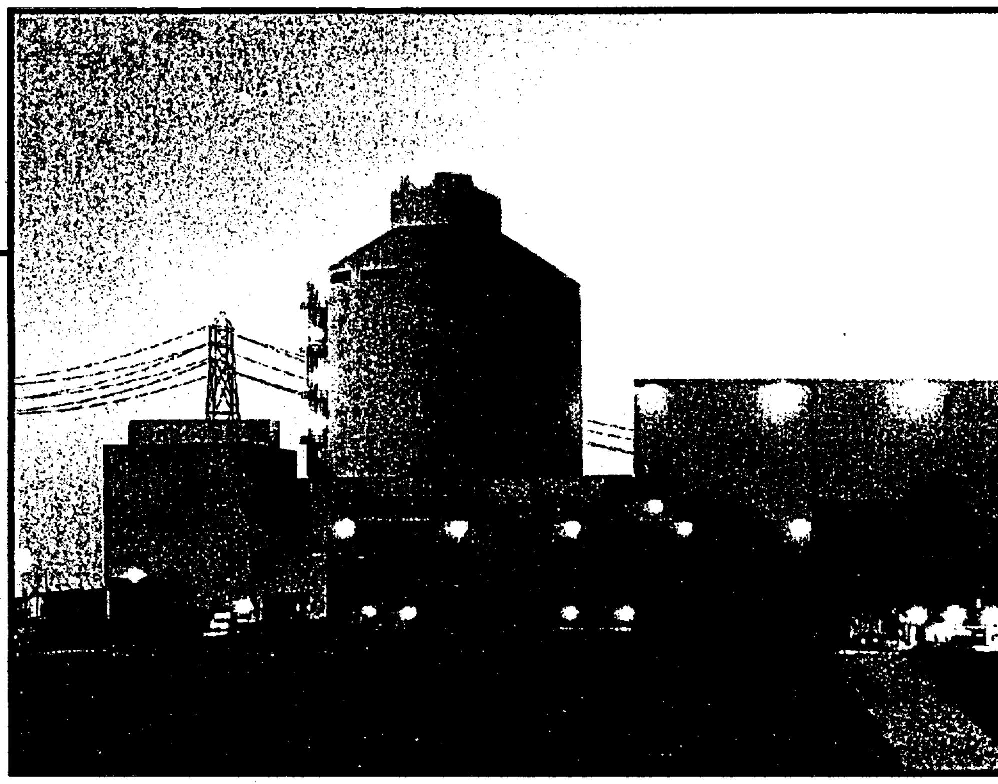
AP1000



AP1000 Design Certification Review

Westinghouse Electric Company

Presentation to

Advisory Committee on Reactor Safeguards

PRA Sub-Committee

January 23 -24 2003

BNFL Westinghouse

Agenda

Thursday January 23, 2003

• **Introduction**	**George Apostalakis, ACRS**	**8:30 am**
– Review goals and meeting objectives		
• **Westinghouse Introduction**	**Mike Corletti, Westinghouse**	**8:35 am**
• **Overview of AP1000 Design**	**Terry Schulz, Westinghouse**	**8:40 am**
– Design Changes from AP600		
– Key AP1000 Design Features		
– Defense-in-Depth		
– PRA as a Design Tool		
• **BREAK**		**10:05 am**
• **AP1000 PRA**	**Selim Sancaktar, Westinghouse**	**10:20 am**
– Background / Approach / Overview		
– Scope		
– Level 1 PRA Internal Events At-Power		
– Sensitivity and Uncertainty Assessments		
– Shutdown / Fire PRA		
• **LUNCH**		**12:20 - 1:30 pm**

Agenda

Thursday January 23, 2003

• **PRA Level 1 Success Criteria**	**Terry Schulz, Westinghouse**	**1:30 pm**
– Overview		
– Thermal-Hydraulic Analysis to Support Level 1 PRA		
– T&H Uncertainty Assessment		
• **BREAK**		**3:30 pm**
• **NRC Staff Presentation**	**Nick Saltos - Walt Jensen - Marie Pohida**	**3:45 pm**
– Staff RAIs on Level 1 PRA and Success Criteria		
• **Westinghouse Summary**	**Mike Corletti**	**5:30 pm**

Agenda

Friday January 24, 2003

• **Introduction**	**George Apostalakis, ACRS**	**8:30 am**
– Review goals and meeting objectives		
• **Level 2 and 3 PRA**	**Jim Scobel, Westinghouse**	**8:35 am**
– Quantification		
• **Invessel Retention of Molten Core Debris**		
• **BREAK**		**10:05 am**
• **Level 2 Phenomenological Studies**		**10:30 am**
• **Summary of PRA Results and Insights**	**Selim Sancaktar, Westinghouse**	**11:45 am**
• **LUNCH**		**12:15 pm**
• **NRC Staff Presentation**	**Bob Palla, NRR - Richard Lee, RES**	**1:15 pm**
• **Westinghouse Summary**	**Mike Corletti, Westinghouse**	**2:15 pm**
• **General Discussion**	**ACRS Members**	**2:30 pm**
• **Adjourn**		**3:00 pm**

Design Certification Schedule

Major Milestones

1. W Submits DCD Application (DCD / PRA)	3/28/02
2. Staff Issues RAI	9/30/02
3. W Provide Responses to All RAI	12/2/02
2. NRC Identify Potential DSER Open Items	2/28/03
4. W Addresses Potential DSER Open Items	4/15/03
5. NRC Issues DSER	6/16/03

W Goal is to Address All Open Items Prior to Issuance of DSER

6. ACRS Full Committee & Letter	7 / 2003

W OBJECTIVE IS TO PROVIDE THE NRC / ACRS WITH THE NECESSARY INFORMATION SO THAT A FINAL SAFETY DETERMINATION ON AP1000 CAN BE MADE IN 2003

W Objectives of the Meeting

- **Provide a Thorough Presentation of AP1000 PRA**
  - Level 1 / 2 / 3
  - Supporting T/H Analyses for Level 1
  - Supporting Phenomenological Studies for Level 2

- **Address All ACRS Issues Related to PRA**

ACRS Meetings

• **Overview to Full Committee**	**Nov. 7, 2002**
• **PRA Subcommittee**	**Jan. 23/24 2003**
• **Thermal-Hydraulic Subcommittee**	**March 2003**
– Safety Analysis / Entrainment Issue	
– Containment cooling	
• **AP1000 Subcommittee**	**April 2003**
– Containment structural design	
– Materials	
– Regulatory Treatment of Non-Safety Systems	
– Shutdown Maintenance	
• **ACRS Full Committee Meeting**	**June - July 2003**

Overview of AP1000 Design

Terry Schulz
Advisory Engineer
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AP600 to AP1000 Design Changes

- Increase Core Length & Number of Assemblies
- Increase Size of Key NSSS Components
  - Increased height of Reactor Vessel
  - Larger Steam Generators (similar to W/CE SGs)
  - Larger canned RCPs (variable speed controller)
  - Larger Pressurizer
- Increase Containment Height & Design Pressure
- Capacity Increases in Passive Safety System Components
- Turbine Island Capacity Increased for Power Rating

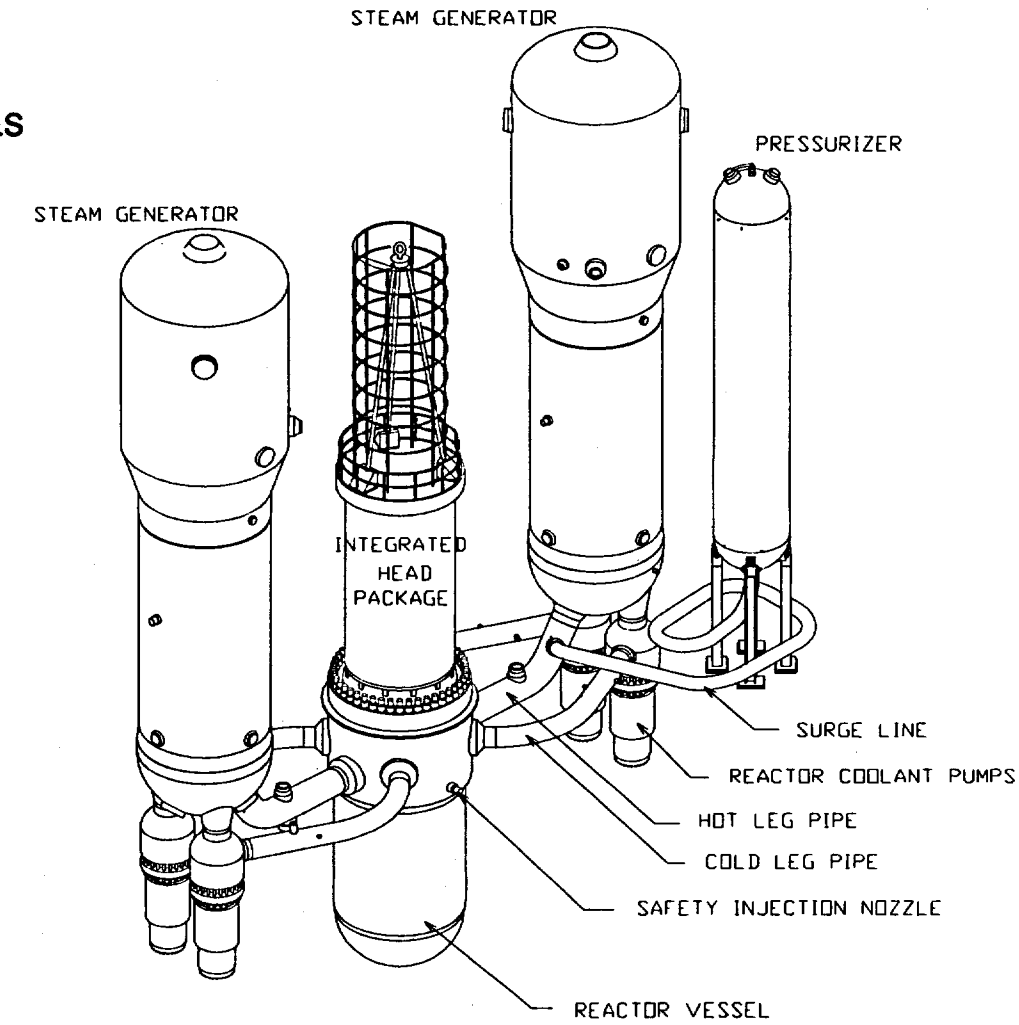
Retained Nuclear Island Footprint

Comparison of Selected Parameters

Parameter	Doel 4/Tihange 3	AP600	AP1000
Net Electric Output, MWe	985	610	1117
Reactor Power, MWt	2988	1933	3400
Hot Leg Temperature, °F	626	600	610
Number of Fuel Assemblies	157	145	157
Type of Fuel Assembly	17x17	17x17	17x17
Active Fuel Length, ft	14	12	14
Linear Hear Rating, kw.ft	5.02	4.1	5.71
Control Rods / Gray Rods	52 / 0	45 / 16	53 / 16
R/V I.D., inches	157	157	157
Vessel flow (Thermal Design)	295,500	194,200	300,000
Steam Generator Surface Area, ft2	68,000	75,000	125,000
Pressurizer Volume, ft3	1400	1600	2100

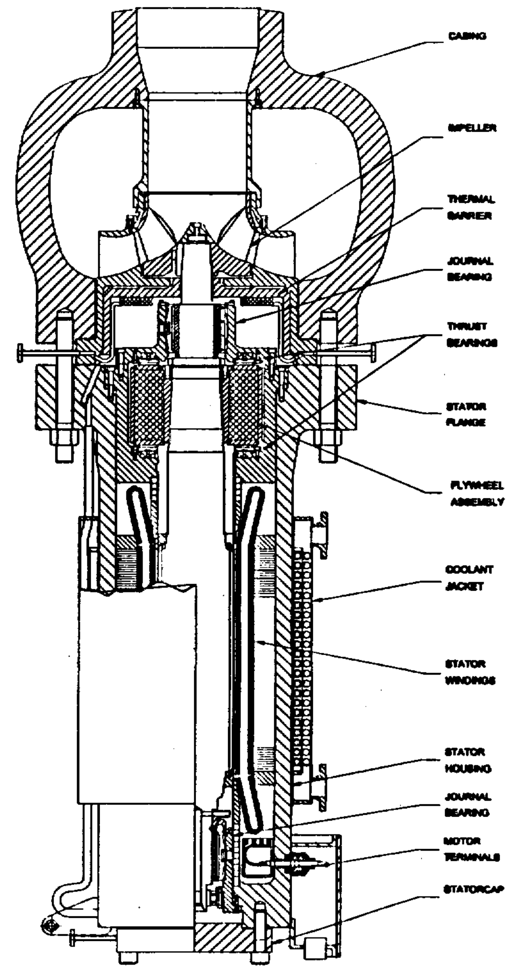
AP1000 Major Components

- **Fuel, Internals, Reactor Vessel**
  - Similar to Doel 4, Tihange 3, S. Texas
  - No bottom-mounted instrumentation
  - Use core shroud ala W/CE plants
  - Improved materials - 60 yr life
- **Steam Generators**
  - Features from W SGs in operation
  - Size from W/CE SGs in operation
- **Reactor Coolant Pumps**
  - Canned motor pumps
    - Naval reactors, early commercial reactors, AP600
- **Simplified Main Loop**
  - Same as AP600
  - Reduces welds 50%, supports 80%
- **Pressurizer**
  - 50% larger than operating plants



AP1000 Reactor Coolant Pump

- **Based on Field-Proven, Canned Motor Pumps**
  - 1300 units in service
  - 12-year mean time between repair
  - No shaft seals
    - No seal injection / leakoff system
    - No seal leakage / failure
  - Water lubricated bearings
    - No oil lubricating / cooling system
  - Compact, high inertia flywheel
  - AP600 pump tests performed
    - Full size test of compact flywheel
    - Scaled hydraulics tests
    - Air-mixing tests of SG / RCP connection

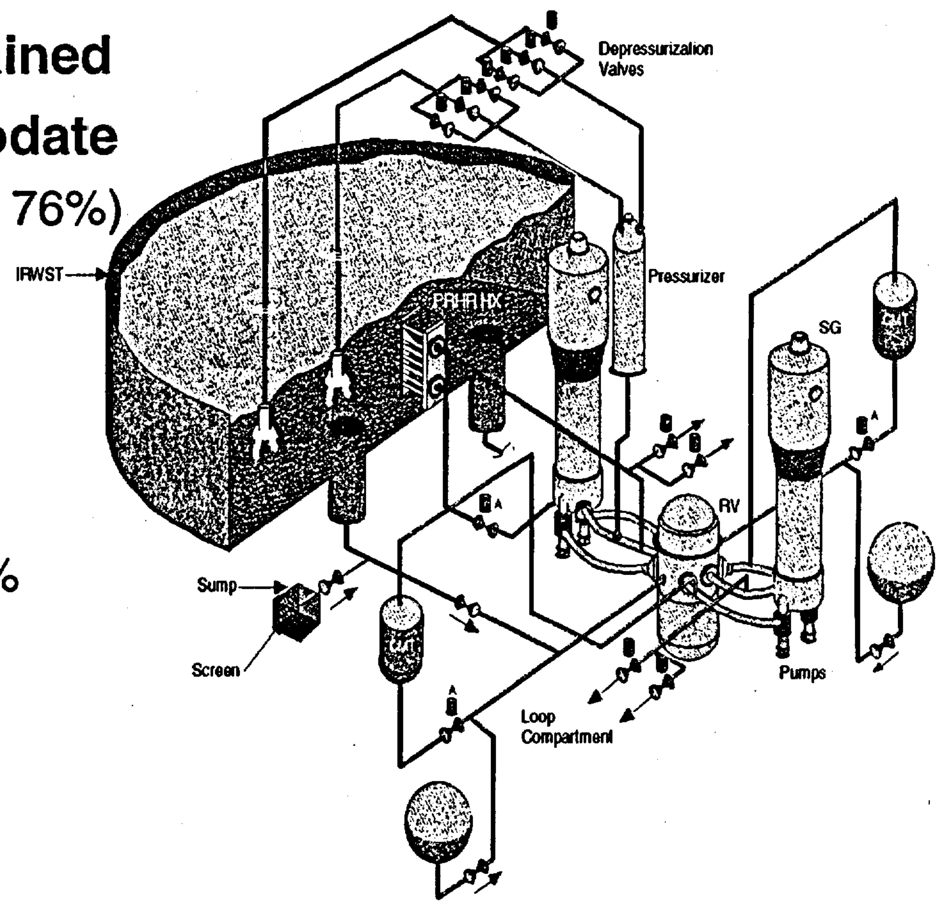


AP1000 Approach to Safety

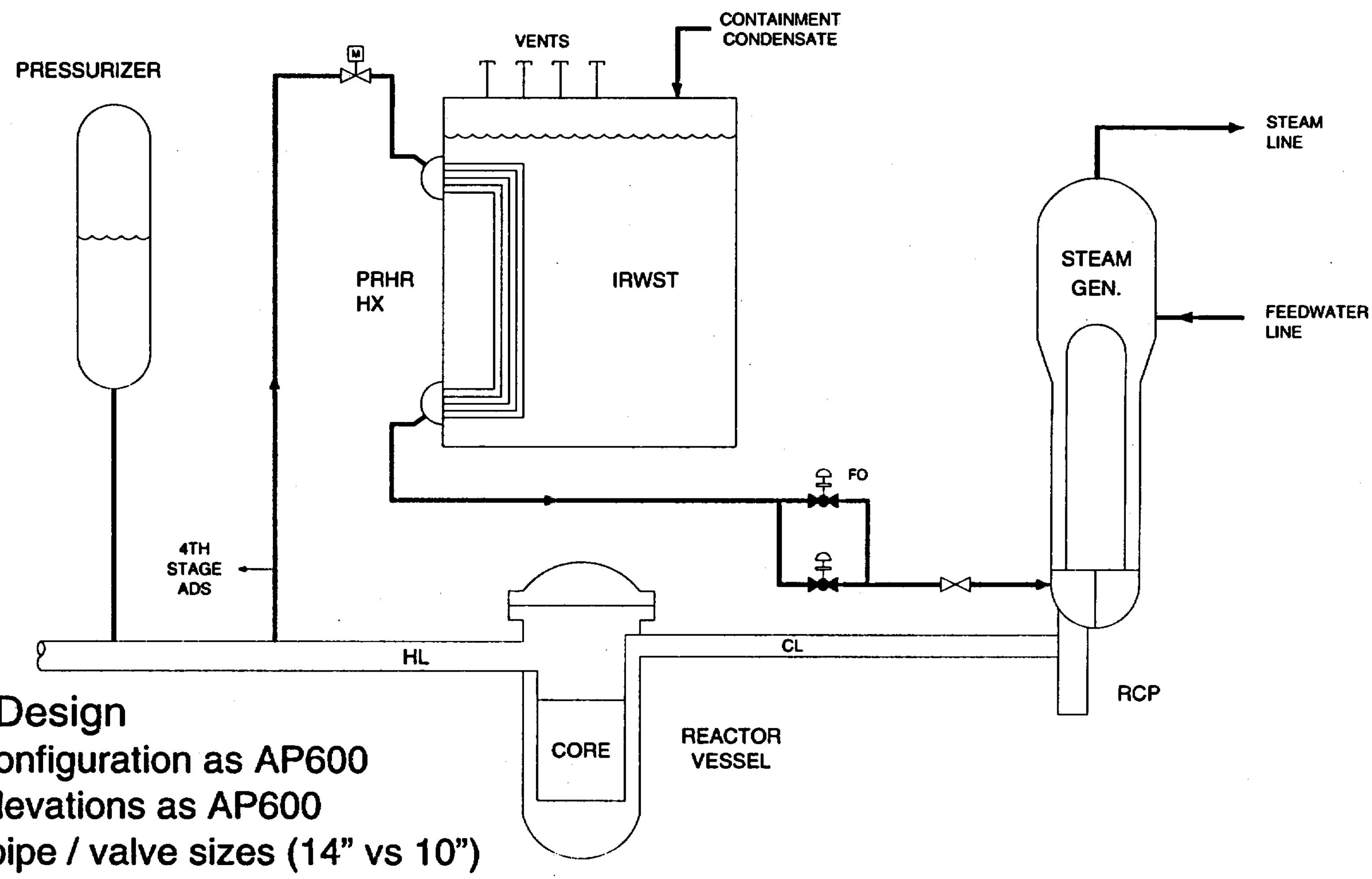
- **Passive Safety-Related Systems**
  - Use “passive” process only, no active pumps, diesels, ...
    - One time alignment of valves
    - No support systems required after actuation
      - No AC power, cooling water, HVAC, I&C
  - Greatly reduced dependency on operator actions
  - Mitigate design basis accidents without nonsafety systems
  - Meet NRC PRA safety goals without use of nonsafety systems
- **Active Nonsafety-Related Systems**
  - Reliably support normal operation
    - Redundant equipment powered by onsite diesels
  - Minimize challenges to passive safety systems
  - Not required to mitigate design basis accidents

AP1000 Passive Core Cooling System

- **AP600 System Configuration Retained**
- **Capacities Increased to Accommodate Higher Power** (1933MW - 3400MW or 76%)
  - PRHR HX Capacity Increased 72%
  - CMT Volume & Flow Increased 25%
  - ADS 4 Flow Increased 93%
  - IRWST Injection Increased 89%
  - Containment Recirc. Increased 139%
- **System Performance Maintained**
  - No core uncovery for SBLOCA
    - ≤ DVI line break
    - Large margin to PCT limit
  - No operator actions required for SGTR



Passive Decay Heat Removal

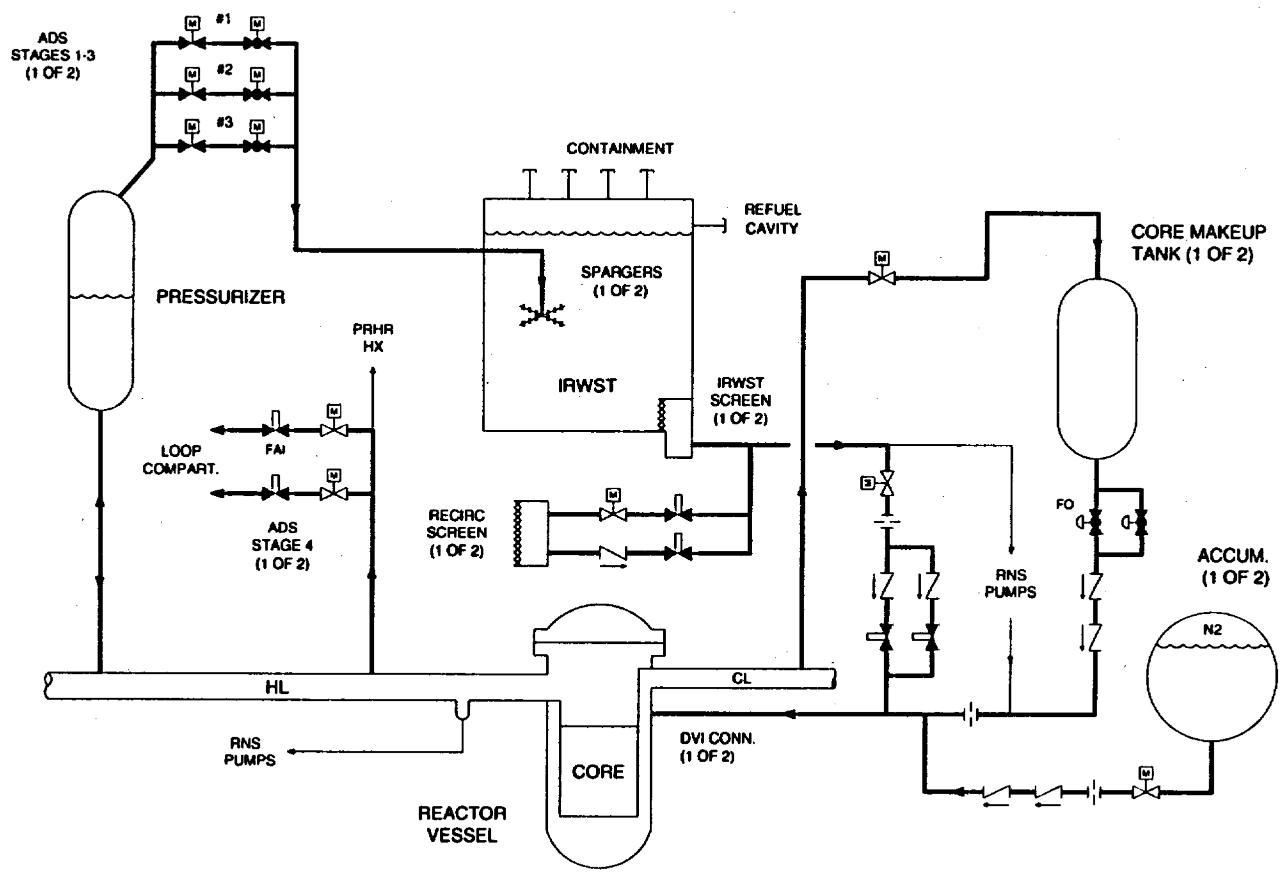


- PRHR HX Design
  - Same configuration as AP600
  - Same elevations as AP600
  - Larger pipe / valve sizes (14" vs 10")
  - Increased HX surface (more tubes / longer horizontal section)

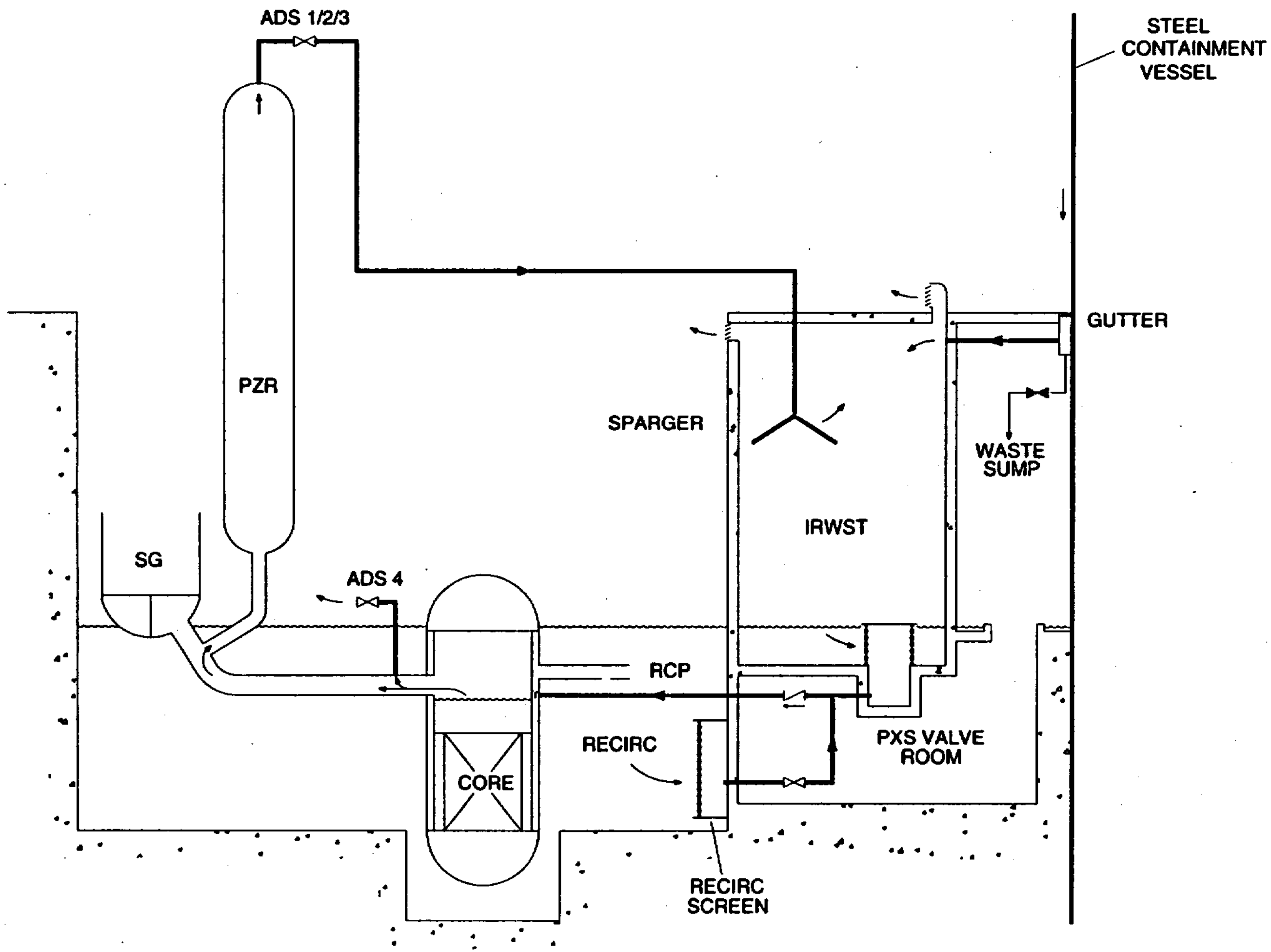
AP1000 Passive Safety Injection

Passive Safety Injection

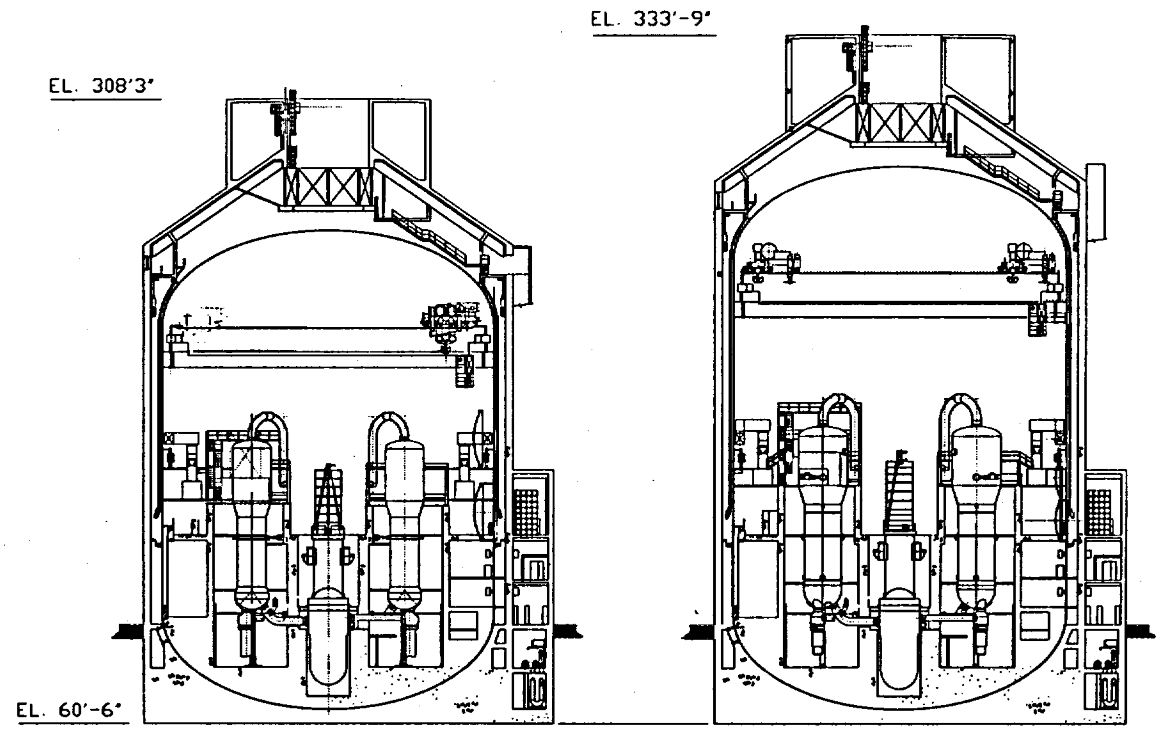
- Same configuration as AP600
- Same elevations as AP600
- Same Accum capacity
- Increased CMT capacity
  - 25% larger tank
  - 25% more flow
  - Same pipe, larger orifice
- Larger IRWST lines
  - 8" vs 6"
- Larger Recirc lines
  - 8" vs 6"
  - Increased cont. flood level
- Same ADS 1/2/3 lines
- Larger ADS 4 lines
  - 14" vs 10"



LOCA Long Term Cooling

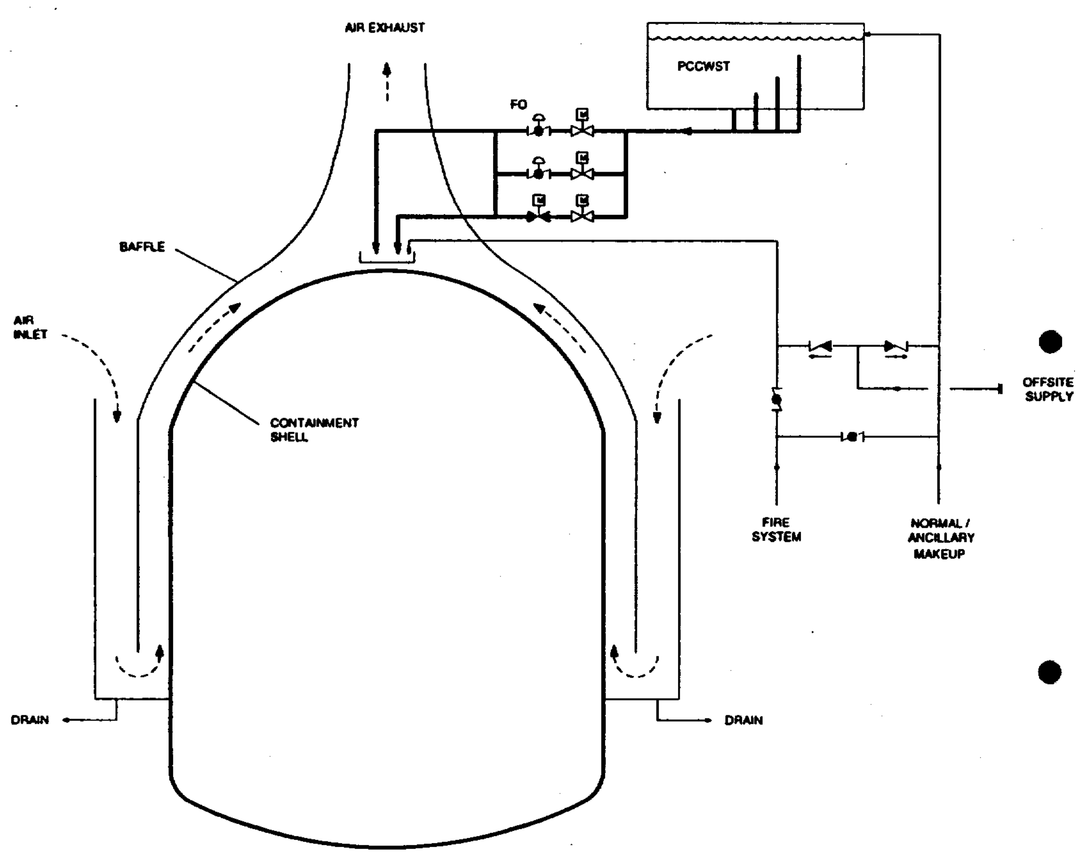


AP1000 Containment Comparison



	AP600	AP1000
Total Free Volume	100%	122%
Design Pressure, psig	45	59
Shell Thickness	1 5/8"	1 3/4"
Material	A537 Class 2	SA738 Grade B

Passive Containment Cooling System



- **PCS Water Storage Tank**
  - Provides 72 hr drain
    - Afterwards use on/offsite water
    - Air only cooling prevents failure
  - Flow decreases with time
    - Uses 4 standpipes
- **PCS Flow Rates**
  - High initial flow
    - Rapidly forms water film
    - Effectively reduces cont pressure
  - Later flows match decay heat
- **Added 3rd Diverse Drain Path**
  - Adds PRA margin
    - T&H uncertainty of cont cooling without water drain

AP1000 Safety Margins

	Typical Plant	AP600	AP1000
- Loss Flow Margin to DNBR Limit	~ 1 - 5%	~16%	~19%
- Feedline Break Subcooling Margin	>0°F	~170°F	~140°F
- SG Tube Rupture	Operator actions required in 10 min	Operator actions NOT required	Operator actions NOT required
- Small LOCA	3" LOCA core uncovers PCT ~1500°F	< 8" LOCA NO core uncovery	< 8" LOCA NO core uncovery
- Large LOCA PCT (with uncertainty)	2000 - 2200°F	1676°F	2124°F

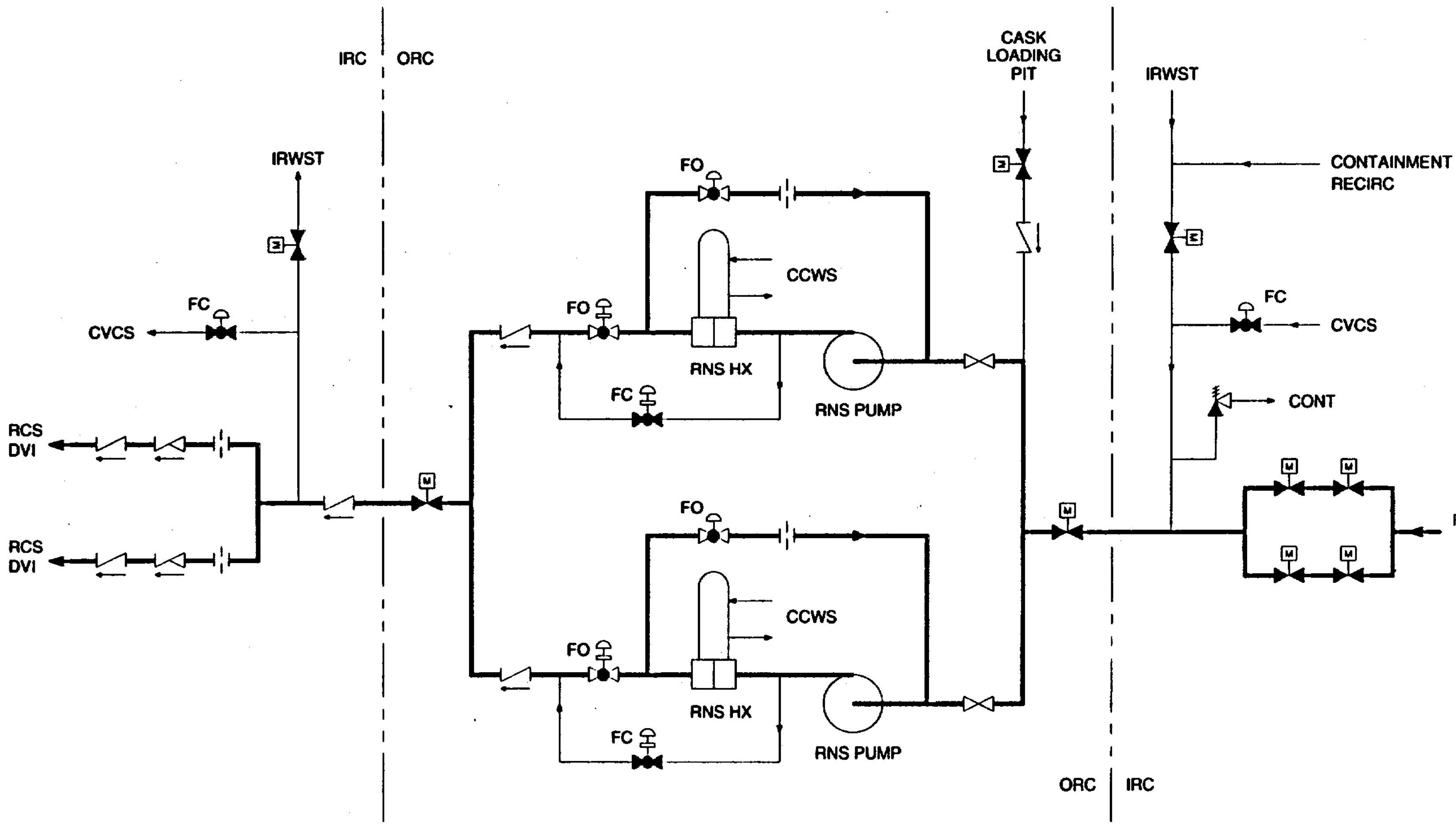
AP1000 Hydrogen Mitigation

- **Design Basis Accidents**
  - Slow long term buildup of H2
  - Uses 2 full size Passive Autocatalyic Recombiners (nonsafety)
    - No power or actuation required
  - Equipment is non-safety based on NRC / industry activities on risk-informed changes to 10 CFR 50.44 (Combustible Gas Control)
- **Severe Accidents**
  - Rapid buildup of H2
  - Uses non-safety igniters distributed in pairs around containment
  - Release paths from RCS ensure standing H2 flames located away from containment walls
    - IRWST vents changed to discharge H2 away from containment wall

AP1000 Active Nonsafety Systems

- **Active Nonsafety System Functions**
  - Reliably support normal operation
  - Minimize challenge to passive safety systems
  - Not required to mitigate design basis accidents
  - Not required to meet NRC safety goals
- **Active Nonsafety System Design Features**
  - Simplified designs (fewer components, separation not required)
  - Redundancy for more probable failures
  - Automatic actuation with power from onsite diesels
- **Active Nonsafety System Equipment Design**
  - Reliable, experienced based, industrial grade equipment
  - Non-ASME, non-seismic, limited fire / flood / wind protection
  - Availability controlled by procedures, no shutdown requirements
  - Reliability controlled by maintenance program

AP1000 Normal RHR System

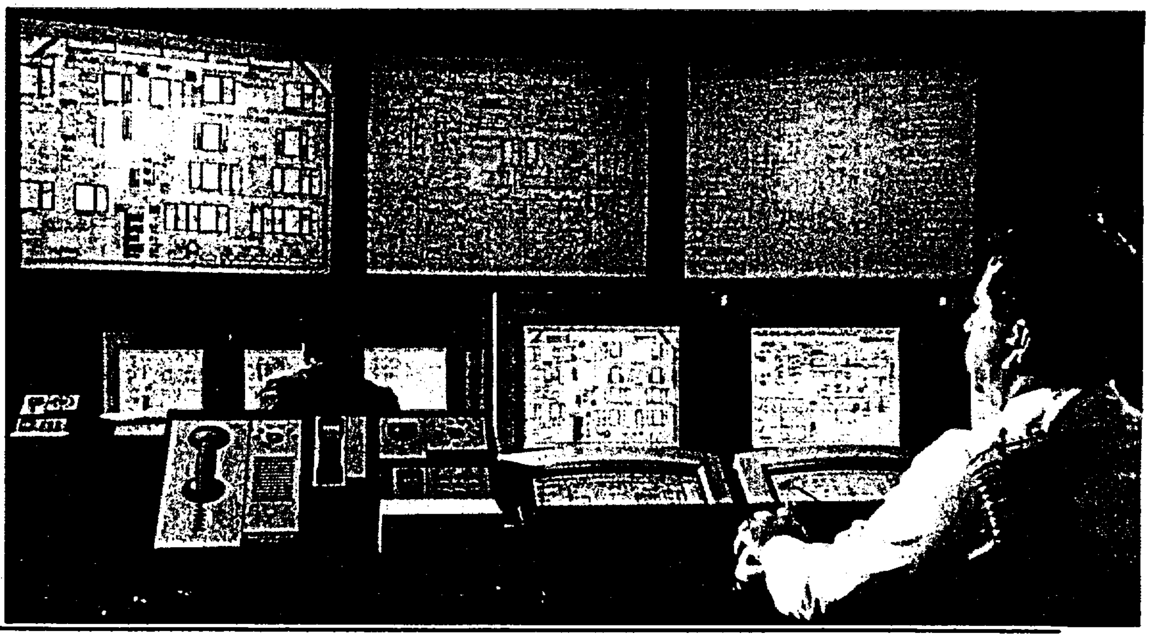


AP1000 I&C Systems

- **Control System (PLS/DDS)**
  - Plant wide non-1E system for all normal displays & controls
  - Microprocessor / software based, multiplexed communications
- **Safety System (PMS)**
  - Plant wide 1E system for all safety displays & controls
  - Microprocessor / software based, multiplexed communications
- **Diverse System (DAS)**
  - Limited scope non-1E system, PRA based displays & controls
    - Backs up PMS where common mode failure is risk important
  - Different hardware & software than PMS, no multiplexing
  - Separate sensors from PMS and PLS

AP1000 Advanced Control Room

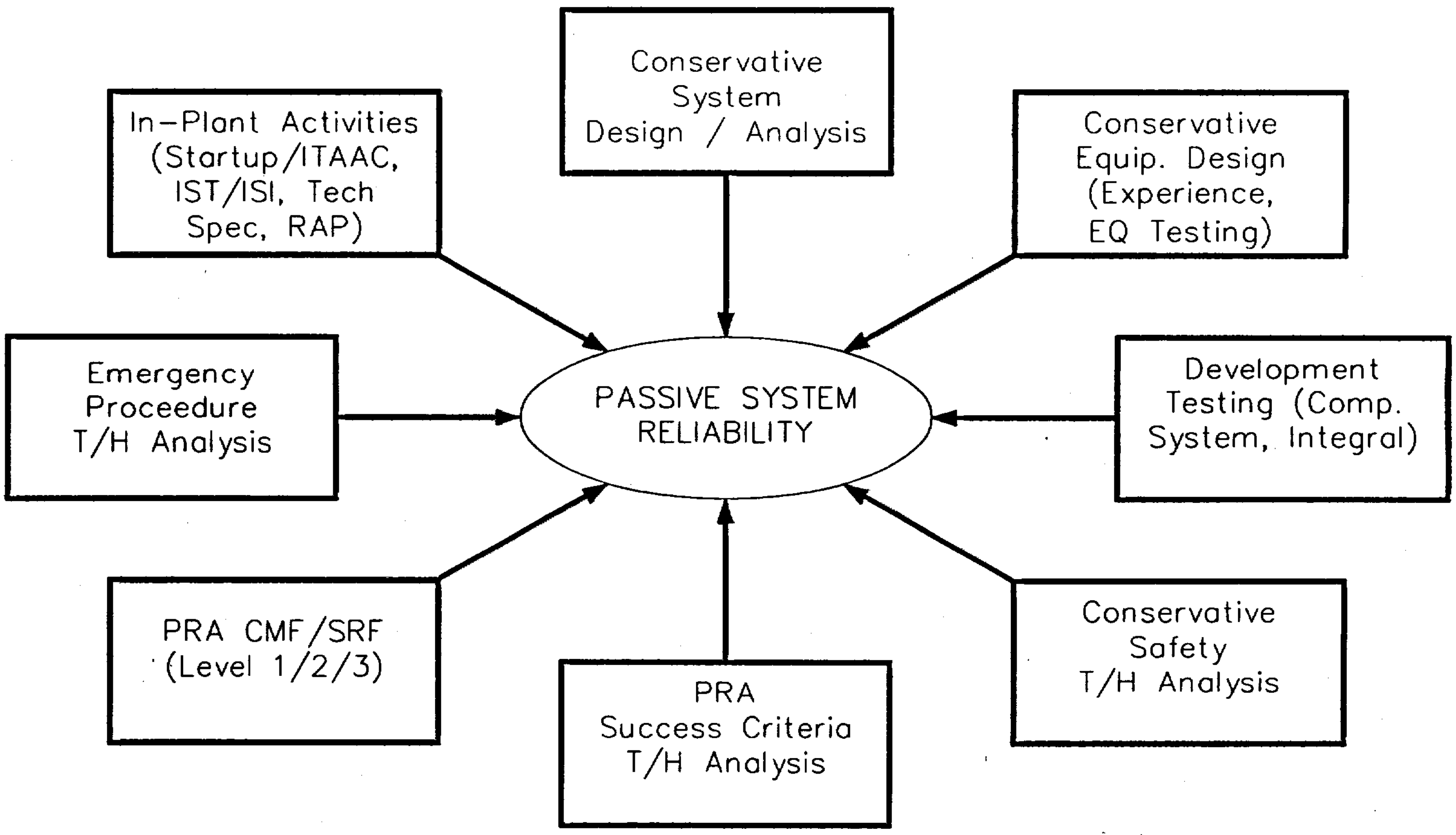
- **Compact Control Room**
  - Designed for 1 Reactor Operator and 1 Supervisor
- **Displays**
  - Plant status / overview via wall panel (DDS, non 1E)
  - Detail display via workstation video displays (DDS, non 1E)
  - Small number dedicated displays; safety (PMS, 1E) & diverse (DAS, non 1E)
- **Controls**
  - Soft controls (DDS, non 1E) for normal operation
  - Small number dedicated switches; safety (PMS, 1E) & diverse (DAS, non 1E)
- **Advanced Alarm Management**
- **Computer Based Procedures**



PMS Reliability Features

- **Redundant Trains**
  - 4 divisions, physically separated with improved isolation (fiber-optic)
    - Each with own independent battery-backed power supply
  - 2 out of 4 bypass logic, fail safe when appropriate
  - Different plant parameters provide functional diversity
- **Extensive Verification and Validation**
- **Extensive Equipment Qualification**
  - Environmental, seismic, EMC
- **Improved In-Plant Testing**
  - Built-in continuous self-testing and manual periodic testing
- **West. Extensive Experience with Digital I&C Designs**
  - Operating plant upgrades and new plants (Sizewell, Temelin)

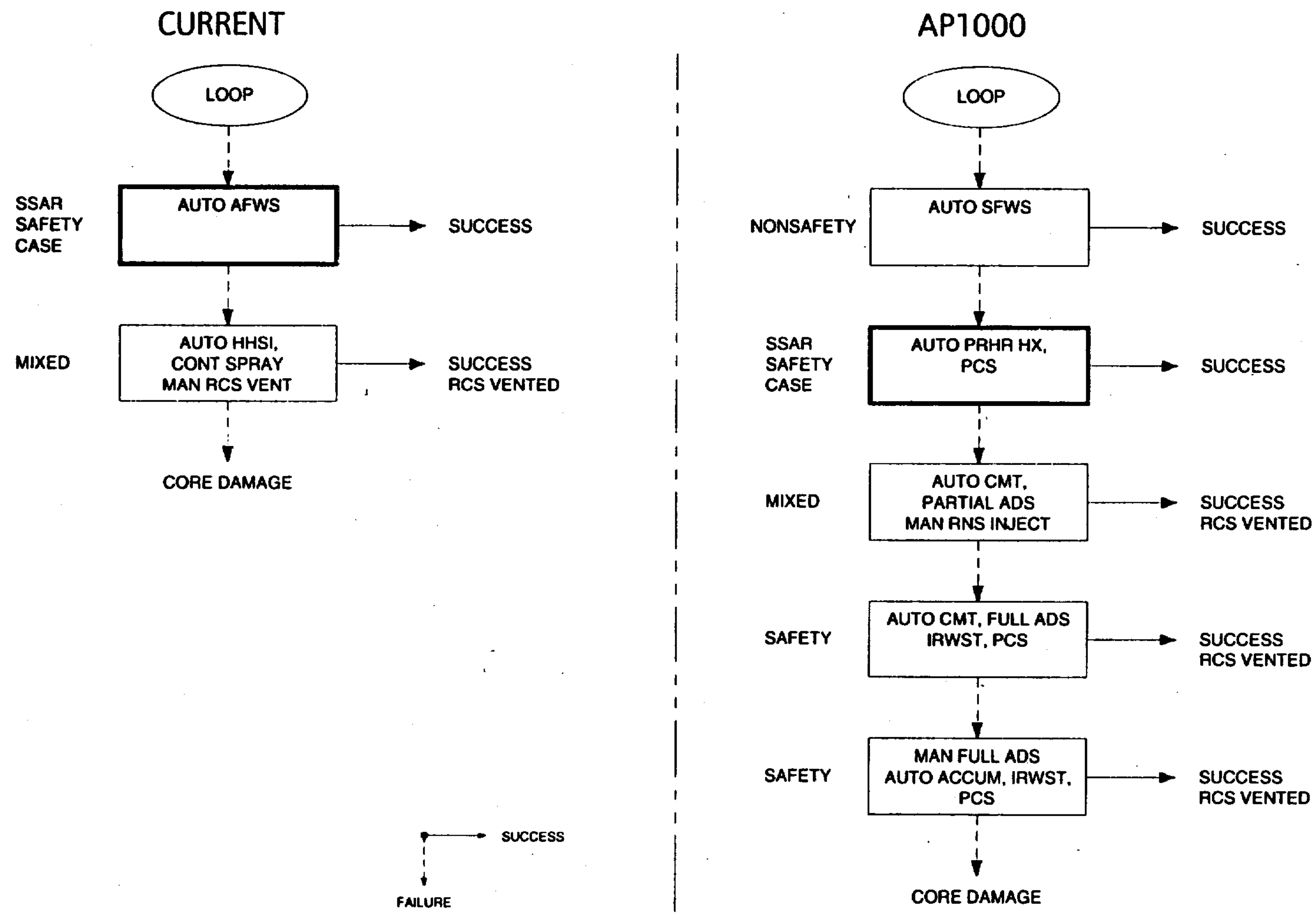
AP1000 System Reliability



System Defense In Depth

- **AP1000 Provides Multiple Levels of Defense**
  - First feature is usually nonsafety active feature
    - High quality industrial grade equipment
  - One feature is safety passive feature
    - Provides safety case for DCD
    - Highest quality nuclear grade equipment
  - Other passive features provide additional defense-in-depth
    - Example; passive feed/bleed backs up PRHR HX
  - Available for all shutdown conditions as well as at power
  - More likely events have more levels of defense

Loss of Offsite Power



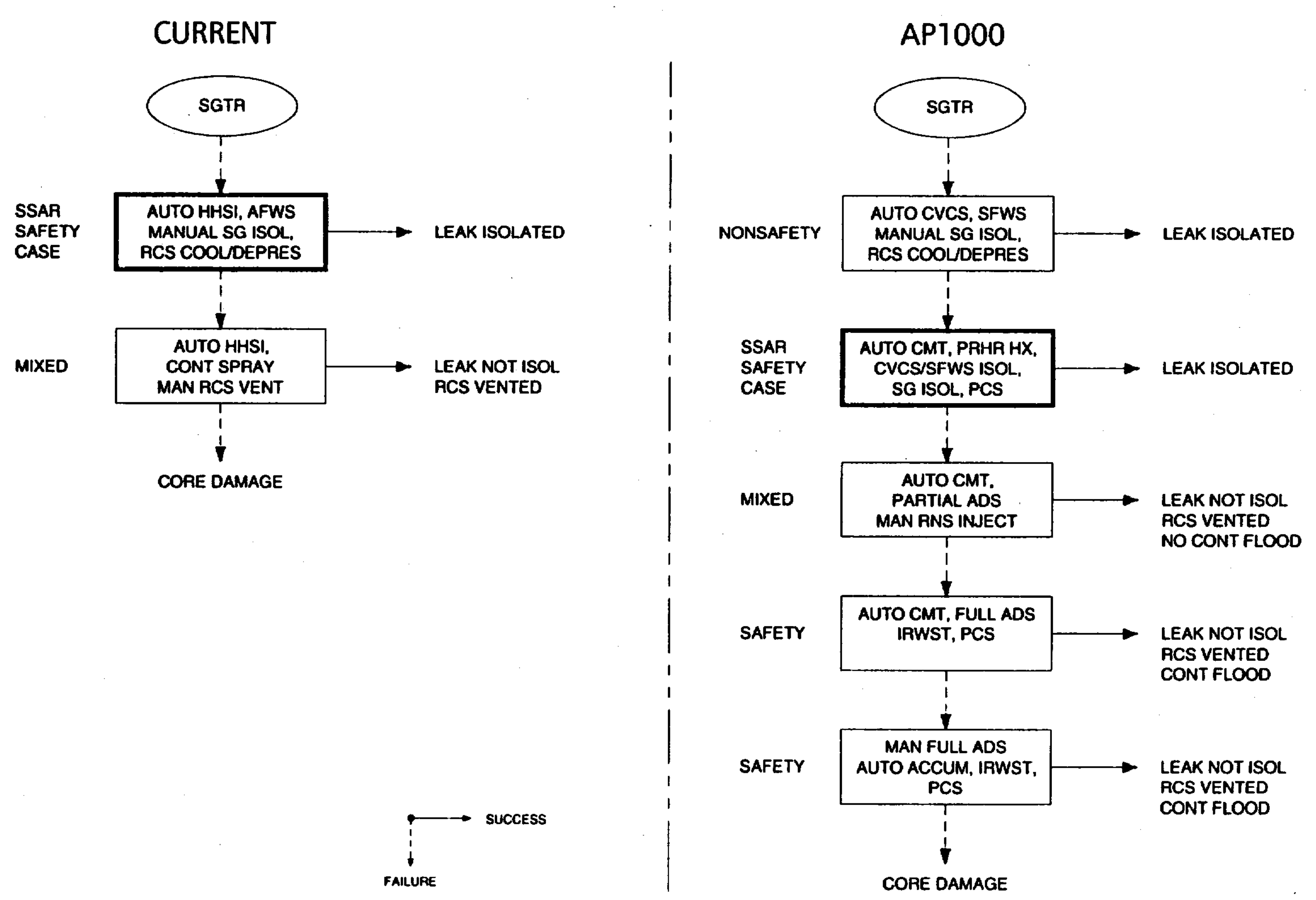
Loss Offsite Power, at Power

Function / System Use	Notes	PLS (1)	DC	AC	CW	HVAC	PMS (1)	DC	DAS (1)
		Support Systems (I&C, Electrical, Cooling, HVAC)							
		Non-Safety					Safety		Diverse
o Reactor Shutdown									
1. Control Rods		-	-	-	-	-	Auto	-	-
2. Control Rods		-	Yes	-	-	-	-	-	Auto
3. Ride Out	(2)	-	Yes	-	-	-	-	-	Auto
o RCS Inventory Control									
1. CVS		Auto	Yes	Yes	Yes	Yes	-	-	-
2. CMT		-	-	-	-	-	Auto	-	-
3. CMT		-	Yes	-	-	-	-	-	Auto
4. CMT, RNS, part ADS		Man	Yes	Yes	Yes	Yes	Auto	Yes	-
5. CMT, IRWST, full ADS		-	-	-	-	-	Auto	Yes	-
6. CMT, IRWST, full ADS		-	Yes	-	-	-	-	Yes	Man
7. Accum, RNS, part ADS		Man	Yes	Yes	Yes	Yes	Man	Yes	-
8. Accum, IRWST, full ADS		-	-	-	-	-	Man	Yes	-
9. Accum, IRWST, full ADS		-	Yes	-	-	-	-	Yes	Man
o RCS Heat Removal									
1. SFW		Auto	Yes	Yes	Yes	Yes	-	-	-
2. PRHR HX		-	-	-	-	-	Auto	-	-
3. PRHR HX		-	Yes	-	-	-	-	-	Auto
4. CMT, RNS, part ADS		Man	Yes	Yes	Yes	Yes	Auto	Yes	-
5. CMT, IRWST, full ADS		-	-	-	-	-	Auto	Yes	-
6. CMT, IRWST, full ADS		-	Yes	-	-	-	-	Yes	Man
7. Accum, RNS, part ADS		Man	Yes	Yes	Yes	Yes	Man	Yes	-
8. Accum, IRWST, full ADS		-	-	-	-	-	Man	Yes	-
9. Accum, IRWST, full ADS		-	Yes	-	-	-	-	Yes	Man
o Containment Heat Removal									
1. Fan Coolers		Auto	Yes	Yes	Yes	Yes	-	-	-
2. CV external air, water drain		-	-	-	-	-	Auto	-	-
3. CV external air, water drain		-	Yes	-	-	-	-	-	Auto
4. CV external water fire sys only		Man	Yes	-	-	-	-	-	-
5. CV external air only		-	-	-	-	-	-	-	-

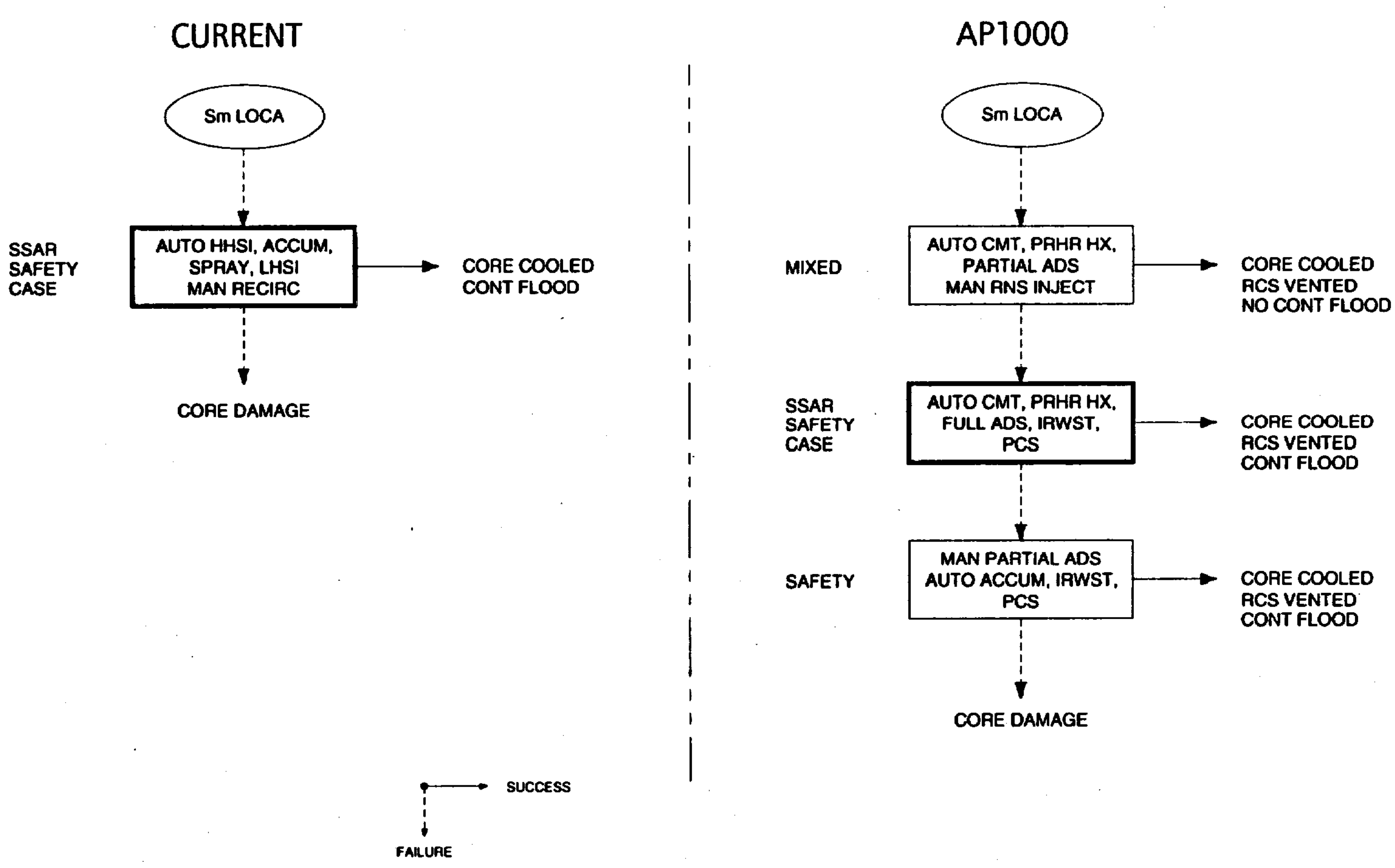
Notes:
1) PLS provides manual control of all nonsafety equipment by nonsafety MCB soft control switches. PMS provides manual control of all safety equipment by safety MCB system level dedicated controls and safety MCB soft switches. DAS provides manual control of selected safety equipment by nonsafety MCB dedicated controls.

2) Reactor is shut down by negative moderator temperature coefficient as the coolant heats up. Requires automatic RCS pressure relief, turbine trip, PRHR HX or SFW, CMT or CVS actuation.

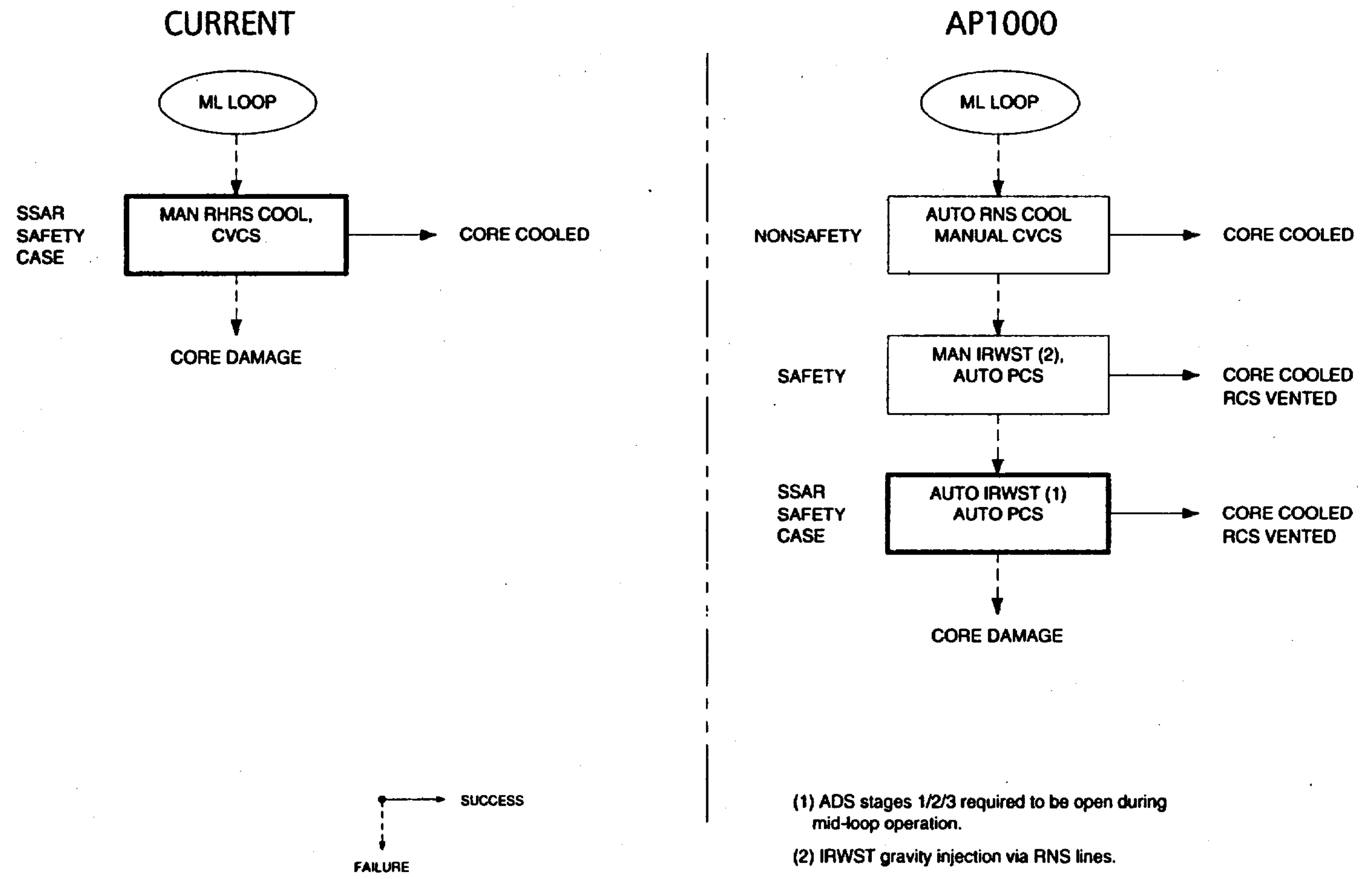
SG Tube Rupture



Small LOCA


CURRENT
Sm LOCA
SSAR SAFETY CASE
AUTO HHSI, ACCUM, SPRAY, LHSI MAN RECIRC
CORE COOLED CONT FLOOD
CORE DAMAGE
AP1000
Sm LOCA
MIXED
AUTO CMT, PRHR HX, PARTIAL ADS MAN RNS INJECT
CORE COOLED RCS VENTED NO CONT FLOOD
SSAR SAFETY CASE
AUTO CMT, PRHR HX, FULL ADS, IRWST, PCS
CORE COOLED RCS VENTED CONT FLOOD
SAFETY
MAN PARTIAL ADS AUTO ACCUM, IRWST, PCS
CORE COOLED RCS VENTED CONT FLOOD
CORE DAMAGE
SUCCESS
FAILURE

Mid-Loop Loss Power



(1) ADS stages 1/2/3 required to be open during mid-loop operation.

(2) IRWST gravity injection via RNS lines.

AP1000 PRA

- **Westinghouse Uses PRA as Design & Licensing Tool**
  - 7 PRA major quantifications performed on AP600
    - First in 1987, final in 1997
    - Extensive interaction with plant designers
    - Extensive NRC review / comment
  - AP1000 PRA quantified in 2001
    - Started with AP600 models / analysis
  - Plant designers interact with risk analysis
    - Results reviewed, improvements made (more in AP600)
      - PRA analysis models and supporting T/H analysis
      - Plant operating procedures
      - Plant design

PRA Based Changes (AP600)

- **Analysis Changes**
  - Accum or CMT sufficient for small / medium LOCA
  - One accum sufficient for large LOCA
  - Multiple ADS valve failures acceptable
- **Operation Changes**
  - Manually start RNS after ADS actuation
  - Require containment closure capability during mid-loop
  - Require PXS features to be available during shutdowns

PRA Based Changes (AP600)

- **Design Changes**
  - RNS alignment valves made remote
  - 4th stage ADS valves made diverse from stages 1, 2, 3
  - Added DAS functions
  - Added redundant IRWST injection check valves
  - Added redundant / diverse IRWST recirc valves
  - Made CMT check valves normally open, diverse from accum
  - Provided logic for automatic SGTR protection without ADS

PRA Based Changes (AP1000)

- **AP1000 Analysis Changes**
  - Initiating event frequency changes
    - Larger SGs (more, longer tubes)
    - Increased number SG safety valves
    - Separated spurious ADS stage 4 and large CL LOCA
      - 2 / 2 accum required for CL LOCA, 1/2 accum required for spur ADS 4
  - PRHR HX operation needed for MLOCA without CMTs
    - Provides operators sufficient time for manual ADS
- **AP1000 Operation Changes**
  - Containment recirc MOV normally open (in series with squib valve)
  - Changed IRWST drain proceedure so it occurs earlier in core melt
  - Added Tech Spec on DAS manual controls

PRA Based Changes (AP1000)

- **AP1000 Design Changes**
  - Increased volume and injection rate of CMTs
  - Added 3rd Passive Cont. Cooling drain valve, MOV diverse to AOV
  - Incorporated low boron core, improves ATWT
  - RNS injection water supply changed from IRWST to Cask Load Pit
  - Improved IVR heat transfer via changes to RV insulation gap
  - Improved H2 vents from IRWST to keep H2 flames away from cont.

AP1000 Probabilistic Risk Assessment

Selim Sancaktar
Fellow Engineer, Reliability and Risk Assessment
412-374-5983 - sancaks@westinghouse.com

OBJECTIVES

- The purpose of the AP1000 PRA is to provide inputs to the optimization of the AP1000 design and to verify that the US NRC PRA safety goals have been satisfied

- As in the AP600, the PRA is being performed interactively with the design, analysis and operating procedures.

TECHNICAL SCOPE

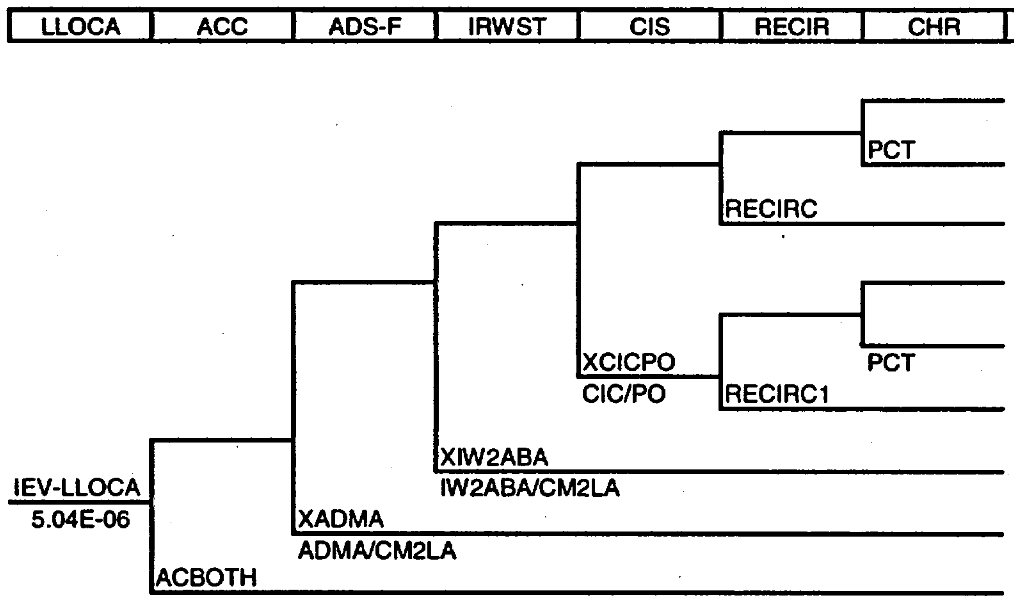
- Since the configuration of the AP1000 reactor and safety systems is the same as the AP600, the AP600 PRA is used as the basis of the AP1000 PRA with relevant changes implemented in the model to reflect the AP1000 design changes

TECHNICAL SCOPE

- AP1000 plant-specific T&H analyses are performed in order to determine the system success criteria

- The CDF and LRF are calculated for internal events at-power. The off-site dose risk analysis is also performed. The external events and shutdown models are also assessed to derive plant insights and plant risk conclusions.

AP1000 Large LOCA Event Tree



	PDS	FREQ.		LCF
1	LLO-OK1			
2	LCF		lcllo-02	6.87E-12
3	3BL	8.43E-11	2lllo-03	
4	LLO-OK2			
5	LCF		lcllo-05	1.60E-12
6	3BL	1.77E-14	2lllo-06	
7	3BE	3.40E-10	2ello-07	
8	3D	1.97E-09	3dllo-08	
9	3BR	4.26E-08	2rllo-09	
Total CDF =		4.50E-08		8.47E-12

List of Top Events

Event	Description
LLOCA	Large LOCA Event Occurs
ACC	Accumulators Inject
ADS-F	Full RCS Depressurization by ADS occurs
IRWST	RCS Refill from IRWST by Gravity Injection Occurs
CIS	Containment Isolation Occurs
RECIR	Water Recirculation to RPV from the Sump Occurs
CHR	Containment Cooling is Established

AP1000 System Failure Probabilities

- Fault Tree Models are used to calculate system failure probabilities & identify minimal cutsets
- All support systems are modeled in detail
- Component random failures, human errors, tests and maintenance unavailabilities, and common cause are modeled based on standard industry practice

AP1000 PRA System Failure Probabilities

Failure System/Function	Probability	Fault Tree Name
CMT Valve Signal	5.70E-07	CMT-IC11 (one train; auto and manual actuation)
PRHR Valve Signal	1.10E-06	RHR-IC01 (one train; auto and manual actuation)
Passive Cont. Cool.	1.80E-06	PCT
Reactor Trip by PMS	1.20E-05	RTPMS (including operator actions)
Accumulators	6.90E-05	AC2AB
IRWST inj.	6.90E-05	IW2AB
ADS	9.30E-05	ADS (including operator actions)
Passive RHR	2.00E-04	PRT
Core Makeup Tanks	1.10E-04	CM2SL
125 vdc 1E Bus	3.10E-04	IDADS1 (one bus only)
DC Bus (Non-1E)	3.40E-04	ED1DS1 (one bus only)
RC Pump Trip	5.90E-04	RCT
Chilled Water	1.40E-03	VWH
Containment Isol.	1.60E-03	CIC
Reactor Trip by DAS failure))	1.70E-03	DAS (including operator action; excluding MGSET
6900 vac Bus	3.20E-03	ECES1 (obe bus only)
CVS	3.40E-03	CVS1
480 vac Bus	5.90E-03	ECEK11 (one bus only)
Service Water	6.20E-03	SWT
Comp. Cooling Water	6.30E-03	CCT
Diesel Generators	1.00E-02	DGEN
Startup Feedwater	1.70E-02	SFWT
Compressed Air	1.30E-02	CAIR
Condenser	2.40E-02	CDS
Main Feedwater	2.80E-02	FWT (including condenser)
RNS	9.10E-02	RNR
Hydrogen Control	1.00E-01	VLH

Contribution of Initiating Events to AP1000 CDF

AP1000

	IEV CATEGORY	CONTRIBUTION TO CDF	CONTRIBUTION TO CDF (%)	IEV FREQUENCY	CONDITIONAL CDF
1	IEV-SI-LB	9.50E-08	39.43	2.12E-04	4.48E-04
2	IEV-LLOCA	4.50E-08	18.66	5.00E-06	8.99E-03
3	IEV-SPADS	2.96E-08	12.28	5.40E-05	5.48E-04
4	IEV-SLOCA	1.81E-08	7.5	5.00E-04	3.62E-05
5	IEV-MLOCA	1.61E-08	6.69	4.36E-04	3.70E-05
6	IEV-RV-RP	1.00E-08	4.15	1.00E-08	1.00E+00
7	IEV-SGTR	6.79E-09	2.82	3.88E-03	1.75E-06
8	IEV-CMTLB	3.68E-09	1.53	9.31E-05	3.95E-05
9	IEV-ATWS	3.61E-09	1.5	4.81E-01	7.49E-09
10	IEV-TRANS	3.08E-09	1.28	1.40E+00	2.20E-09
11	IEV-RCSLK	1.71E-09	0.71	6.20E-03	2.75E-07
12	IEV-POWEX	1.66E-09	0.69	4.50E-03	3.69E-07
13	IEV-LCOND	1.24E-09	0.52	1.12E-01	1.11E-08
14	IEV-LOSP	9.58E-10	0.4	1.20E-01	7.98E-09
15	IEV-LMFW	8.70E-10	0.36	3.35E-01	2.60E-09
16	IEV-ATW-T	7.12E-10	0.3	1.17E+00	6.09E-10
17	IEV-LCAS	6.72E-10	0.28	3.48E-02	1.93E-08
18	IEV-SLB-V	6.06E-10	0.25	2.39E-03	2.54E-07
19	IEV-PRSTR	5.02E-10	0.21	1.34E-04	3.74E-06
20	IEV-LMFW1	4.53E-10	0.19	1.92E-01	2.36E-09
21	IEV-LCCW	3.23E-10	0.13	1.44E-01	2.24E-09
22	IEV-SLB-U	1.31E-10	0.05	3.72E-04	3.51E-07
23	IEV-ATW-S	1.11E-10	0.05	1.48E-02	7.48E-09
24	IEV-ISLOC	5.00E-11	0.02	5.00E-11	1.00E+00
25	IEV-LRCS	3.52E-11	0.01	1.80E-02	1.96E-09
26	IEV-SLB-D	9.15E-12	0	5.96E-04	1.54E-08
	Totals =	2.41E-07	100.0	2.38*	

* - The total initiating event frequency excludes the three ATWS precursor frequencies

Comparison of AP600 and AP1000 CDF

IEV CATEGORY	AP600 CONTRIBUTION TO CDF	AP600 CONTRIBUTION TO CDF (%)	AP600 IEV FREQUENCY	AP600 CONDITIONAL CDP (P1)	AP1000 CONTRIBUTION TO CDF	AP1000 CONTRIBUTION TO CDF (%)	AP1000 IEV FREQUENCY	AP1000 CONDITIONAL CDP (P2)	RATIO P2/P1
IEV-LLOCA	5.02E-08	29.67	1.05E-04	4.78E-04	4.50E-08	18.66	5.00E-06	8.99E-03	18.8
IEV-SI-LB	3.82E-08	22.58	1.04E-04	3.67E-04	9.50E-08	39.43	2.12E-04	4.48E-04	1.2
IEV-NLOCA	3.15E-08	18.63	7.70E-04	4.09E-05					
IEV-RV-RP	1.00E-08	5.91	1.00E-08	1.00E+00	1.00E-08	4.15	1.00E-08	1.00E+00	1
IEV-ATWS	8.98E-09	5.31	4.81E-01	1.87E-08	3.61E-09	1.5	4.81E-01	7.49E-09	0.4
IEV-MLOCA	6.23E-09	3.68	1.62E-04	3.85E-05	1.61E-08	6.69	4.36E-04	3.70E-05	1
IEV-SGTR	6.08E-09	3.6	5.20E-03	1.17E-06	6.79E-09	2.82	3.88E-03	1.75E-06	1.5
IEV-SLOCA	4.05E-09	2.4	1.01E-04	4.01E-05	1.81E-08	7.5	5.00E-04	3.62E-05	0.9
IEV-CMTLB	3.54E-09	2.09	8.94E-05	3.96E-05	3.68E-09	1.53	9.31E-05	3.95E-05	1
IEV-RCSLK	2.26E-09	1.34	1.20E-02	1.89E-07	1.71E-09	0.71	6.20E-03	2.75E-07	1.5
IEV-POWEX	1.83E-09	1.08	4.50E-03	4.07E-07	1.66E-09	0.69	4.50E-03	3.69E-07	0.9
IEV-TRANS	1.14E-09	0.67	1.40E+00	8.14E-10	3.08E-09	1.28	1.40E+00	2.20E-09	2.7
IEV-LCOND	1.03E-09	0.61	1.12E-01	9.23E-09	1.24E-09	0.52	1.12E-01	1.11E-08	1.2
IEV-LOSP	1.01E-09	0.6	1.20E-01	8.40E-09	9.58E-10	0.4	1.20E-01	7.98E-09	1
IEV-ATW-T	7.12E-10	0.42	1.17E+00	6.09E-10	7.12E-10	0.3	1.17E+00	6.09E-10	1
IEV-PRSTR	5.58E-10	0.33	2.50E-04	2.23E-06	5.02E-10	0.21	1.34E-04	3.74E-06	1.7
IEV-SLB-V	4.82E-10	0.28	1.21E-03	3.98E-07	6.06E-10	0.25	1.21E-03	5.01E-07	1.3
IEV-ATW-S	3.82E-10	0.23	2.05E-02	1.86E-08	1.11E-10	0.05	1.48E-02	7.48E-09	0.4
IEV-LMFW	3.03E-10	0.18	3.35E-01	9.04E-10	8.70E-10	0.36	3.35E-01	2.60E-09	2.9
IEV-LMFW1	1.76E-10	0.1	1.92E-01	9.16E-10	4.53E-10	0.19	1.92E-01	2.36E-09	2.6
IEV-LCAS	1.73E-10	0.1	3.48E-02	4.98E-09	6.72E-10	0.28	3.48E-02	1.93E-08	3.9
IEV-SLB-U	1.23E-10	0.07	3.72E-04	3.31E-07	1.31E-10	0.05	3.72E-04	3.51E-07	1.1
IEV-LCCW	1.23E-10	0.07	1.44E-01	8.52E-10	3.23E-10	0.13	1.44E-01	2.24E-09	2.6
IEV-ISLOC	5.00E-11	0.03	5.00E-11	1.00E+00	5.00E-11	0.02	5.00E-11	1.00E+00	1
IEV-LRCS	1.27E-11	0.01	1.80E-02	7.06E-10	3.52E-11	0.01	1.80E-02	1.96E-09	2.8
IEV-SLB-D	9.46E-12	0.01	5.96E-04	1.59E-08	9.15E-12	0	5.96E-04	1.54E-08	1
IEV-SPADS					2.96E-08	12.28	5.40E-05	5.48E-04	
Totals:	**1.69E-07**	**100**	**2.38E+00**		**2.41E-07**	**100**	**2.37E+00**		

AP1000 PRA Dominant CDF Sequences

	Sequence Frequency	% Contrib	Cum. % Contrib	Sequence ID	Sequence Description	Event Identifier
1	6.88E-08	28.52	28.52	2esil-07	SAFETY INJECTION LINE BREAK INITIATING EVENT OCCURS	IEV-SI-LB
					RCPS TRIP AND CMT INJECTION IS SUCCESSFUL - 1 OF 2 CMT TRAINS	DEL-XCM1A
					SUCCESS OF FULL ADS DEPRESSURIZATION	DEL-ADM
					FAILURE OF ONE OF ONE IRWST INJECTION LINE	SYS-IW1A
2	4.26E-08	17.66	46.18	2rllo-09	LARGE LOCA INITIATING EVENT OCCURS	IEV-LLOCA
					ANY ONE OF TWO ACCUMULATOR TRAINS FAIL	SYS-ACBOTH
3	2.13E-08	8.82	55	3dsad-08	SPURIOUS ADS INITIATING EVENT OCCURS	IEV-SPADS
					SUCCESS OF 1/2 OR 2/2 ACCUMULATORS	DEL-AC2AB
					FAILURE OF ADS OR CMT	SYS-XADMA
4	1.98E-08	8.23	63.23	3dsil-08	SAFETY INJECTION LINE BREAK INITIATING EVENT OCCURS	IEV-SI-LB
					RCPS TRIP AND CMT INJECTION IS SUCCESSFUL - 1 OF 2 CMT TRAINS	DEL-XCM1A
					FAILURE OF FULL ADS DEPRESSURIZATION	SYS-ADM
5	1.00E-08	4.15	67.38	3crvr-02	REACTOR VESSEL RUPTURE INITIATING EVENT OCCURS	IEV-RV-RP
6	8.44E-09	3.5	70.88	2lslo-05	SMALL LOCA INITIATING EVENT OCCURS	IEV-SLOCA
					SUCCESS OF CMT & RCP TRIP	DEL-XCM2SL
					SUCCESS OF PASSIVE RHR SYSTEM	DEL-PRL
					SUCCESS OF FULL ADS DEPRESSURIZATION	DEL-ADS
					FAILURE OF NORMAL RHR IN INJECTION MODE	SYS-RNR
					SUCCESS OF TWO OF TWO IRWST INJECTION LINES	DEL-IW2AB
					SUCCESS OF CIS & PRE-EXISTING CONTAINMENT OPENING	DEL-XCICPO
					FAILURE OF RECIRCULATION	SYS-RECIRC

AP1000 PRA Dominant CDF Sequences

	Sequence Frequency	% Contrib	Cum. % Contrib	Sequence ID	Sequence Description	Event Identifier
7	7.35E-09	3.05	73.93	2lmlo-05	MEDIUM LOCA INITIATING EVENT OCCURS	IEV-MLOCA
					SUCCESS OF CMT & RCP TRIP	DEL-XCM2NL
					SUCCESS OF FULL ADS DEPRESSURIZATION	DEL-ADM
					FAILURE OF NORMAL RHR IN INJECTION MODE	SYS-RNR
					SUCCESS OF TWO OF TWO IRWST INJECTION LINES	DEL-IW2AB
					SUCCESS OF CIS & PRE-EXISTING CONTAINMENT OPENING	DEL-XCICPO
					FAILURE OF RECIRCULATION	SYS-RECIRC
8	5.11E-09	2.12	76.05	3dmlo-12	SMALL LOCA INITIATING EVENT OCCURS	IEV-SLOCA
					SUCCESS OF CMT & RCP TRIP	DEL-XCM2SL
					SUCCESS OF PASSIVE RHR SYSTEM	DEL-PRL
					FAILURE OF FULL ADS DEPRESSURIZATION	SYS-ADS
					SUCCESS OF PARTIAL ADS DEPRESSURIZATION	DEL-ADV
					FAILURE OF NORMAL RHR IN INJECTION MODE	SYS-RNR
9	4.46E-09	1.85	77.9	3dmlo-12	MEDIUM LOCA INITIATING EVENT OCCURS	IEV-MLOCA
					SUCCESS OF CMT & RCP TRIP	DEL-XCM2NL
					FAILURE OF FULL ADS DEPRESSURIZATION	SYS-ADM
					SUCCESS OF PARTIAL ADS DEPRESSURIZATION	DEL-ADU
					FAILURE OF NORMAL RHR IN INJECTION MODE	SYS-RNR
10	3.72E-09	1.54	79.44	2rsad-09	SPURIOUS ADS INITIATING EVENT OCCURS	IEV-SPADS
					FAILURE OF 2/2 ACCUMULATORS	SYS-AC2AB
11	3.67E-09	1.52	80.96	2esad-07	SPURIOUS ADS INITIATING EVENT OCCURS	IEV-SPADS
					SUCCESS OF 1/2 OR 2/2 ACCUMULATORS	DEL-AC2AB
					SUCCESS OF ADS & CMT	DEL-XADMA
					FAILURE OF IRW OR CMT	SYS-XIW2ABA

Summary of Sensitivity Analysis Results

Case Description	Results
Set LCF sequences to core damage	SI-LB initiating event is the most important contributor (30.64%) to CDF. CDF increases by a factor of 1.3.
Initiating Event Importances	SI-LB (39.43) and LLOCA (18.66) initiating events are the most important contributors to CDF
Accident Sequence Importances	IEV-SI-LB, DEL-XCM1A, DEL-ADM, SYS-IW1A (28.52%) is the most important sequence contributor to CDF.
End State Importances	3BE (33.4%) and 3D+1D (23.9%) are the most important contributors to CDF.
Common Cause Failure Importances	Software CCF of all cards and IRWST sump strainers plugging CCF are the most important contributors to CDF.
Human Error Importances	Operator failure to diagnose SG tube rupture event is the most important contributor to CDF.
Component Importances	IRWST strainer plugged, PRHR H/X plug/leak and IRWST tank failure are most important contributors to CDF.
Set HEPs to 1.0 in core damage output file (no credit for HEPs)	CDF increases by a factor of 57.
Set HEPs to 0.0 in core damage output file (perfect operator)	CDF decreases 8%.
Set HEPs to 0.1 in core damage output file	CDF increases by a factor of 6.5.
Impact of passive system check valve failure probabilities	CDF increases by a factor of 3.7.
Impact of explosive valve failure probabilities	CDF increases by a factor of 2.7.
Impact of reactor trip breaker failure probabilities	CDF has negligible increase.
Impact of RCP breaker failure probabilities	CDF increases by a factor of 1.2.
Sensitivity to standby non-safety systems (CVS,SFW,RNS,DAS,DG)	CDF increases by a factor of 31.

AP1000 PRA System Importances

AP1000 SYSTEM IMPORTANCES BY RISK (CDF) INCREASE			
PMS DC-1E IRWST-REC ADS IRWST-INJ	CMT ACC PRHR	DC-Non 1E DAS AC PLS	CAS N-RHR SWS CCS SFW DG MFW SG Overfill Protection
> 300	50-300	2-50	<2

AP1000 PRA System Importances

PMS	No credit is taken for PMS in CD sequences
DC-1E	No credit is taken for 1E DC Power in CD sequences
IRWST-REC	No credit is taken for IRWST Recirculation in CD sequences
ADS	No credit is taken for ADS in CD sequences
IRWST-INJ	No credit is taken for IRWST Injection in CD sequences
CMT	No credit is taken for CMT in CD sequences
ACC	No credit is taken for Accumulators in CD sequences
PRHR	No credit is taken for Passive RHR in CD sequences
DC-Non 1E	No credit is taken for Non-1E DC Power in CD sequences
DAS	No credit is taken for DAS in CD sequences
AC	No credit is taken for AC Power in CD sequences
PLS	No credit is taken for PLS in CD sequences
CAS	No credit is taken for CAS in CD sequences
N-RHR	No credit is taken for Normal RHR in CD sequences
SWS	No credit is taken for SWS in CD sequences
CCS	No credit is taken for CCS in CD sequences
SFW	No credit is taken for Startup Feedwater in CD sequences
DG	No credit is taken for Diesel Generators in CD sequences
MFW	No credit is taken for Main Feedwater in CD sequences
SG Overfill Protection	No credit is taken for SG Overfill Protection in CD sequences

Importance of PMS and DC-1E Systems

- PMS and DC-1E are the most important systems (by risk increase measure)

- PMS is very reliable and redundant; its reliability is only limited by postulated CCF (such as CCF software).

- In case of a total postulated failure of PMS, the plant relies on DAS (auto or manual) and control systems (only for some transients); in this scenario, the plant CDF goes up by orders of magnitude

Sensitivity Analyses Results

- The component, operator action, and system importance analyses provide us input for other AP1000 programs (such as RTNSS, reliability assurance program)

- The sensitivity analyses increase our confidence in the stability of PRA numerical results.

UNCERTAINTY ANALYSIS

- The plant CDF uncertainty range is found to be 7.3 E-07 – 2.1 E-08 for the 95% to 05 % interval

- For a lognormal distribution, this would correspond to an error factor of 6, which can be considered as low for rare events

UNCERTAINTY ANALYSIS

- The mean values of the dominant accident sequence frequencies are close to the upper bound (95%) estimates;
- Among the initiating event categories, SI-LB has the highest 95-percentile CDF of 3.2E-07 /year.
- Among the dominant sequences, sequence # 07 of SI-LB event has the highest 95-percentile CDF of 2.1E-07/yr.

SHUTDOWN EVENTS

- A quantitative shutdown risk evaluation is performed for AP1000 for internal events
- The risk profiles of AP1000 and AP600 for events during shutdown conditions are almost identical
- The AP1000 Shutdown PRA has a CDF of 1.23E-07 events per year. This CDF is an 18% increase of the AP600 Level 1 Shutdown CDF of 1.04E-07 events per year

SHUTDOWN EVENTS

- The three events dominating the CDF for each plant are loss of component cooling / service water during drained condition, loss of offsite power during drained condition, and loss of RNS during drained condition

- The initiating event CDF contributions show that the initiating event importance to be similar for the two plants

SHUTDOWN EVENTS

- **The twelve dominant accident sequences comprise 77 percent of the level 1 shutdown CDF. They consist of:**

  - Loss of component cooling or service water system initiating event during drained condition with a contribution of 64 percent of the CDF

SHUTDOWN EVENTS

- Loss of RNS initiating event during drained condition with a contribution of 6 percent of the CDF

- Loss of offsite power initiating event during drained condition with a contribution of 5 percent of the CDF

- RCS overdraining event during drainage to mid-loop with a contribution of a 2 percent of the CDF.

INTERNAL FLOODING AND FIRE

- The internal flooding-induced CDF is estimated to be 8.8E-10 events per year for power operations

- The CDF from flooding events at power is not an appreciable contributor to the overall AP1000 plant CDF

INTERNAL FLOODING AND FIRE

- The top five at-power flooding scenarios comprise 91 percent of the at-power flooding-induced core damage frequency

- These scenarios are for large pipe breaks in the turbine building with an initiating event frequency in the range of 1.4 – 2.0 E-03 / year, leading to a loss of CCW/SW event
  - Each scenario has a CDF of 1.2 – 1.8E-10/year.

INTERNAL FLOODING AND FIRE

- **Extensive fire hazards analysis review completed for AP600 subsequent to fire AP600 PRA**
  - Fire separation improved
  - Fire suppression features incorporated
  - Design features incorporated to address hot-shorts

- **AP1000-specific Fire PRA is performed with a resulting CDF of 5.61E-08/yr (for internal events)**

INTERNAL FLOODING AND FIRE

- **AP600 design features important for fire protection are included in the AP1000**
  - Fire separation / fire zones
  - Systems used to achieve safe shutdown
  - Fire suppression features

- **AP1000 design is sufficiently robust that internal fires during power operation or shutdown do not represent a significant contribution to plant CDF**

SEISMIC MARGINS EVALUATION

- The seismic margin analysis shows the systems, structures, and components required for safe shutdown. HCLPF values are greater than or equal to 0.50g

- This HCLPF is determined by the seismically induced failure of the fuel in the reactor vessel, core assembly failures, IRWST failure, or containment interior failures

SEISMIC MARGINS EVALUATION

- The SMA result assumes no credit for operator actions at the 0.50g review level earthquake, and assumes a loss of offsite power for all sequences

- The SMA shows the plant to be robust against seismic event sequences that contain station blackout coupled with other seismic or random failures

- AP1000 structural design and seismic analysis will be discussed at a future ACRS meeting

Comparison of Low HCLPF SSCs in AP1000 and AP600 Designs

AP1000

Basic Event ID	Description	AP600 HCLPF	AP1000 HCLPF
EQ-CER-INSULATOR	Failure of Ceramic Insulators	0.09g	.09g
EQ-CORE-ASSEMBLY	Core Assembly Failure (not fuel)	0.50g	.50g
EQ-CV-INTER	Interior Containment	0.60g	.50g
EQ-IRWST-TANK	IRWST Failure	0.60g	.50g
EQ-RV-FUEL	Fuel Failure	0.50g	.50g
EQ-AB-EXTWALL	Aux. Building Exterior wall	0.58g	.51g
EQ-AB-FLOOR	Aux. Building Floor	0.58g	.51g
EQ-AB-INTWALL	Aux. Building Interior wall	0.58g	.51g
EQ-PCC-TANK	PCC Tank Failure	0.58g	.51g
EQ-SHDBLD-ROOF	Shield Building Roof	0.58g	.51g
EQ-SHDBLD-WALL	Shield Building Wall	0.58g	.51g
EQ-CABLETRAY	Cable trays - support controlled	0.54g	.54g
EQ-CMT-TANKS	Tank PXS 2A/B (Core Makeup Tank)	0.63g	.54g
EQ-SG-FAILS	Steam Generator Fails	0.65g	.54g
EQ-SGTR	Steam Generator Piping (one or a few)	0.65g	.54g
EQ-ACDISPANEL	120 vac distribution panel	0.51g	.55g
EQ-DC-SWBRD	125 vdc switchboard	0.51g	.55g
EQ-DCDISPANEL	125 vdc distribution panel	0.51g	.55g
EQ-PRZR-FAILS	Pressurizer Fails	0.67g	.55g
EQ-TRSFSWITCH	Transfer switch	0.51g	.55g

Comparison of AP600 and AP1000 PRA Results

Scope	AP600	AP1000
Level 1 At-Power Internal Initiating Events	Quantification Performed CDF = 1.7E-07 Several additional cases quantified in response to NRC RAIs	Quantification Performed CDF = 2.4E-07 AP600 additional cases incorporated into the model
Level 2 At-Power Internal Initiating Events	Quantification Performed LRF = 1.8E-08 Containment Effectiveness = 89.5%	Quantification Performed LRF = 2.0E-08 Containment Effectiveness = 91.8%
Level 3 At-Power Internal Initiating Events	Quantification Performed	Quantification Performed
Internal Fire Events	Conservative (via focused PRA) Quantification Performed CDF = 6.5E-07 (internal) CDF = 3.5E-07 (shutdown)	Quantification performed CDF = 5.61E-08
Internal Flooding Events	Quantification Performed CDF = 2.2E-10	Quantification Performed CDF = 8.8E-10
Shutdown Events	Quantification Performed for Level 1 and 2 CDF = 1.0E-07 LRF = 1.5 E-08 Several additional cases quantified in response to NRC RAIs	Quantitative Evaluation Performed CDF = 1.2E-07 LRF = 2.0E-08

SUMMARY OF RESULTS

- **The AP1000 PRA results show that**
  - The very low risk of the AP600 has been maintained in the AP1000
  - The AP1000 PRA meets the US NRC safety goals with significant margin

PRA Level 1 Success Criteria

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Overview

- **Success Criteria Justification**
  - Summary of success criteria (Chapter 6 of PRA)
    - Changes in success criteria vs AP600
  - Success criteria justification
    - Based on analysis - DCD, specific PRA, or other analysis / calculations
    - Summary of PRA analysis
      - Analysis results for small LOCA, large LOCA and ATWS
    - T&H Uncertainty Evaluations
      - Calc of low margin / risk important sequences
      - T&H analysis to bound T&H uncertainty

AP1000 Success Criteria

- **Similar to AP600**
  - Similar system design, arrangement, capabilities
  - Several Changes Made to the AP1000 Success Criteria
    - Due to increase in power and other factors
- **Verified Using Same Approach as AP600**
  - Use DCD analysis where applicable
  - Perform special analysis where DCD analysis not applicable
- **AP1000 Success Criteria More Conservative / Robust**
  - Uses same or more equipment for success than AP600
    - For example, uses 3/4 ADS 4 instead of 2/4 ADS 4 (AP600)
      - Even though AP1000 ADS 4 is larger / MW
  - Reduces T&H issues / uncertainty

Success Criteria Basis

- **Provides Critical Functions**
  - Decay heat removal (core cooling)
    - Peak clad temperature < 2200°F
  - RCS inventory control
  - RCS pressure control
    - Less than emergency stress limits, < 3200 psig
  - Containment heat removal and containment isolation
    - Less than emergency stress limits, < ??? psig
  - Reactivity control

AP1000 Full ADS Success Criteria

TABLE A2.3-1 FULL ADS SUCCESS CRITERIA[1]				
	PRHR HX - on		PRHR HX - off	
	CMT - on	CMT - off	CMT - on	CMT - off
Event	Accum - off	Accum - on	Accum - off	Accum - on
RCS Transients, Loss of Power, Station Blackout	None (2)	None (2)	Auto 1/2 ADS stage 2/3 and auto 3/4 ADS stage 4	Man 3/4 ADS stage 4
RCS Leak	Auto 3/4 ADS stage 4	Man 3/4 ADS stage 4	Auto 1/4 ADS stage 2,3 and auto 3/4 ADS stage 4	Man 3/4 ADS stage 4
SGTR	None (3)	None (3)	Auto 1/4 ADS stage 2,3 and auto 3/4 ADS stage 4	Man 3/4 ADS stage 4
Small LOCA	Auto 3/4 ADS stage 4	Man 3/4 ADS stage 4	Auto 1/4 ADS stage 2,3 and auto 3/4 ADS stage 4	Man 3/4 ADS stage 4
Medium LOCA	Auto 3/4 ADS stage 4	Man 3/4 ADS stage 4	Auto 3/4 ADS stage 4	(7)
Spurious ADS	(4)		Auto 3/4 ADS stage 4 (5)	
Large LOCA	(4)		Auto 3/4 ADS stage 4 (6)	

Notes:
1. Automatic ADS actuation via PMS. ADS actuation can also be performed manually via PMS or DAS.
2. Successful PRHR HX operation obviates need for ADS.
3. SGTR does not require ADS operation if PRHR HX operates and SGs are isolated.
4. Operation of PRHR HX has no effect on ADS success criteria, use "PRHR HX - off" success criteria.
5. Spurious ADS requires 1/2 accumulators and 1/2 CMT to work.
6. Large LOCA requires 2/2 accumulators and 1/2 CMT to work.
7. No credit is given for success for this case; the time available for operator action is short.

Post ADS Success Criteria

- **Changes Made to Post ADS Success Criteria**
  - Full ADS (IRWST) >> requires 3/4 ADS stage 4
    - AP600 PRA used 2/4 ADS stage 4
    - AP1000 ADS 4 capacity has been increased by more than power
  - Partial ADS (RNS) >> requires 2 of 4 ADS stage 2 or 3
    - AP600 PRA used 1/4 stage 2 or 3
    - ADS stages 1, 2, 3 capacities not increased for AP1000
  - Requires PRHR HX for MLOCAs with only Accum
    - Provides operators more time (> 20 min) to take action
  - Requires 2/4 Cont Recirc if Cont Isol fails
    - 1/4 Cont Recirc if Cont Isol works
  - Full ADS required for large LOCAs to support long term cooling

LOCA Size Definitions

- **Large LOCA (> 9" ID)**
  - Requires 2 of 2 accum
- **Spurious ADS Stage 4 (1 to 4 ADS 4 valves)**
  - Require 1 of 2 accum and 1 CMT
- **Medium LOCA, DVI LOCA, CMT Line LOCA (2-9" ID)**
  - Only requires 1 accum or 1 CMT
  - Depressure RCS below ADS 4 pressure interlock
- **Small LOCA (3/8-2" ID)**
  - Requires PRHR HX or ADS 1/2/3 todepressure RCS below ADS 4 pressure interlock
  - CVS makeup not sufficient
- **RCS Leak (< 3/8" ID)**
  - CVS makeup is sufficient

PRA Success Criteria Analysis

• Transient (PRHR HX)	DCD, LOFTRAN
• SGTR (PRHR HX)	DCD, LOFTRAN
• Non-LOCA Feed-Bleed	PRA, MAAP4
• LOCA (Small/Med. LOCA)	PRA, MAAP4
• LOCA (Lg LOCA)	PRA, WCOBRA-TRAC
• Spurious ADS 4 (Lg LOCA)	PRA, WCOBRA-TRAC
• ATWS	PRA, LOFTRAN

MAAP4 Code Use

- **Same Approach As AP600**
  - Used for defining success criteria for LOCAs and feed-bleed cooling sequences
    - Provides integrated RCS / containment response
    - Runs fast (hours vs days)
      - Important because of large numbers of runs (hundreds)
        - » Break sizes, locations, different sets of multiple failures
    - MAAP4 has been bench marked against NOTRUMP for AP600
      - NOTRUMP has been shown to be applicable to AP1000
    - T&H uncertainty analysis confirms that low margin / risk important sequences will be success
      - Uses detailed DCD codes and methods (NOTRUMP, WCOBRA-TRAC)
- **AP1000 Success Criteria is More Robust**

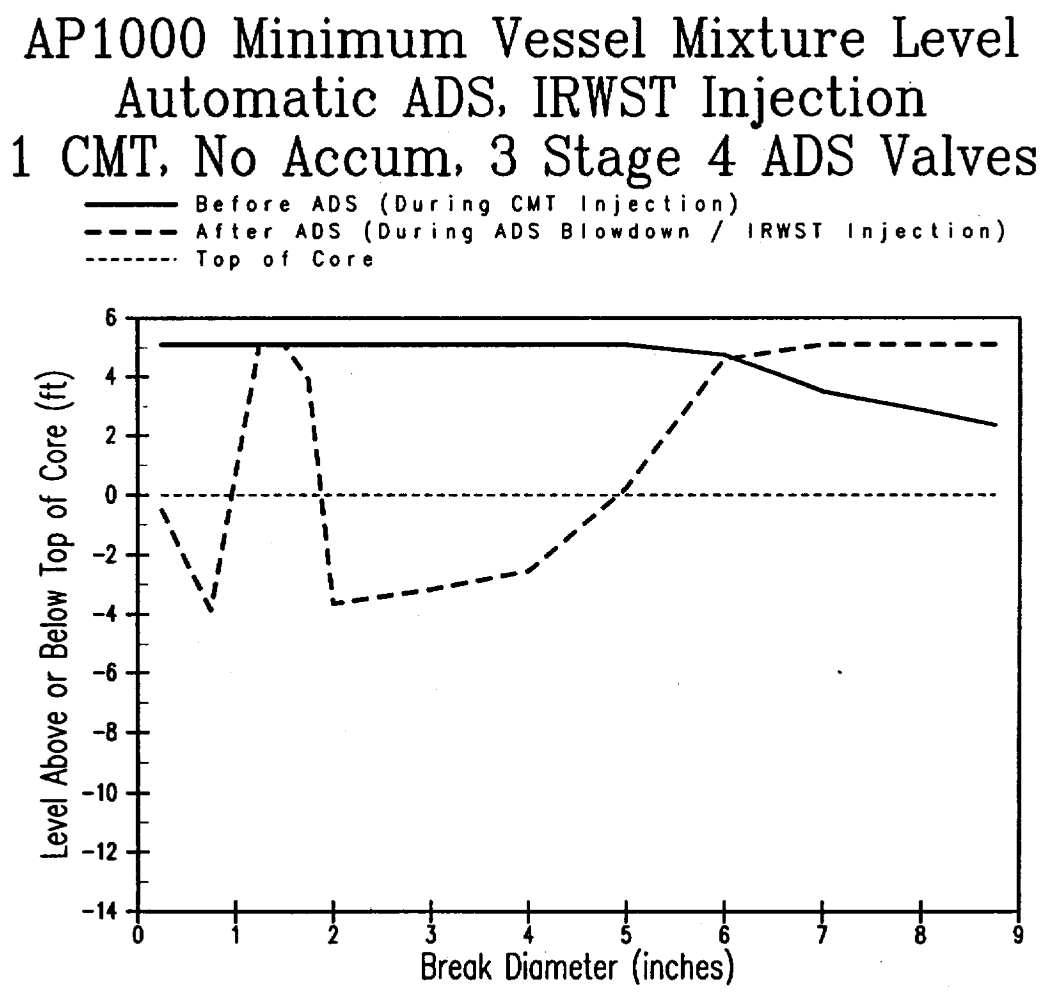
PRA T&H Analysis

- **LOCAs and Feed-Bleed Cooling Analysis**
  - Considers many different factors
    - Initiating event, LOCA or Feed-Bleed Cooling after non-LOCA
    - LOCA size and location
    - Available mitigating equipment including CMT, Accum, RNS, PRHR HX, ADS, IRWST, Cont Recirc
  - Made use of lessons learned from AP600
    - Test results, DCD analysis, PRA analysis (both success criteria and T&H uncertainty
    - Divided into four groups of analysis
      1. Automatic ADS with CMT and IRWST gravity injection
      2. CMT and RNS pumped injection
      3. Manual ADS with Accum and IRWST gravity injection
      4. Accum and RNS pumped injection

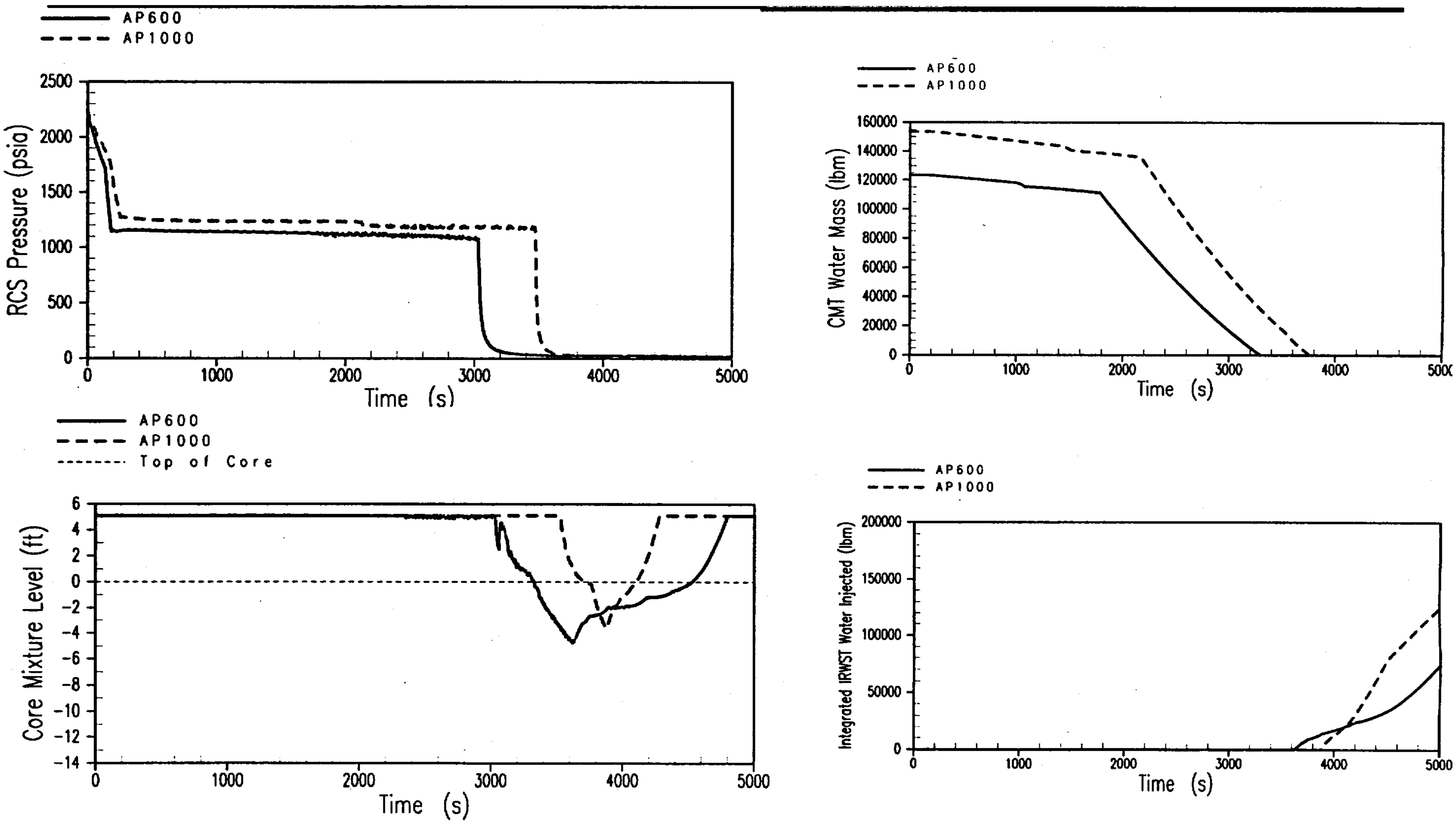
1. Auto ADS with IRWST Gravity Injection

- **Limiting Success Criteria Equipment Assumed**
  - One CMT, no Accum, 1 valve path in one IRWST injection line
    - Same as AP600
  - 3/4 ADS stage 4 , no ADS stage 1/2/3, no PRHR HX
    - AP600 used 2/4 ADS 4
    - For LOCAs < 2" some ADS 1/2/3 or PRHR HX required to reduce RCS pressure to below ADS 4 pressure interlock
  - Containment isolation fails
- **MAAP4 Analysis Was Performed**
  - Break sizes 0.5" up to 8.75"
  - Core uncovery depth and duration is less than AP600
    - Increased capacity PXS, especially ADS 4 & IRWST injection
  - AP1000 success criteria verified

1. Auto ADS with IRWST Gravity Injection



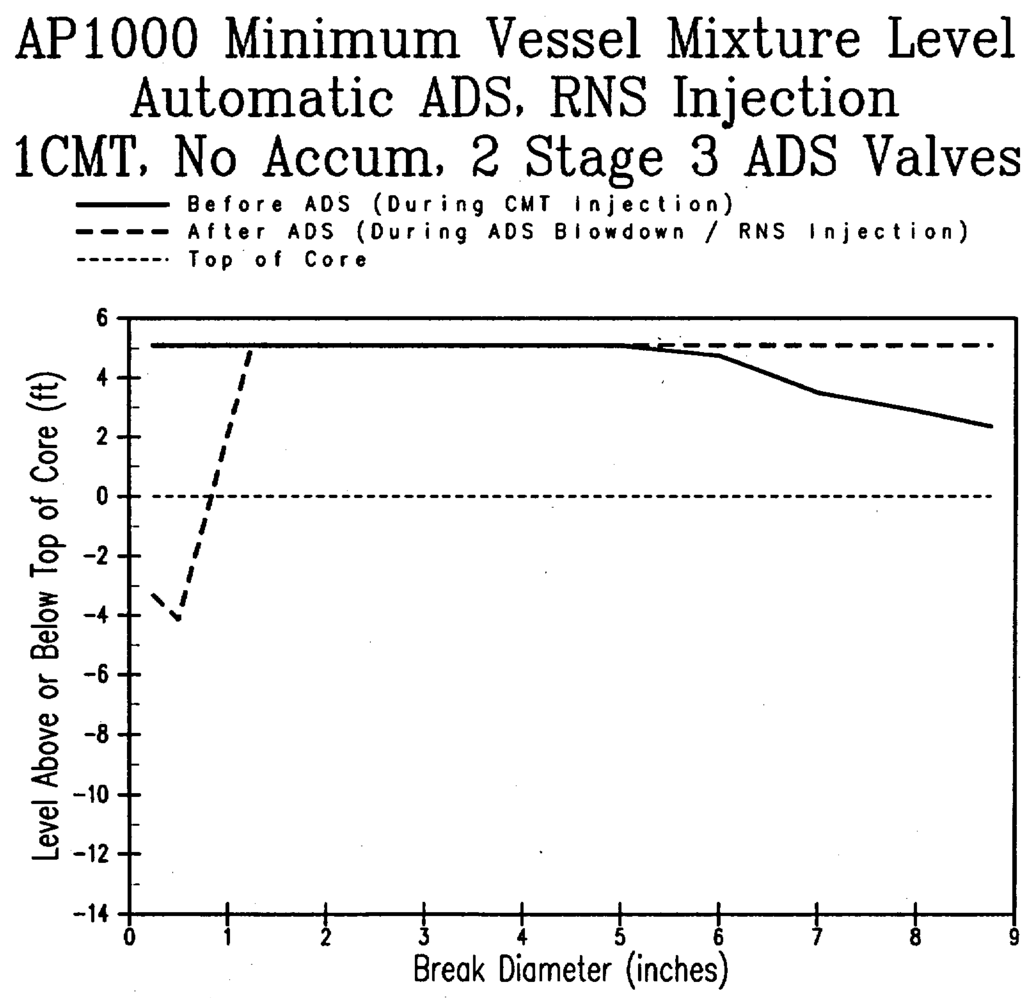
2" HL LOCA, 3/4 ADS4, 1 CMT, 1/1 IRWST AP1000
No ADS 1/2/3, Accum or PRHR HX



2. Auto ADS with RNS Injection

- **Limiting Success Criteria Equipment Assumed**
  - One CMT, no Accum, 1 RNS pump (SFP Cask Loading Pit)
  - 2/4 ADS stage 2/3, no ADS stage 4, no PRHR HX
    - AP600 used 1/4 ADS 2/3
  - Containment isolation fails
- **MAAP4 Analysis Was Performed**
  - Break sizes 0.5" up to 8.75"
  - Core uncovery depth and duration is less than AP600
  - AP1000 success criteria verified

2. Auto ADS with RNS Injection

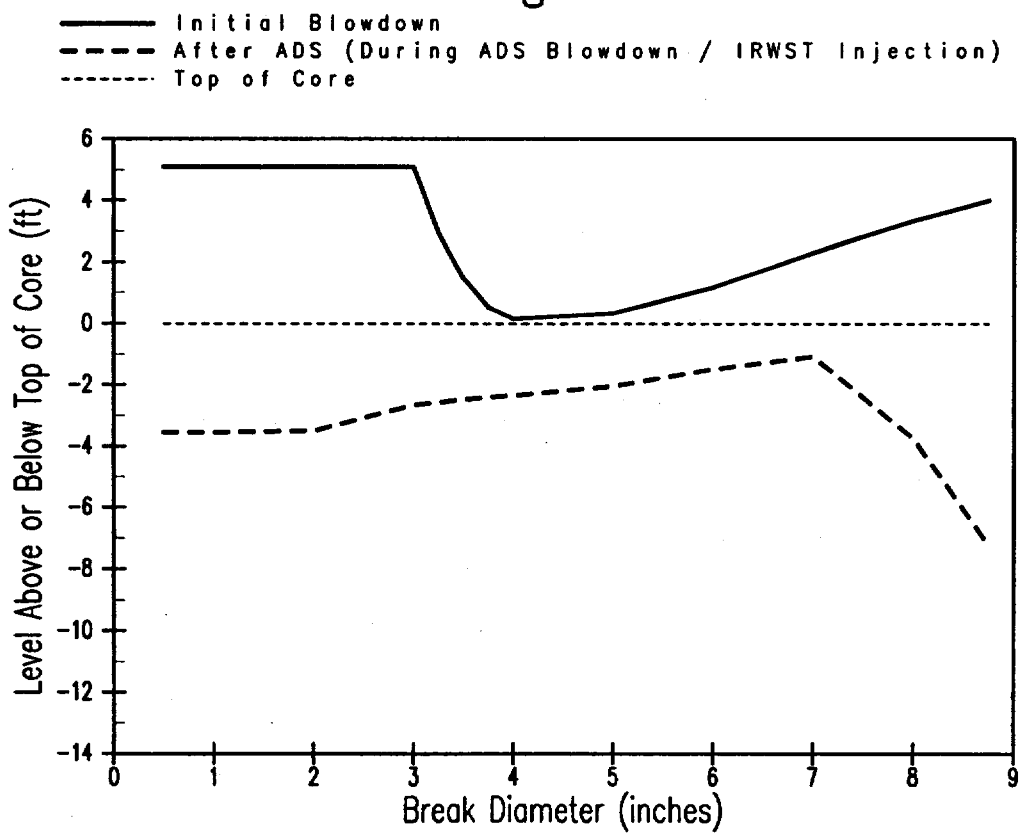


3. Manual ADS w. IRWST Gravity Injection

- **Limiting Success Criteria Equipment Assumed**
  - One Accum, no CMT, PRHR HX, 1/1 valve / path IRWST injection
    - AP600 does not require PRHR HX, increases time for operator action
  - 3/4 ADS stage 4 , no ADS stage 1/2/3, no PRHR HX
    - ADS 4 manually actuated at 20 min.
    - AP600 uses 2/4 ADS 4
  - Containment isolation fails
- **MAAP4 Analysis Was Performed**
  - Break sizes 0.5" up to 8.75"
  - Core uncovery depth and duration is less than AP600
    - Increased capacity PXS, especially ADS 4 & IRWST injection
  - AP1000 success criteria verified

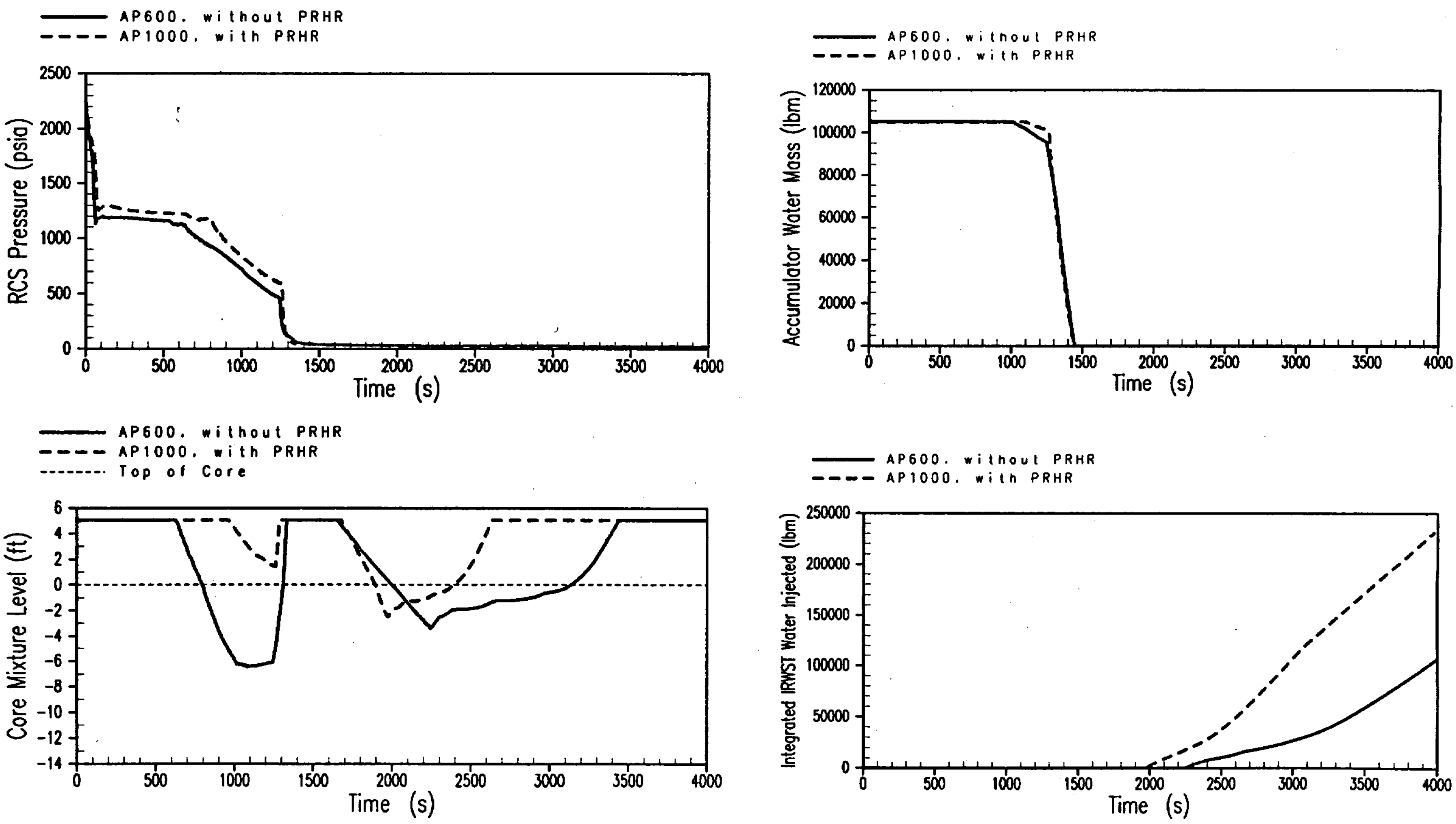
3. Manual ADS w. IRWST Gravity Injection

AP1000 Minimum Vessel Mixture Level
Manual ADS at 20 Min, IRWST Injection
1 Accum, No CMT, 3 Stage 4 ADS Valves, PRHR



3.5" LOCA, 2/4 ADS 3, 1 Acc, 1/1 IRWST PRHR HX, No ADS 4 or CMT

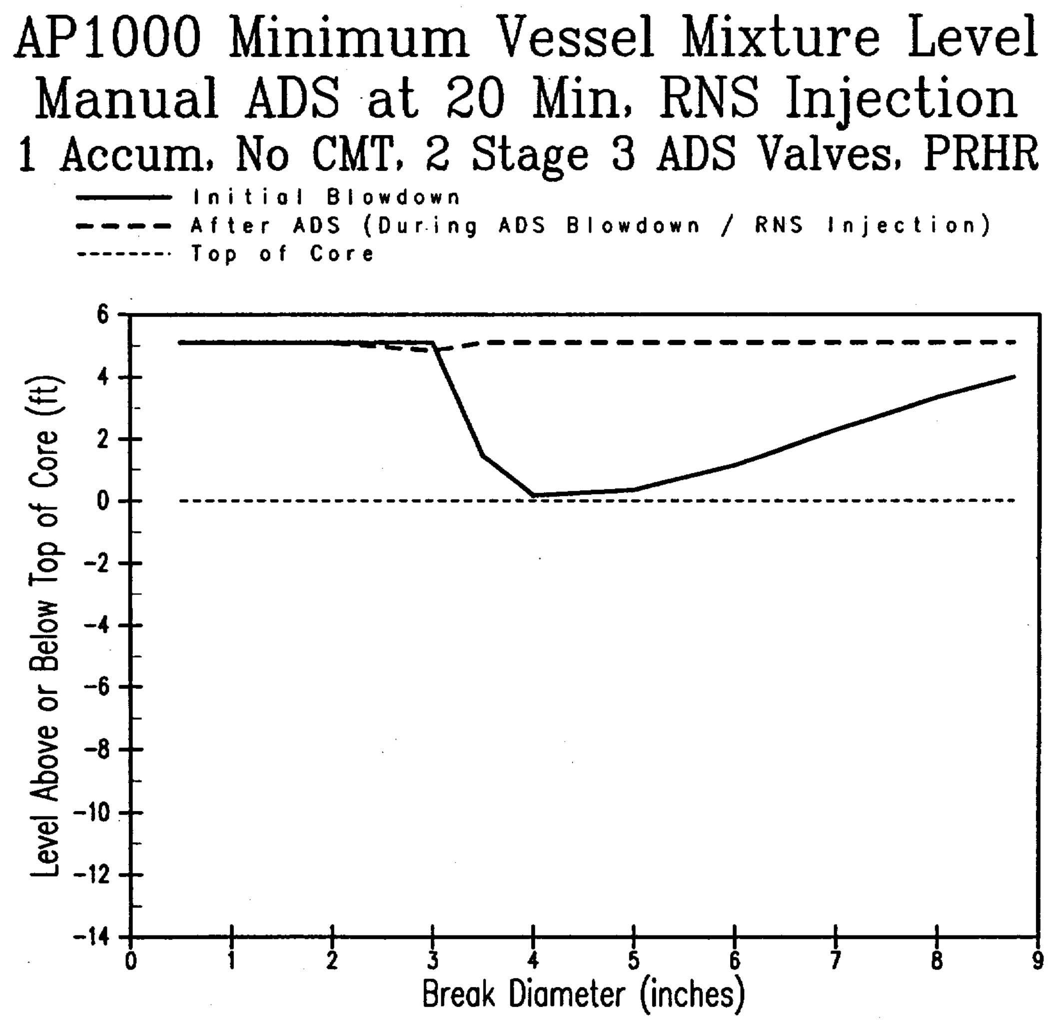
AP1000



4. Manual ADS with RNS Injection

- **Limiting Success Criteria Equipment Assumed**
  - One Accum, no CMT, PRHR XH, 1 RNS pump (Cask Loading Pit)
  - 2/4 ADS stage 2/3, no ADS stage 4
    - ADS manually actuated at 20 min.
    - AP600 used 1/4 ADS 2/3
  - Containment isolation fails
- **MAAP4 Analysis Was Performed**
  - Break sizes 0.5" up to 8.75"
  - AP1000 success criteria verified

4. Manual ADS with RNS Injection



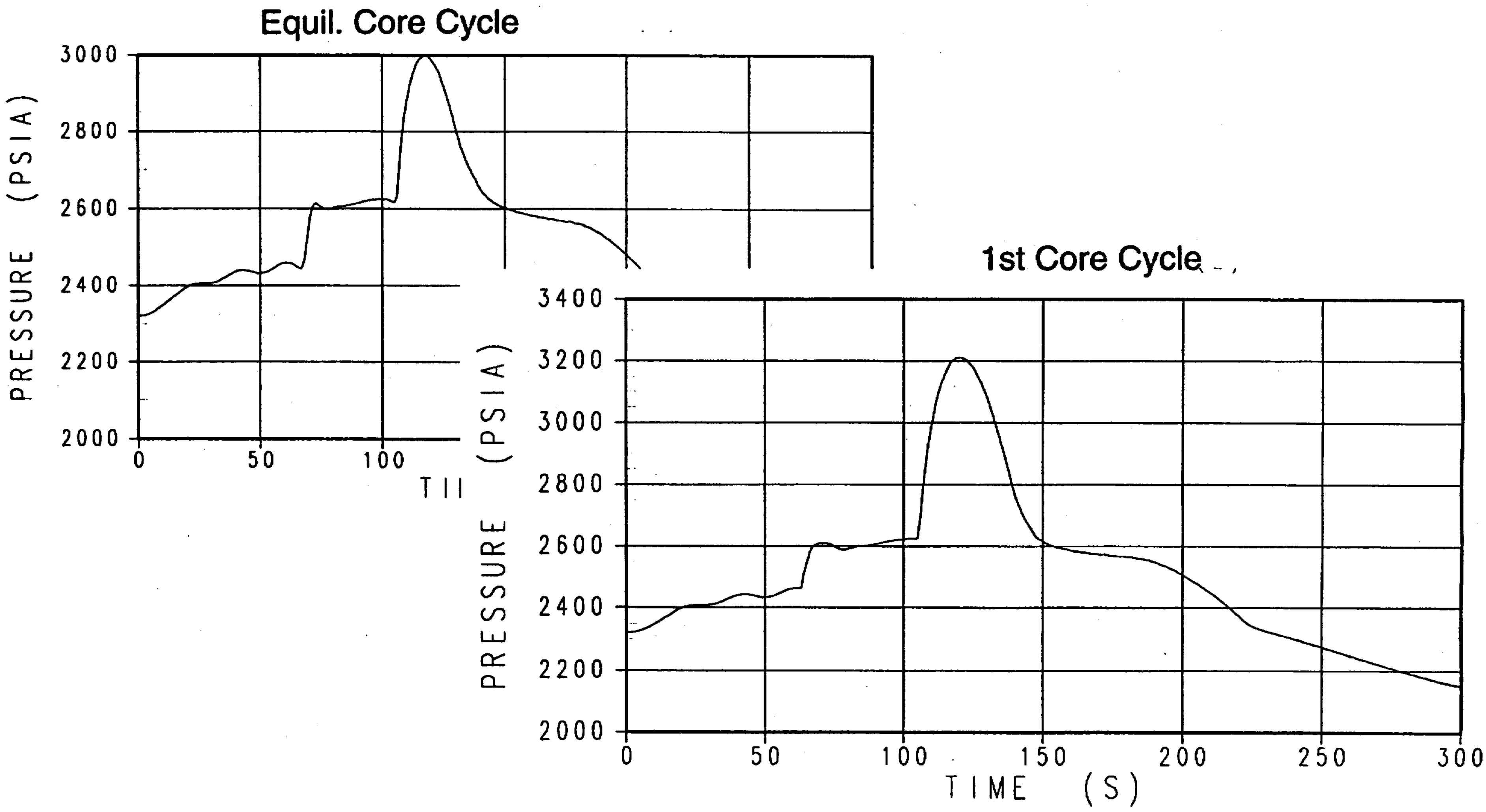
Large LOCA Success Criteria

- **Large CL LOCAs**
  - Uses 2 of 2 Accum, like DCD analysis
  - Unlike DCD assumes failure of containment isolation and availability of offsite power
  - Was analyzed with WCOBRA-TRAC (RAI 720.012)
    - Calc PCT 1628 F without uncertainty
    - PCT less than DCD case because offsite power was available
- **Spurious ADS 4 Large LOCAs**
  - Limiting case is all four ADS 4 valves opening
  - Uses 1 of 2 Accum, failure cont. isolation, offsite power available
  - Was analyzed with WCOBRA-TRAC (RAI 720.010)
    - Calc PCT 833 F without uncertainty
    - Case analyzed assumed cont isol, because of margin fail cont isol will be OK
- **Both Cases Are Successful**

ATWS Analysis

- **Provides Very Low Unfavorable Exposure Time**
  - AP1000 has low boron core
    - MTC is more negative
    - ATWS "ride out" capability is possible for more than 98.5% of core life
      - Throughout equilibrium core cycles, peak RCS pressure < 3000 psig
      - Through 60% of 1st core cycle, peak RCS pressure < 3200 psig
      - UET < 1.5% over 40 years
- **AP1000 ATWS Analysis**
  - Analyzed with LOFTRAN
  - Equilibrium core has MTC = -12.5 pcm/F at BOL
  - 1st core has MTC = -10.0 pcm/F at 40% life

AP1000 ATWS Analysis Results



T&H Uncertainty

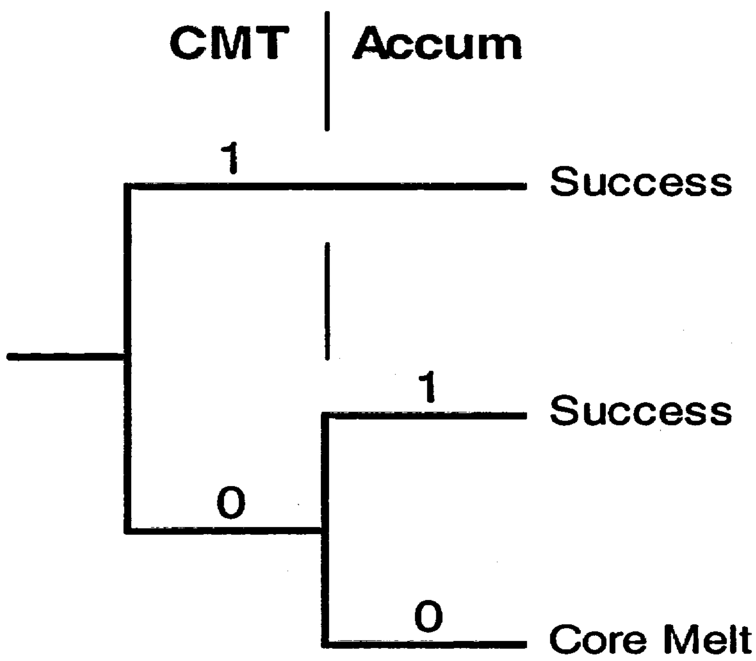
- **Same Approach As AP600**
  - Detailed evaluation performed (RAI 720.012)
  - Bounds AP1000 T&H uncertainty
    - Determined high risk / low margin cases
      - MAAP4 success criteria analysis used to identify low margin sequences
      - "Expanded" event trees used to identify high risk sequences
      - Bounds more than 98% of LOCA core melt
    - Identified limiting analysis cases
      - 3 small LOCAs, 2 large LOCAs, 2 LTC cases identified
    - Analyzed limiting cases with DCD codes and assumptions
      - » Conservative decay heat (Appendix K), line resistances, plant parameters
      - » All show successful core cooling

Expand Event Trees

- **Purpose of Expanded Event Trees**
  - Branches with safety equipment are expanded to identify the numbers of safety components that are available
    - The normal event trees only identify the minimum number of safety components that are required
  - Branches with non safety equipment are removed
  - End states changed to differentiate success paths
    - Two general classes, high margin (OK) and low margin (UC)
      - Low margin cases have core uncovery, high margin cases do not
    - More detailed sub-grouping made
      - Based on equipment available / not available
      - Supports selection of T&H uncertainty cases that are analyzed
  - Allows probability of low / high T&H margin cases to be calculated

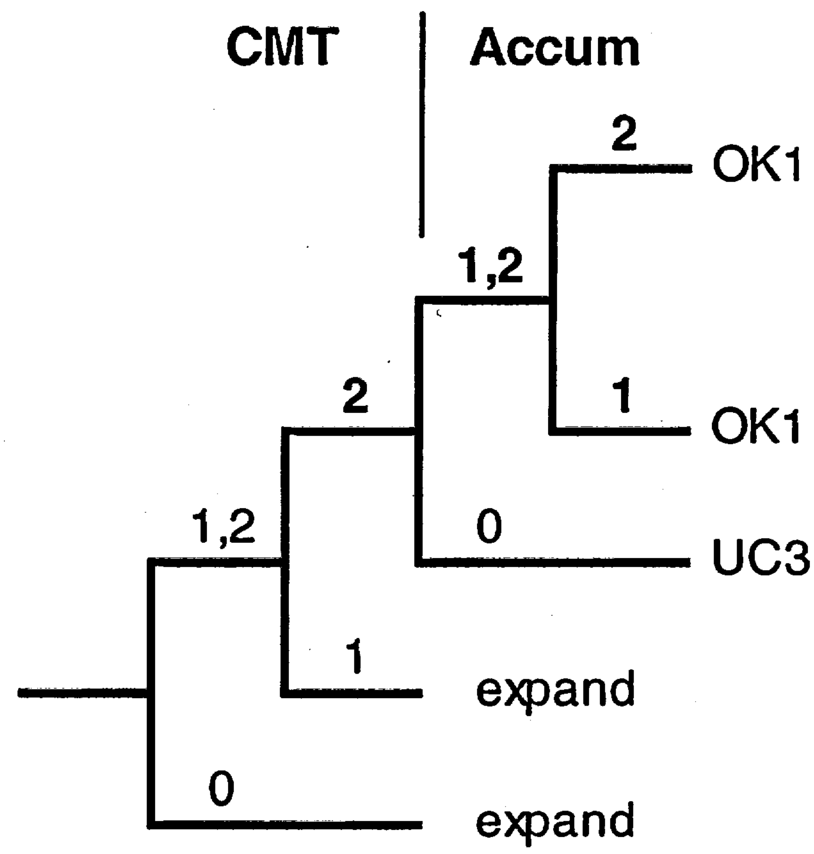
Expanded Event Tree Example

Normal Event Tree



Numbers on branches indicate number of components that are available.

Expanded Event Tree



AP1000

Expanded Event Tree End States

1. OK1 More ADS-4 than Design Basis (DB)
2. OK2 Design Basis
3. OK3 More ADS-4 / Less ADS-1, 2, 3 than DB
4. OK4 Less ADS-1, 2, 3 than DB
5. OK5A More ADS-4 / CI fails
6. OK5B More ADS-4 / CI fails / Less ADS-1, 2, 3
7. OK6 DB ADS / CI fails
8. OK7 2 Accumulators / DB for LLOCA
9. OK8 SI line break with Auto ADS from faulted CMT

0\. OK9 Loss of CMTs for smaller breaks

1\. UC1 No make-up of inventory if RCS pressure greater than 700 psig

2\. UC2A 1 Accumulator depletes prior to operator intervention

3\. UC2B 2 Accumulators deplete prior to operator intervention

4\. UC3 No rapid inventory make-up during blowdown

5\. UC4 Reduced inventory make-up during LLOCA reflood

6\. UC5 No make-up when ADS is actuated

7\. UC6 Less ADS-4 than DBA (ie < 3 of 4 ADS-4)

8\. UC7 Less ADS-4

9\. UC8 No containment isolation / DBA

!0. UC9 No containment isolation / reduced ADS

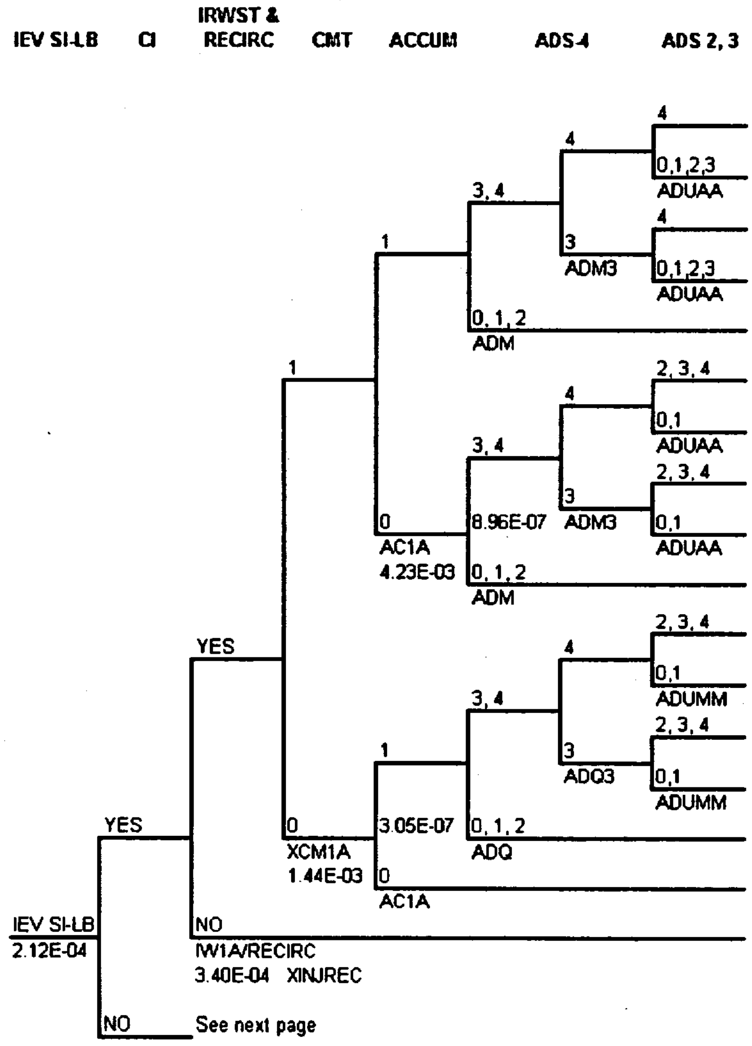
Which Event Trees

- **Selection of Level 1 Event Trees to Expand**
  - AP600 expanded 8 event trees, all with ADS actuation
    - No core uncovery in events / sequences without ADS
  - AP1000 expanded 5 event trees, all with ADS actuation
    - 3 event trees included in AP600 were not expanded for AP1000 since they did not result in limiting T&H analysis cases
      - Small LOCAs, Transients with ADS, SGTR with ADS were not expanded
      - These events did not add any limiting T&H uncertainty analysis cases
        - » Some of their end states are not success in AP1000 (for example, 2 / 4 ADS 4 was considered success in AP600 but is not considered success in AP1000)
        - » They tend to have more equipment available because they are more probable events
        - » ADS occurs later in these events with lower decay heat

Expanded Event Trees

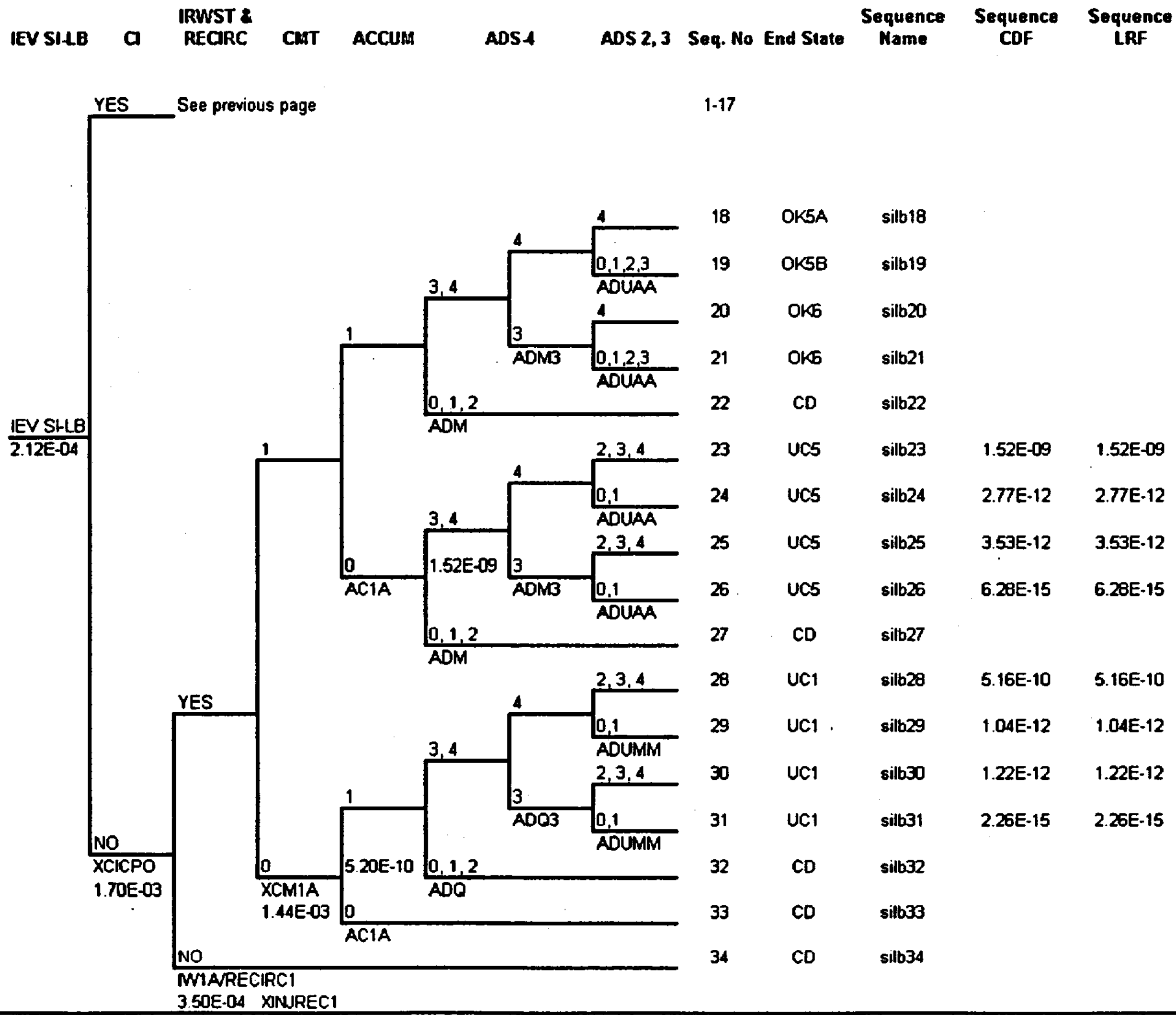
Initiating Event	AP600	AP1000
Large LOCA	yes	yes
Spurious ADS 4	na	yes
Medium LOCA	yes	yes
CMT Line LOCA	yes	yes
DVI LOCA	yes	yes
Intermediate LOCA	yes	na
Small LOCA	yes	-
SGTR with ADS	yes	-
Transients with ADS	yes	-

Expanded Event Tree - DVI LOCA



Seq. No	End State	Sequence Name	Sequence CDF	Sequence LERF
1	OK1	silb01		
2	OK3	silb02		
3	OK2	silb03		
4	OK4	silb04		
5	CD	silb05		
6	UC5	silb06	8.96E-07	5.37E-08
7	UC5	silb07	1.64E-09	9.83E-11
8	UC5	silb08	2.09E-09	1.25E-10
9	UC5	silb09	3.85E-12	2.31E-13
10	CD	silb10		
11	UC1	silb11	3.05E-07	1.83E-08
12	UC1	silb12	6.15E-10	3.69E-11
13	UC1	silb13	7.21E-10	4.32E-11
14	UC1	silb14	1.57E-12	9.45E-14
15	CD	silb15		
16	CD	silb16		
17	CD	silb17		

Expanded Event Tree - DVI LOCA



Calculation of CDF / LRF

- **Potential CDF**
  - Conservatively assumes low margin sequences (UC) may be core damage
  - System reliabilities based on fault tree calc
    - Base PRA or special fault trees as needed
- **Potential LRF**
  - Based on potential core damage sequences
  - Uses constant ratio 6% for containment isol branches
    - Conservative, same as AP600

Determination of Risk Important Sequences

- **All Low Margin Sequences Are Collected**
  - Includes all UC sequences
  - Sorted by CDF and LRF
  - Criteria for risk importance
    - 1% of baseline CDF or LRF
    - Residue of less important sequences must be small
      - Required to be less than twice the risk important sequences
- **Results**
  - 102 low margin sequences quantified in 5 expanded event trees
  - 13 low margin sequences selected as risk important
    - Covers 99.4% of risk from all low margin sequences
    - Residue of other sequences is < 6% of CDF and LRF

Sorted UC Sequences (Top 25 of 102)

Table 3-1 UC Sequences Sorted by CDF Frequency

	End State	Seq. Name	Sequence CDF	Sequence LRF	% CDF	% LRF	CI	IRWST & RECIRC	CMT	ACC	ADS 4	ADS 2,3	Bounded By Short/Long-Term		
>>	UC5	silb06	8.96E-07	5.37E-08	371.66%	275.60%	YES	YES	1	0	4	2-4	C	FG	
>>	UC	sad06	4.58E-07	2.75E-08	190.05%	140.93%	YES	YES	2	1	4	2-4	E	FG	
>>	UC1	silb11	3.05E-07	1.83E-08	126.76%	94.00%	YES	YES	0	1	4	2-4	A	FG	
>>	UC2B	mlo31	2.89E-07	1.73E-08	119.85%	88.88%	YES	YES	0	2	4	2-4	AB	FG	
>>	UC2B	cmt31	1.34E-07	8.05E-09	55.67%	41.28%	YES	YES	0	2	4	2-4	AB	FG	
>>	UC	sad25	9.12E-08	5.47E-09	37.82%	28.05%	NO	YES	2	2	4	2-4	E	G	(2)
>>	UC3	mlo11	3.01E-08	1.81E-09	12.48%	9.26%	YES	YES	2	0	4	2-4	C	FG	
>>	UC8	llo15	8.51E-09	8.51E-09	3.53%	43.63%	NO	YES	2	2	4	2-4	D	G	
>>	UC3	cmt26	6.42E-09	3.85E-10	2.67%	1.98%	YES	YES	1	0	4	2-4	C	FG	
>>	UC2A	mlo36	2.44E-09	1.47E-10	1.01%	0.75%	YES	YES	0	1	4	2-4	A	FG	
	UC5	silb08	2.09E-09	1.25E-10	0.87%	0.64%	YES	YES	1	0	3	2-4	C	F	
	UC5	silb07	1.64E-09	9.83E-11	0.68%	0.50%	YES	YES	1	0	4	0-1	C	FG	
>>	UC5	silb23	1.52E-09	1.52E-09	0.63%	7.77%	NO	YES	1	0	4	2-4	C	G	
	UC2A	cmt36	1.14E-09	6.85E-11	0.47%	0.35%	YES	YES	0	1	4	2-4	A	FG	
	UC	sad08	1.07E-09	6.42E-11	0.44%	0.33%	YES	YES	2	1	3	2-4		F	
	UC	sad07	8.40E-10	5.04E-11	0.35%	0.26%	YES	YES	2	1	4	0-1	E	FG	
	UC	sad30	7.77E-10	4.66E-11	0.32%	0.24%	NO	YES	2	1	4	2-4	E	G	(2)
	UC1	silb13	7.21E-10	4.32E-11	0.30%	0.22%	YES	YES	0	1	3	2-4		F	
	UC2B	mlo33	6.92E-10	4.15E-11	0.29%	0.21%	YES	YES	0	2	3	2-4		F	
	UC	sad17	6.76E-10	4.05E-11	0.28%	0.21%	YES	YES	1	1	4	2-4	E	FG	
	UC2B	mlo32	6.44E-10	3.86E-11	0.27%	0.20%	YES	YES	0	2	4	0-1	AB	FG	
	UC1	silb12	6.15E-10	3.69E-11	0.26%	0.19%	YES	YES	0	1	4	0-1	A	FG	
>>	UC1	silb28	5.16E-10	5.16E-10	0.21%	2.65%	NO	YES	0	1	4	2-4	A	G	
>>	UC2B	mlo73	4.88E-10	4.88E-10	0.20%	2.50%	NO	YES	0	2	4	2-4	A	G	
	UC2B	cmt33	3.17E-10	1.90E-11	0.13%	0.10%	YES	YES	0	2	3	2-4		F	

Risk Important Sequences

Table 3.4 AP1000 T&H Uncertainty Low Margin / Risk Important Sequences

Case	Sequence	CI	IRWST & RECIRC	CMT	ACC	ADS 4	ADS 2/3	PRHR	Sequence CDF	Sequence LRF	% CDF	% LRF	Short Term	Long-Term
1	silb06	YES	YES	1	0	4	2-4	N/A	8.96E-07	5.37E-08	371.7%	275.6%	C	F
2	sad06	YES	YES	2	1	4	2-4	N/A	4.58E-07	2.75E-08	190.1%	140.9%	E	F
3	silb11	YES	YES	0	1	4	2-4	YES	3.05E-07	1.83E-08	126.8%	94.0%	A	F
4	mlo31	YES	YES	0	2	4	2-4	YES	2.89E-07	1.73E-08	119.9%	88.9%	B	F
5	cmt31	YES	YES	0	2	4	2-4	YES	1.34E-07	8.05E-09	55.7%	41.3%	B	F
6	sad25	NO	YES	2	2	4	2-4	N/A	9.12E-08	5.47E-09	37.8%	28.0%	E	G
7	mlo11	YES	YES	2	0	4	2-4	N/A	3.01E-08	1.81E-09	12.5%	9.3%	C	F
8	llo15	NO	YES	2	2	4	2-4	N/A	8.51E-09	8.51E-09	3.5%	43.6%	D	G
9	cmt26	YES	YES	1	0	4	2-4	N/A	6.42E-09	3.85E-10	2.7%	2.0%	C	F
10	mlo36	YES	YES	0	1	4	2-4	YES	2.44E-09	1.47E-10	1.0%	0.8%	A	F
11	silb23	NO	YES	1	0	4	2-4	N/A	1.52E-09	1.52E-09	0.6%	7.8%	C	G
12	silb28	NO	YES	0	1	4	2-4	YES	5.16E-10	5.16E-10	0.2%	2.6%	A	G
13	mlo73	NO	YES	0	2	4	2-4	YES	4.88E-10	4.88E-10	0.2%	2.5%	A	G
								Totals =	2.22E-06	1.44E-07				
			Residue from UC Sequences not selected						1.26E-08	8.62E-10	5.2%	4.4%		
			Residue from sequences with PRHR failure						1.58E-10	9.67E-12	0.1%	0.0%		

Bounding T&H Analysis Cases

- **T&H Uncertainty Cases**
  - 5 short term and 2 long term cooling cases are selected to bound the 13 risk important cases
  - These cases also bound 58 of the 102 low margin cases
    - Covers 99.8% of risk from all low margin sequences

Analysis Case	Initiating Event (1)	Cont. Isol.	IRWST & RECIRC	CMT	ACC	ADS 4	ADS 2/3	PRHR	Bounds Dominant Case
Short-Term Cooling									
A	RCS hot leg (3.0")	no	yes	0	1	4	0	yes	3,10,12,13
B	DE CMT balance line (6.8")	yes	yes	0	2	4	0	yes	4,5
C	DE DVI line (4")	no	yes	1	0	3	0	no	1,7,9,11
D	DE CL LLOCA	no	yes	2	2	4	0	yes	8
E	Spur ADS4 (2)	no	yes	1	1	4	0	yes	2,6
Long-Term Cooling									
F	DE DVI	yes	1/1&1/1	1	0	3	0	no	1-5, 7, 9, 10
G	DE DVI	no	1/1&2/1	1	0	4	0	no	6, 8, 11-13

Notes (1) Break sizes are effective sizes (inside diameter or orifice; not outside pipe diameter).
(2) Spurious ADS assumes all 4 ADS stage 4 valves open at same time as initiating event.

T&H Uncertainty Analysis

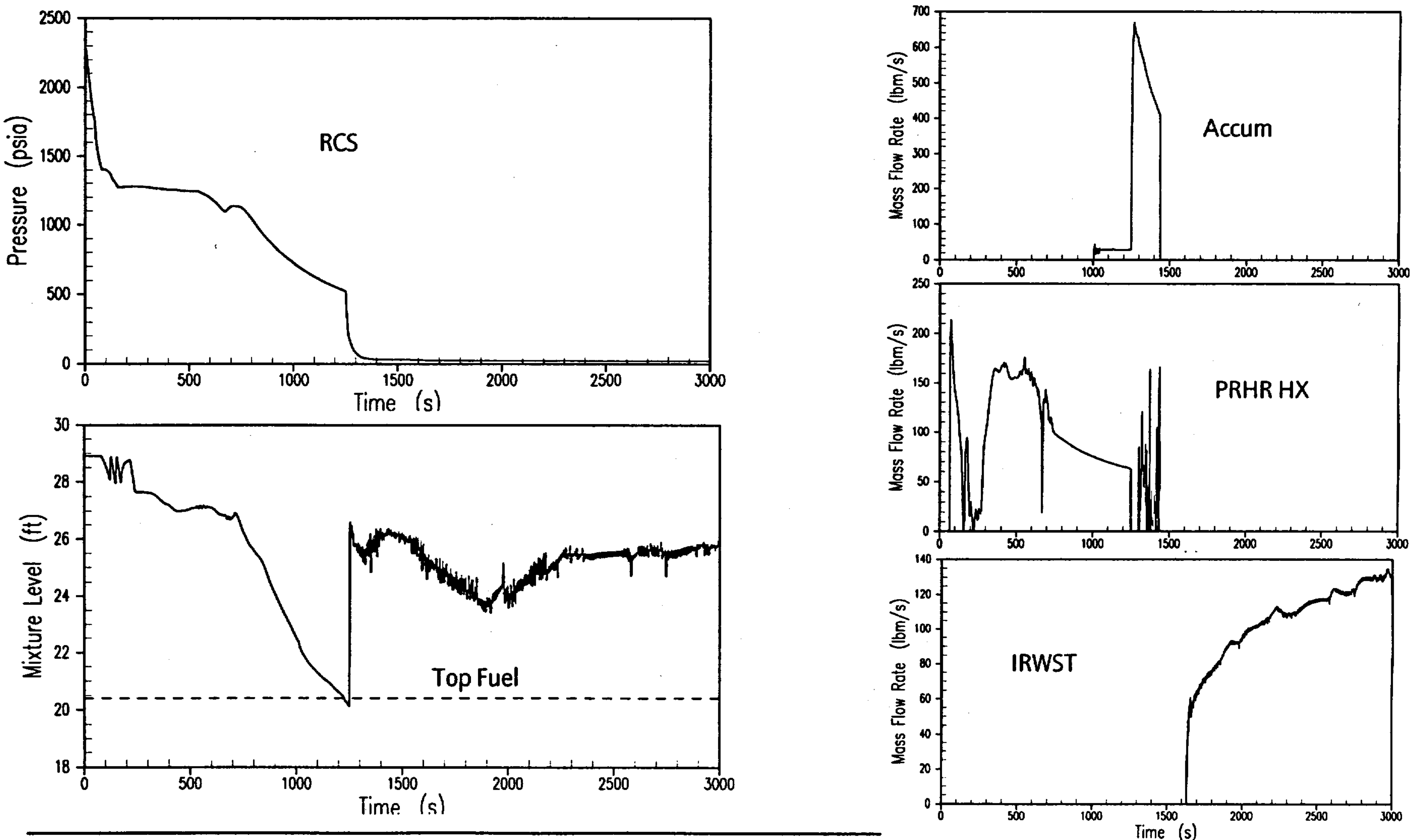
- **All of These 7 Cases Have Been Analyzed**
  - Using DCD codes and methods
  - All cases show successful core cooling

Case	Initiating Event	Cont Isol.	IRWST	REC	CMT	ACC	ADS 4	ADS 2/3	PRHR	CODE	Results	Reference
Short-Term Cooling												
A	RCS hot leg (3.0")	no	yes	yes	0	1	4	0	yes	NOTRUMP	No core uncovery	RAI 720.015
B	DE CMT bal.line (6.8")	yes	yes	yes	0	2	4	0	yes	NOTRUMP	No core uncovery	PRA App A
C	DE DVI line (4")	no	yes	yes	1	0	3	0	no	NOTRUMP	PCT = 1570 F	PRA App A
D	DE CL LLOCA	no	yes	yes	2	2	4	0	yes	WCOBRA-TRAC	PCT = 1856 F (1)	RAI 720.012
E	Spur ADS4	no	yes	yes	1	1	4	0	yes	WCOBRA-TRAC	PCT = 1061 F (1)	RAI 720.010
Long-Term Cooling												
F	DE DVI	yes	1/1	1/1	1	0	3	0	no	WCOBRA-TRAC	No core uncovery	RAI 720.013
G	DE DVI	no	1/1	2/1	1	0	4	0	no	WCOBRA-TRAC	No core uncovery	RAI 720.013

Notes:
(1) Includes DCD Large LOCA uncertainties.

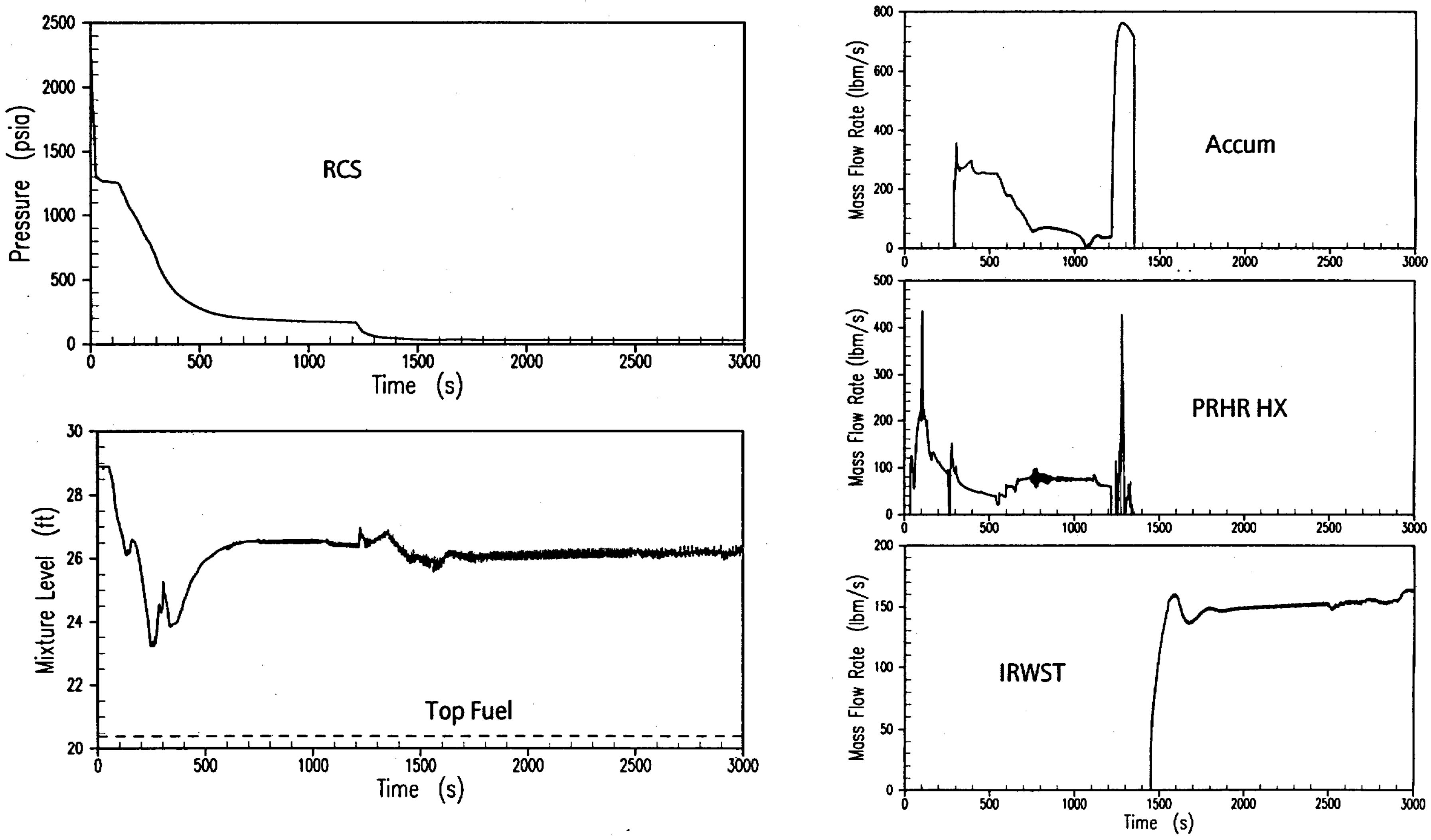
Case A, 3.0" LOCA, 1 Acc, 0 CMT, PRHR 4/4 ADS 4, no Cont Isol (NOTRUMP)

AP1000



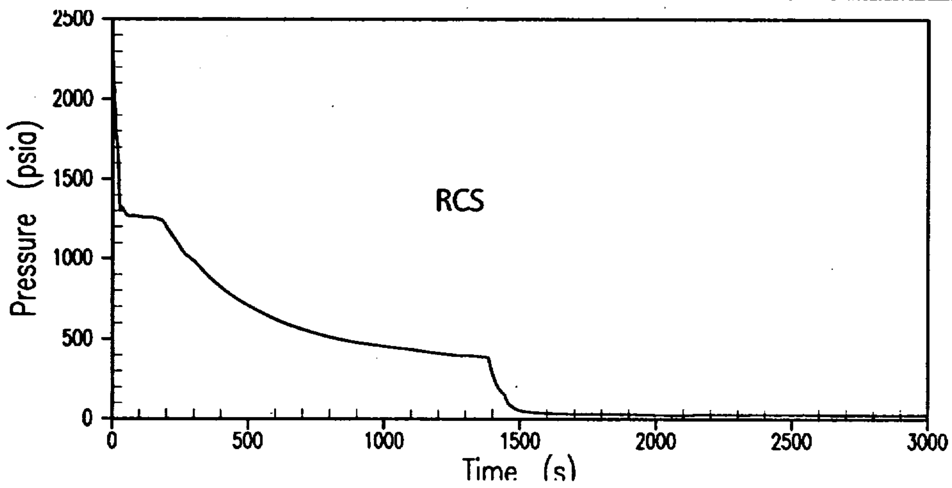
Case B, 6.8" CMT LOCA, 2 Acc, 0 CMT PRHR, 4/4 ADS 4, Cont Isol (NOTRUMP)

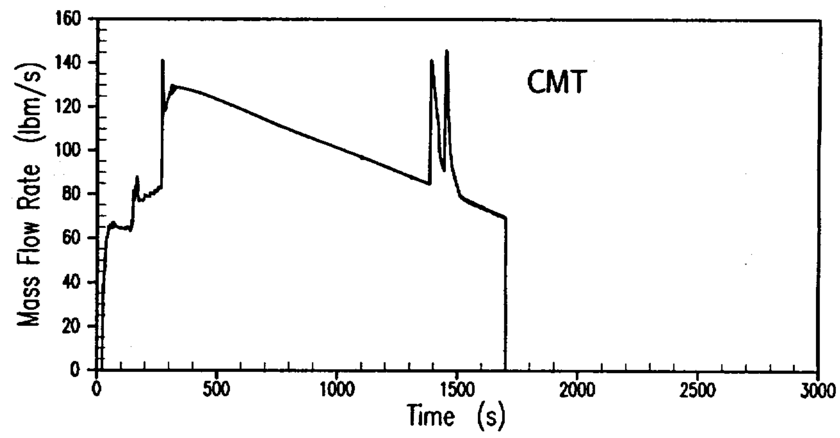
AP1000

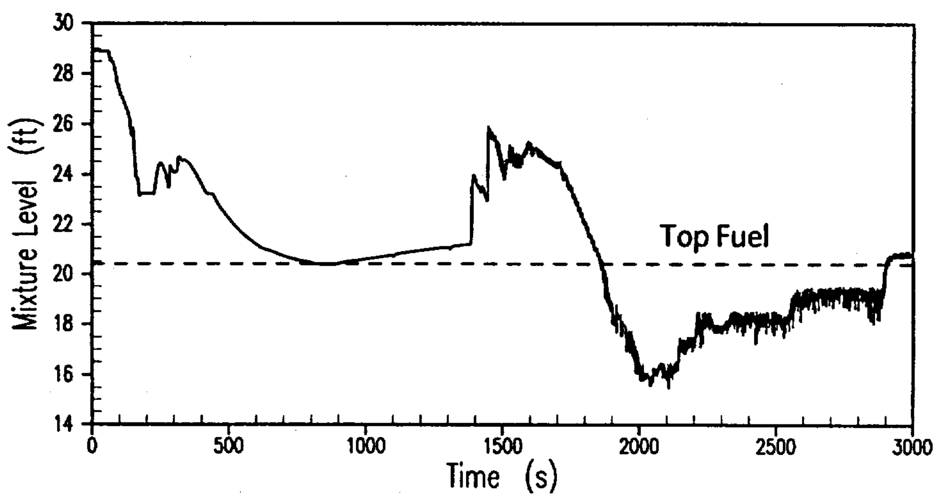


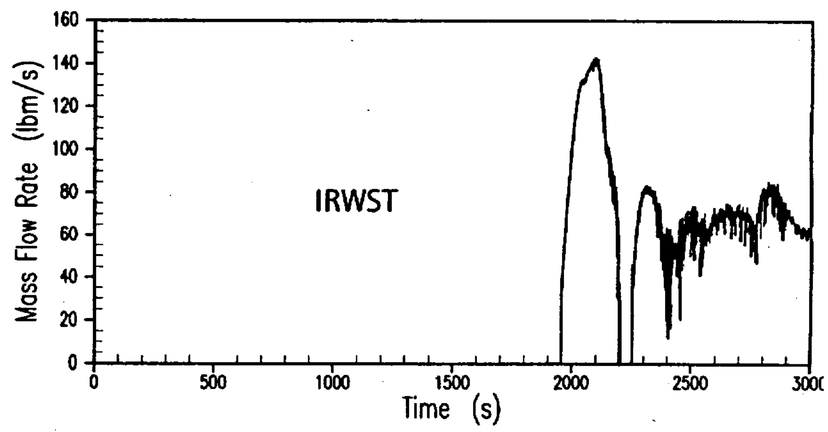
Case C, DVI LOCA, 0 Acc, 1 CMT, no PRHR 3/4 ADS 4, no Cont Isol (NOTRUMP)

AP1000







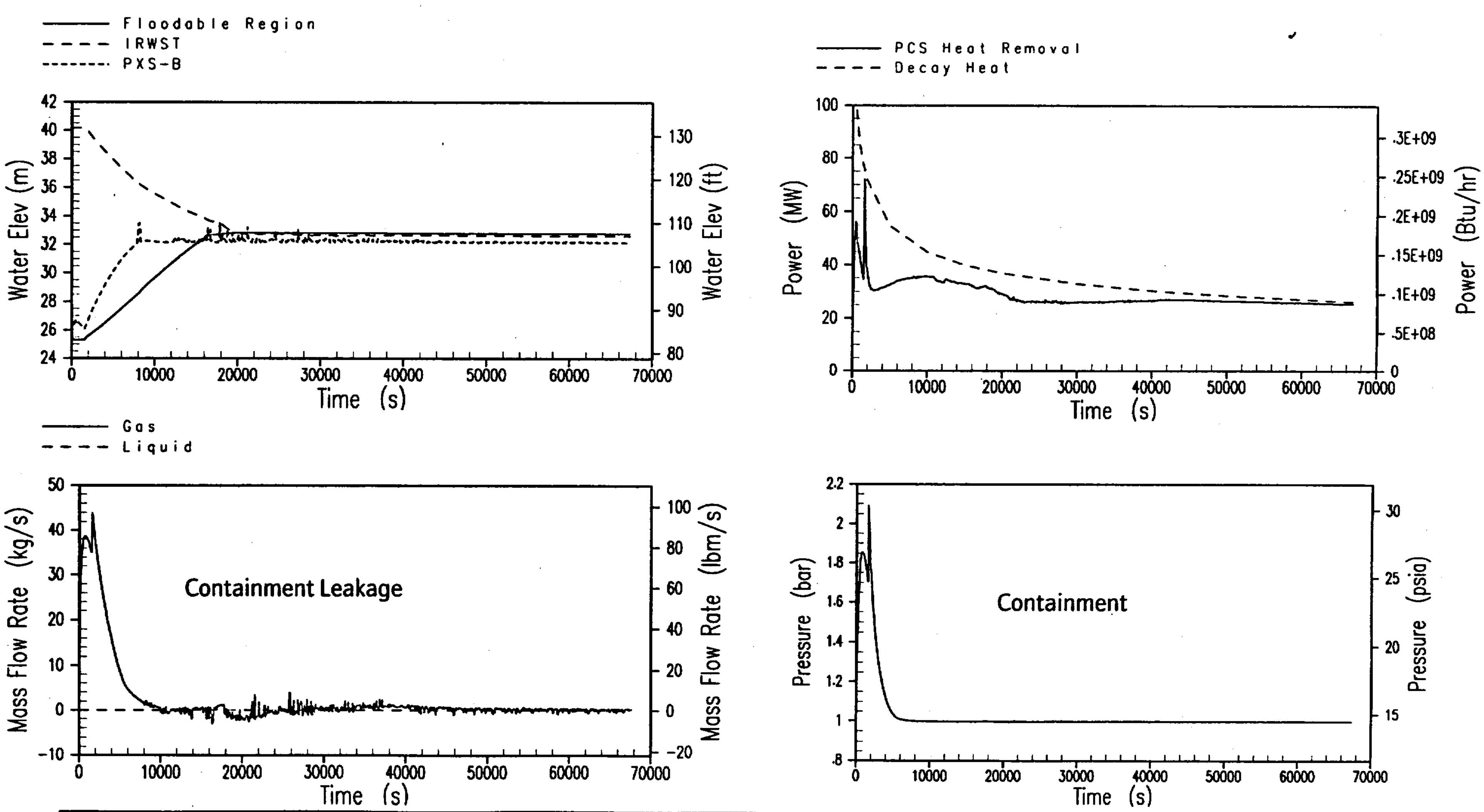


T&H Uncertainty Case for Long-Term Cooling with Cont. Isol. Failure

AP1000

- **Conservative / Limiting Case Analyzed**
  - Largest containment penetration is open (18" HVAC line)
  - DVI LOCA assumed to give lowest initial containment level
    - Causes flooding of PXS valve room where break is located
      - Reduces containment level by ~ x ft
- **LTC Analysis Results**
  - Containment leakage terminated in ~ 2.8 hr (MAAP4)
    - PCS is able to remove decay heat with cont. at atmospheric pressure
    - Leakage of steam/air mix removes air from containment
    - PCS heat transfer improves as partial pres of steam increases
    - Containment recirc level is reduced by ~ 0.3 ft
  - Core remains covered (WCOBRA-TRAC)

Case G, LTC Analysis with Cont. Isol. Failure



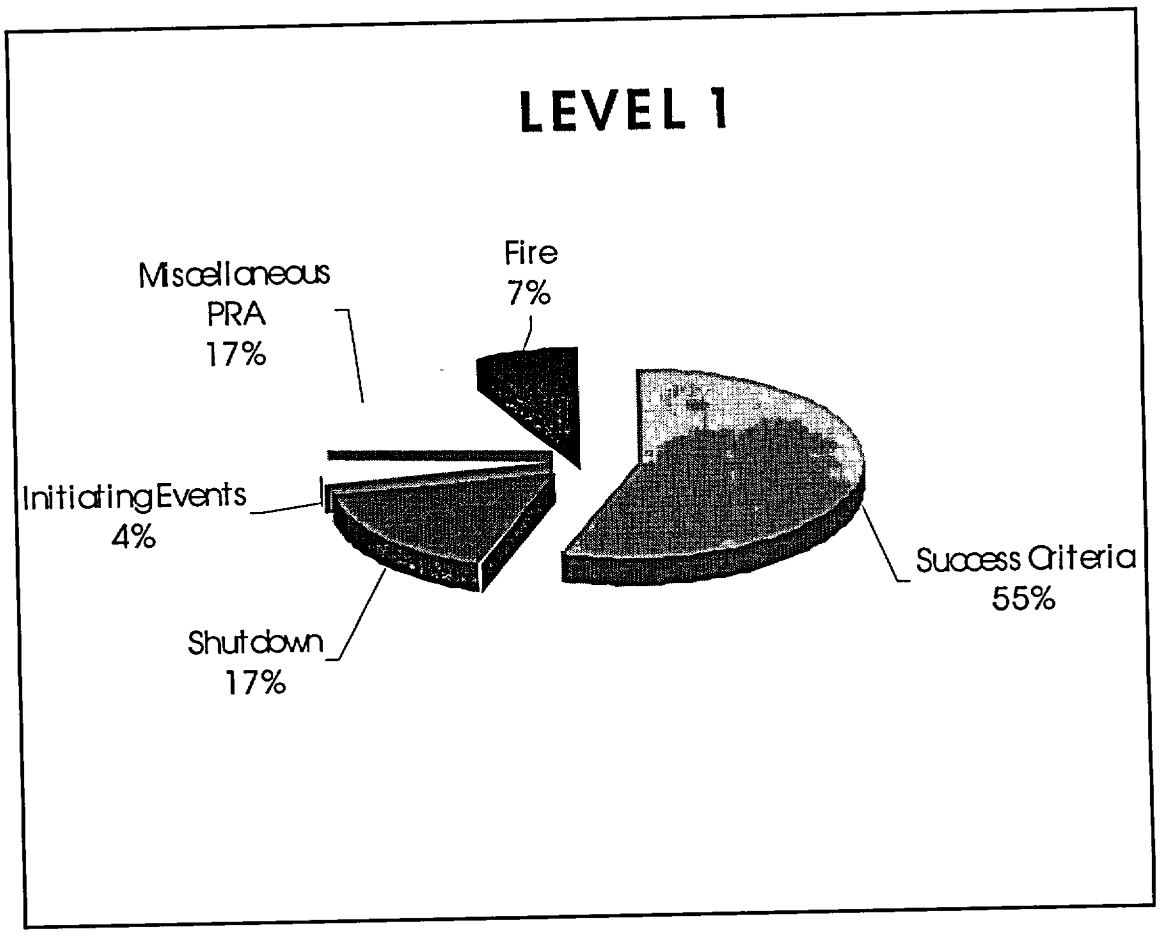
T&H Uncertainty Summary

- **AP1000 T&H Uncertainty Analysis**
  - Has calculated probabilities of low margin sequences
  - Has selected risk important, low margin sequences
  - Has defined 7 bounding T&H uncertainty cases
    - 5 Short and 2 Long-term
  - T&H Analysis has been performed on these cases
    - Using DCD Codes and methods
    - Shows successful core cooling

- **AP1000 T&H Uncertainty is Not Risk Important**
  - ~ 99% of CDF and LRF is bounded by conservative T&H analysis

Summary of RAI on AP1000 Level 1 PRA

RAIs on PRA Level 1	
Success Criteria	30
Shutdown	9
Initiating Events	2
Miscellaneous PRA	9
Fire	4
TOTAL	54



AP1000 PRA Report Updates Included with RAI Responses

Level 1 PRA Updates

- T/H Uncertainties Explicitly Addressed
  - Expanded Event Trees
  - Additional T/H Analyses Performed
    - 99% of Success Sequences Backed -Up with DBA Analysis Models
- Operator Action Times Addressed
- Revision of PRA Chapter 6 and Appendix A
- AP1000-Specific Fire PRA Performed

AP1000 Level 2 / 3 PRA

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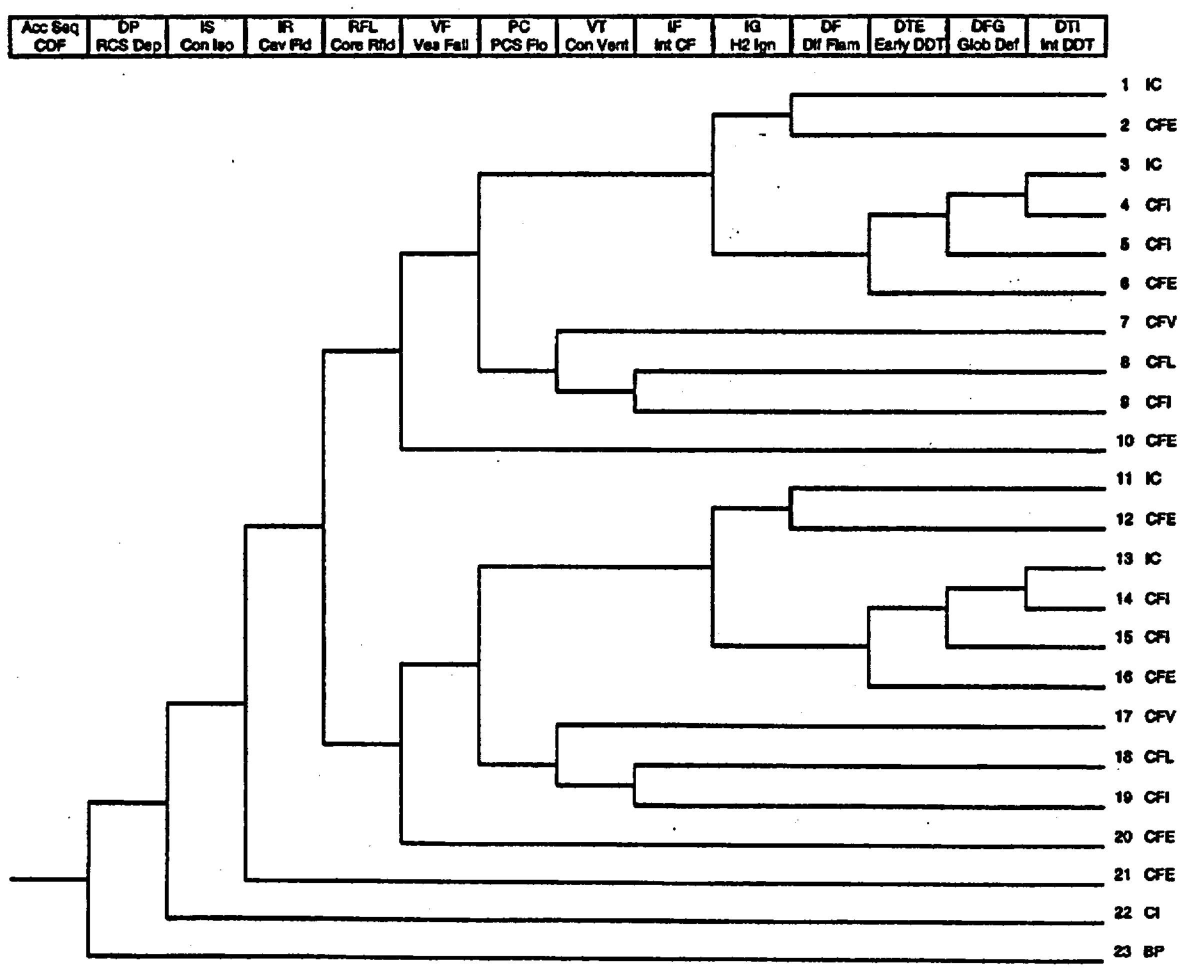
AP1000 Containment Event Tree

- Used to quantify frequency and magnitude of releases to the environment

- Essentially the same structure as AP600 Containment Event Tree

AP1000 Containment Event Tree Structure



AP1000 Containment Event Tree

- **Phenomena and System Availability**
  - reactor coolant system pressure
  - containment isolation
  - cavity flooding for external reactor vessel cooling
  - in-vessel reflooding
  - vessel failure
  - passive containment cooling water

AP1000 Containment Event Tree (continued)

- **Phenomena and System Availability (continued)**
  - hydrogen control (igniters)
  - containment overtemperature (diffusion flame)
  - hydrogen combustion (deflagration and detonation)
  - containment integrity

AP1000 Containment Event Tree

- **Operator actions**
  - Recovery Actions
    - depressurize RCS
    - isolate containment
    - actuate PCS water
  - Manual Severe Accident Management Actions
    - flood reactor cavity
    - actuate hydrogen control