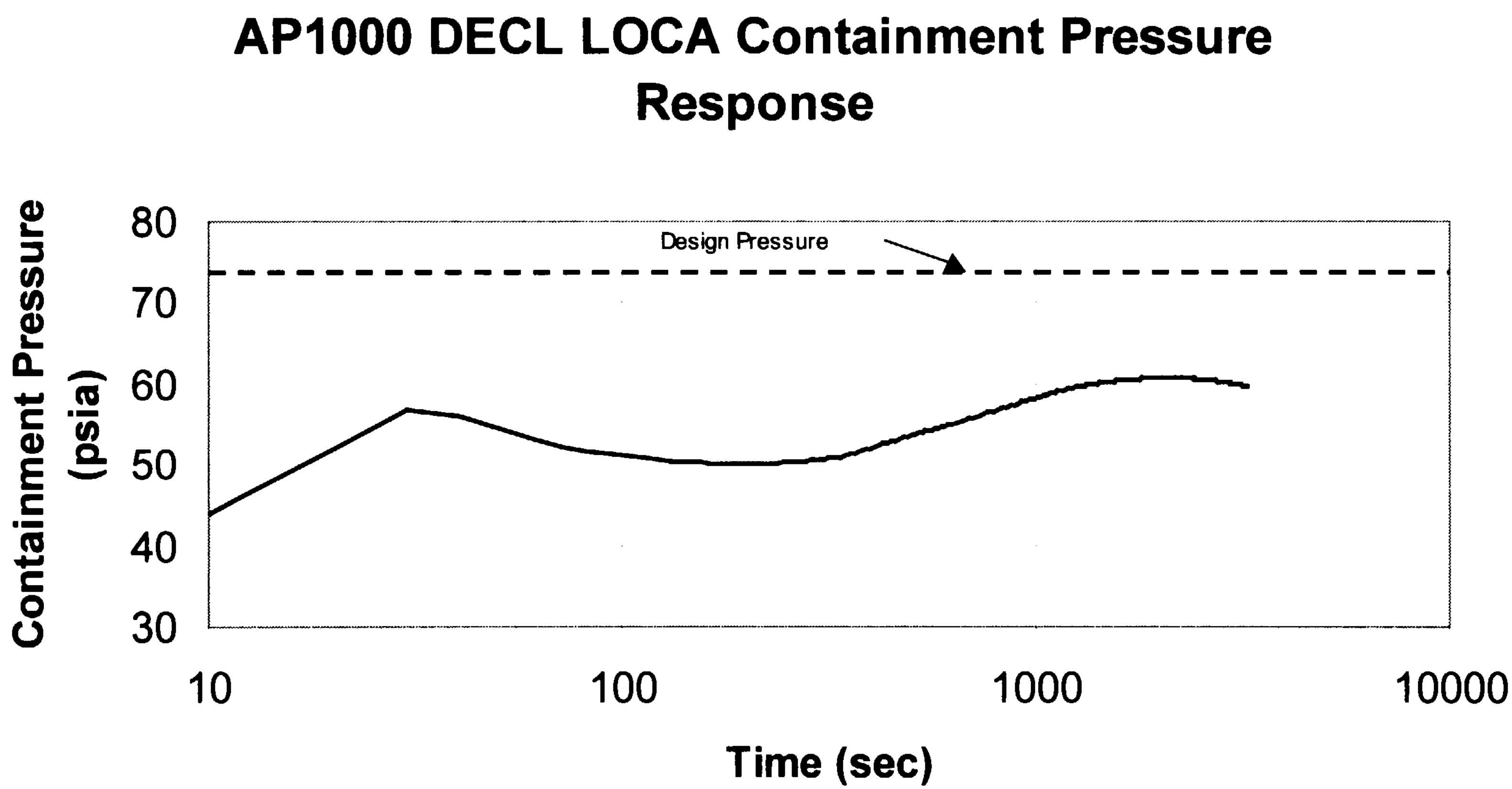
# Containment Scoping Analyses



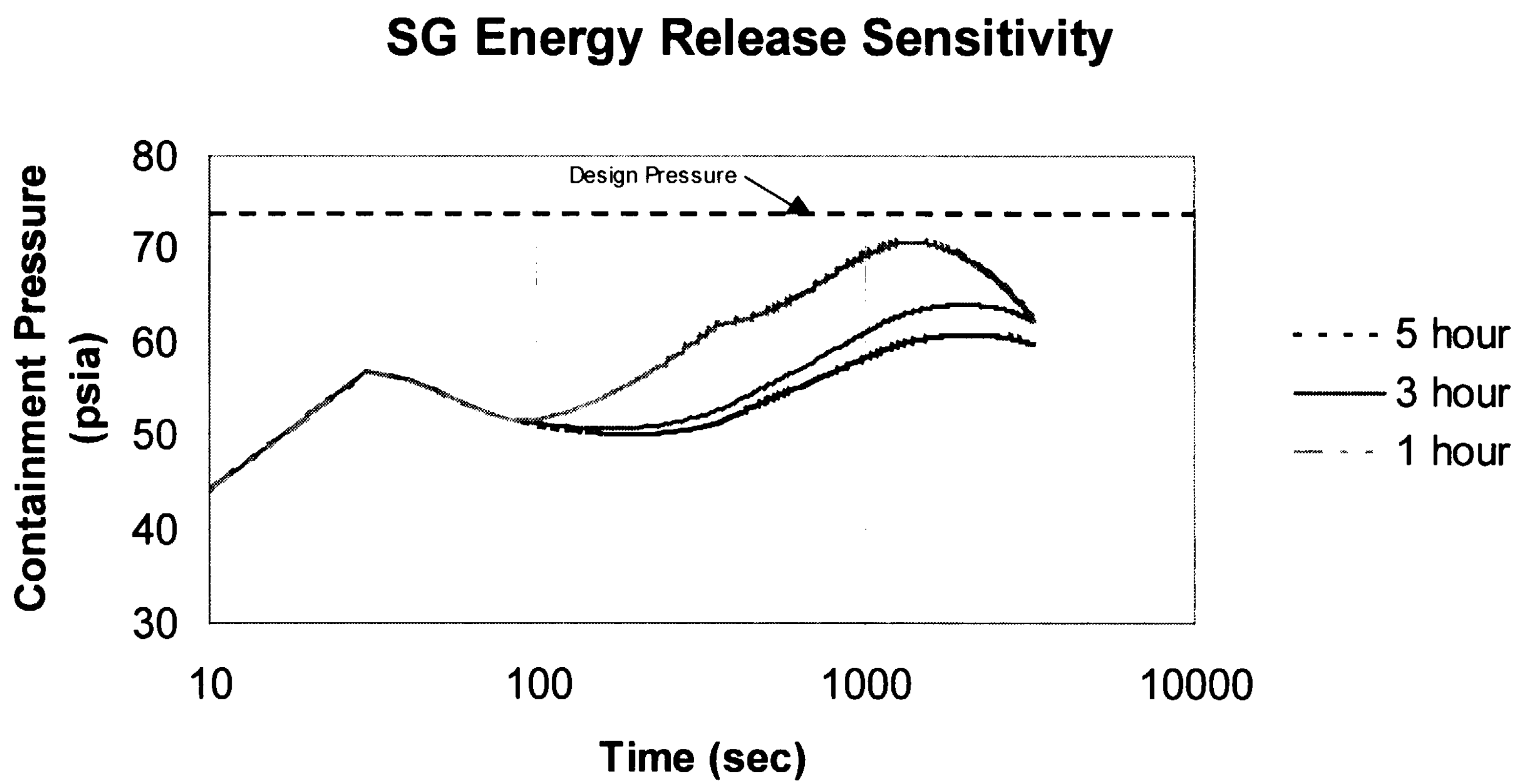
# Containment Scoping Analyses



# Containment Scoping Analyses



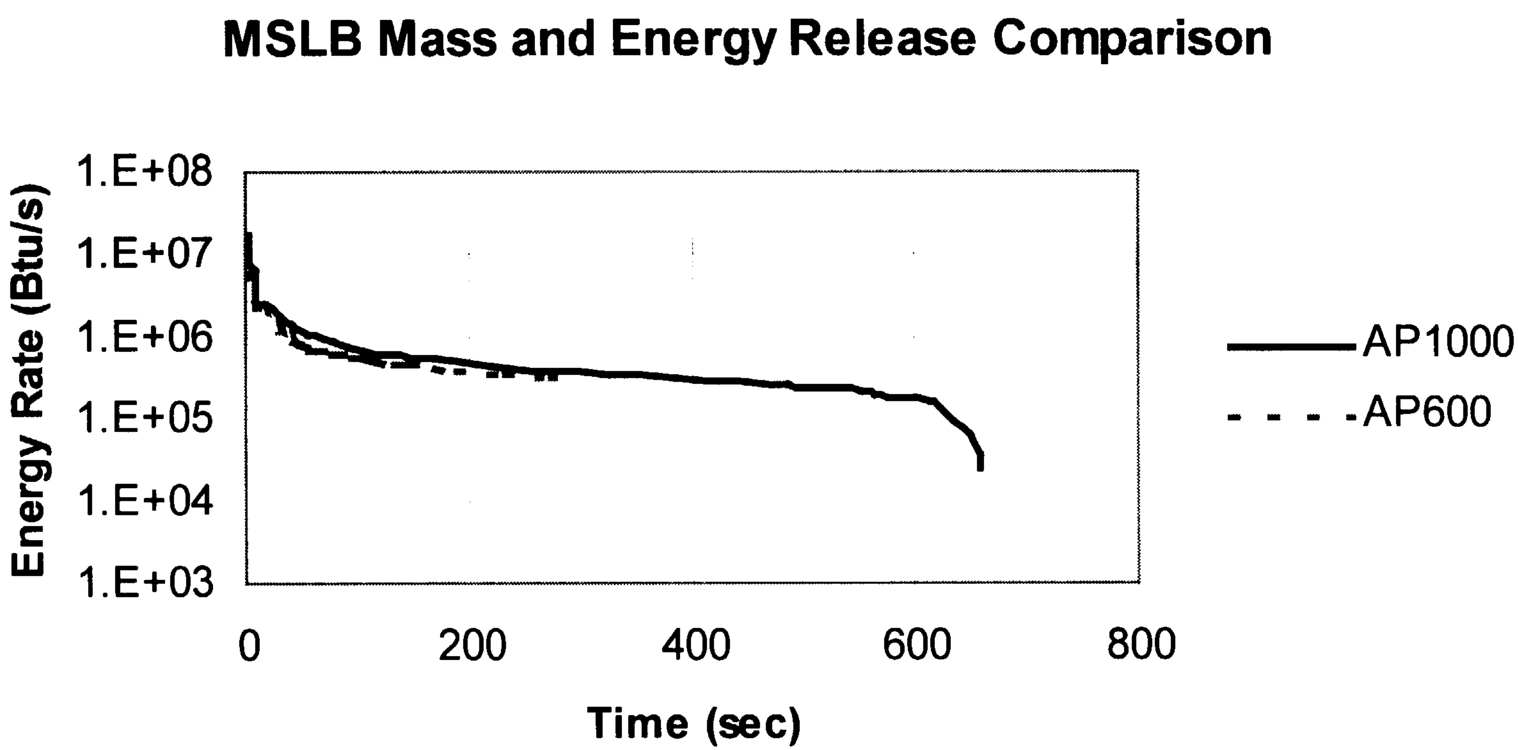
# Containment Scoping Analyses



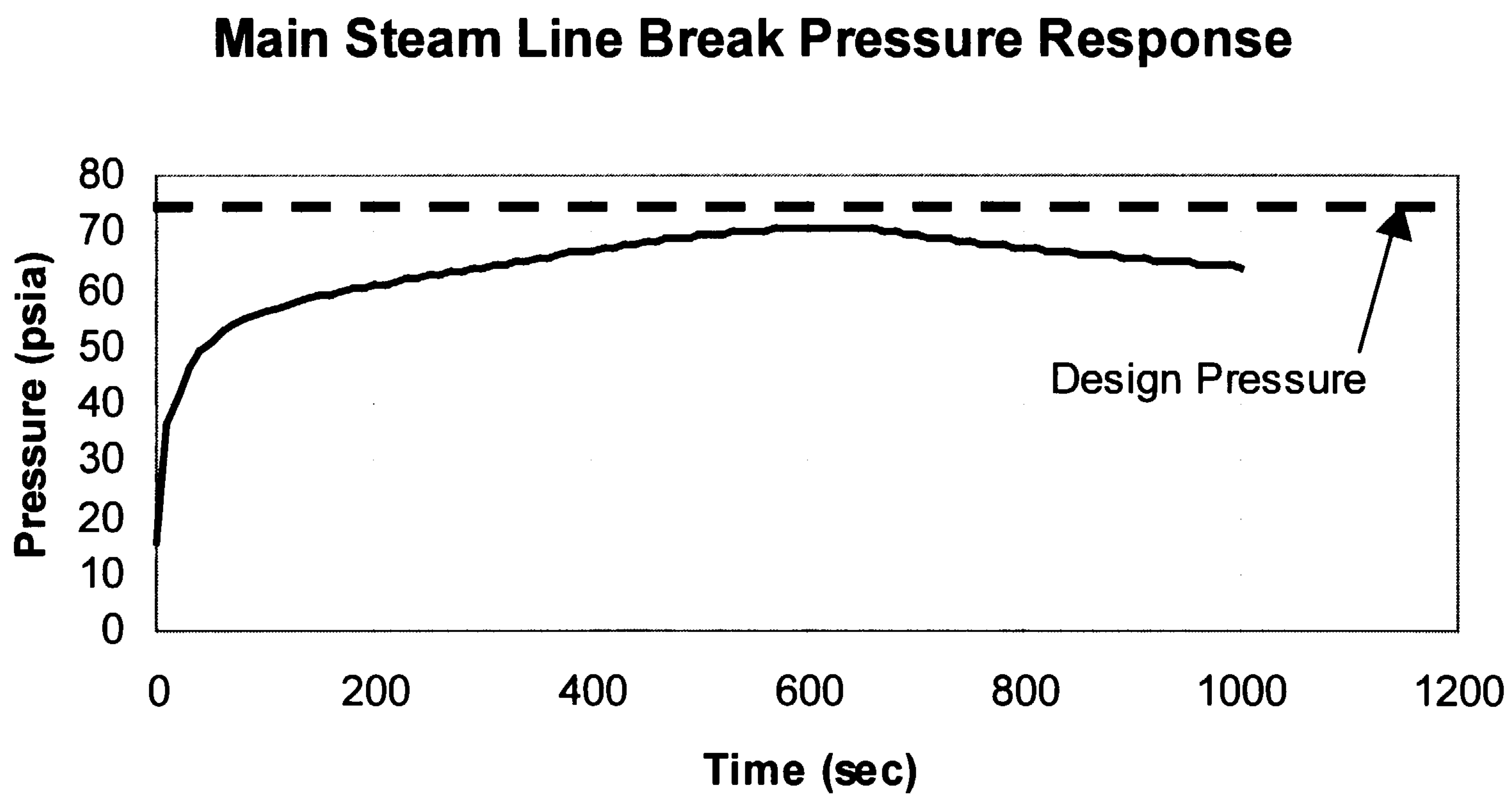
# Containment Scoping Analyses

- A preliminary AP1000 model was constructed using the existing AP600 LOFTRAN MSLB model to calculate the MSLB M&E releases
  - Increased pressurizer, SG, and CMT volumes
  - Increased power level
  - Changed initial temperatures

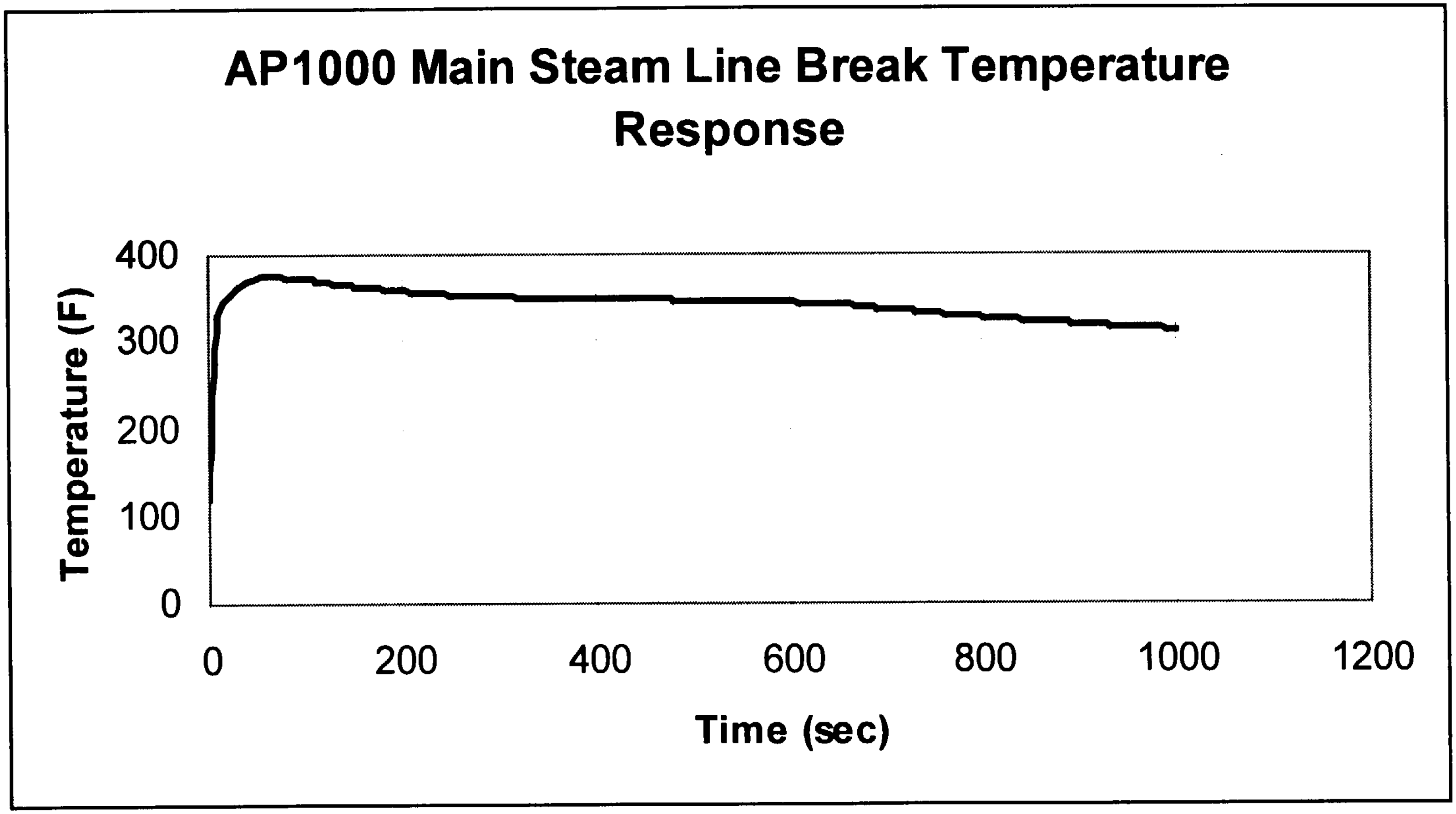
# Containment Scoping Analyses



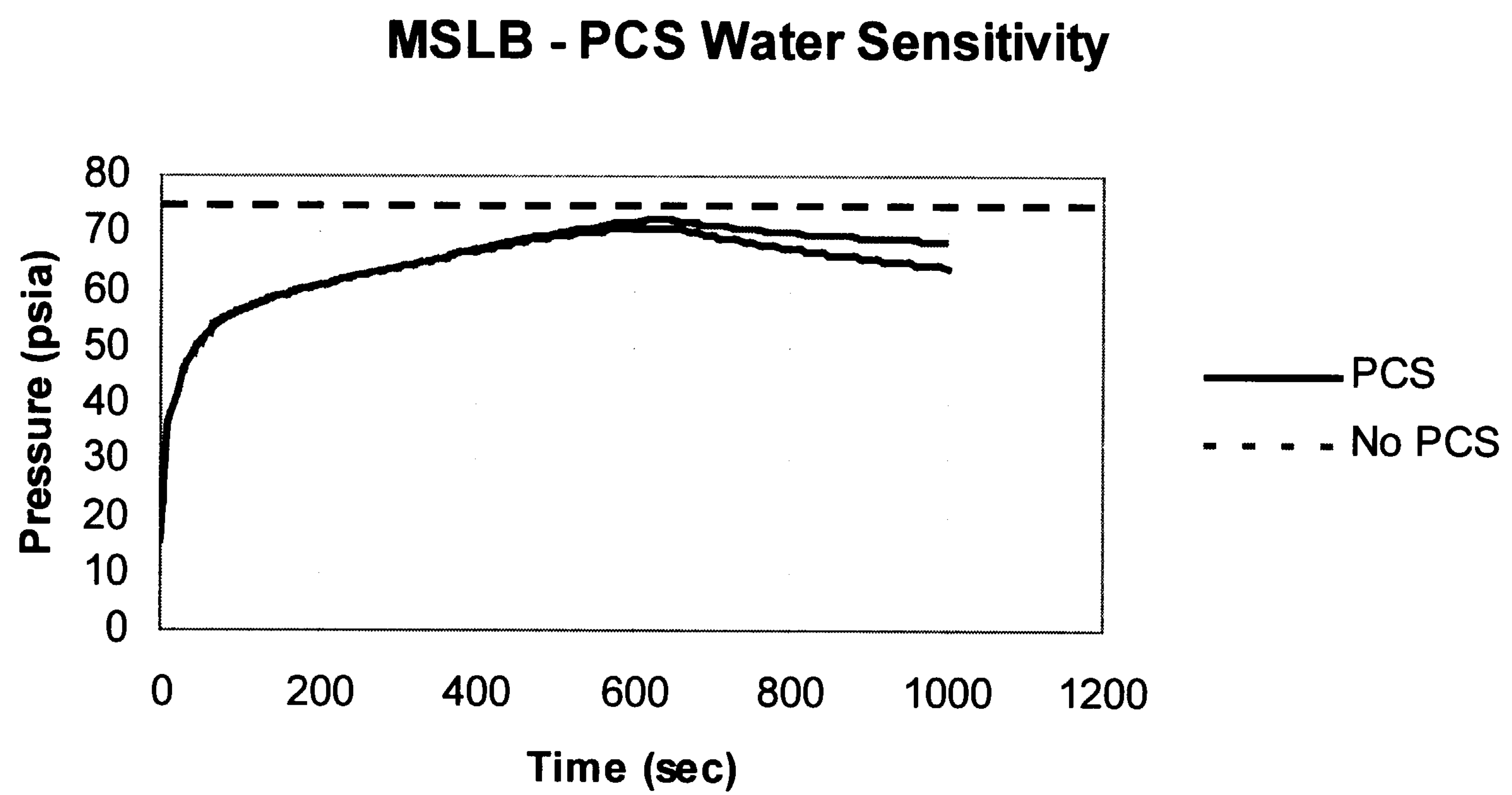
# Containment Scoping Analyses



# Containment Scoping Analyses



# Containment Scoping Analyses



# Containment Scoping Analyses

- Conclusions
  - AP1000 containment transient response for the DECL LOCA and MSLB events was similar to AP600
  - No new phenomena were observed
  - The AP1000 has a larger margin to the containment design pressure than the AP600

# WGOTHIC 4.2 Code

- Code Development Overview
  - GOTHIC version 4.0 developed, qualified and maintained by NAI/EPRI
  - WGOTHIC 4.0 Westinghouse added subroutines for PCS heat and mass transfer and PCS film tracking (Climes)
  - WGOTHIC 4.1 corrected Clime dryout error and other minor changes (see WCAP-14967 for details)
  - WGOTHIC 4.2 added a new Clime-specific cell-centered velocity subroutine and other minor changes (see WCAP-14407 for details)

# WGOTHIC 4.2 Code

- Code Licensing Basis
  - GOTHIC 4.0 Code Manuals: NTD-NRC-95-4563
  - WGOTHIC Comparison to GOTHIC: NTD-NRC-95-4595
  - PCS Heat and Mass Transfer Correlations: WCAP-14326
  - WGOTHIC Clime Description and Qualification: WCAP-14382, WCAP-14407, WCAP-14967
- AP600 Containment Evaluation Model Licensing Basis
  - Containment PIRT/Scaling: WCAP-14845, WCAP-14812
  - Input Description(including PCS water coverage, internal mixing and stratification, initial conditions): WCAP-14407

# WGOTHIC 4.2 Code

- WGOTHIC 4.2 Code Usage
  - The pre-processor creates a solver input file (.SIN file) and a graphics input file (.GIN file)
  - The solver solves the transient T/H calculations and produces the solver and clime output files (.SOT, .CLM files) and output graphics data file (.SGR file)
  - The post-processor creates an output plot data file (.GOT file) and the updates the plots in the pre-processor file

# WGOTHIC Code

- GOTHIC 4.0 code documentation was previously sent to NRC in 1995 (NTD-NRC-95-4563)
- AP600 containment evaluation model description was previously sent to NRC (WCAP-14407)
- Deliverables to NRC
  - WGOTHIC 4.2 source and executable code
  - AP1000 pre-processor input files for the LOCA and MSLB scoping analyses
  - WGOTHIC Clime Users Manual

# Code Review Meeting Summary

- Phase 2 Review
  - Determine the basis for applicability of AP600 codes for AP1000
    - Basis for AP600 acceptability
    - Review AP1000 design differences / margins
    - Scalability of Tests where important for code validation
    - Exercise code to assess applicability
      - ◆ Westinghouse will provide codes beginning in March
        - Detailed schedule will be provided
      - ◆ Westinghouse will provide analytical support to improve efficiency of review