October 18, 1995

APPLICANT: Westinghouse Electric Corporation

PROJECT: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS THERMAL-HYDRAULIC RELIABILITY IN THE AP600 PASSIVE SYSTEM DESIGN

The subject meeting was held in Monroeville, Pennsylvania from September 12 through 14, 1995, between representatives of Westinghouse and the NRC staff. The purpose of the meeting was to discuss the thermal-hydraulic (T/H) uncertainties in the various multiple failure accident sequences as presented in Appendix A of the AP600 probabilistic risk assessment (PRA). This meeting was part of an ongoing effort to resolve T/H uncertainty concerns raised by the staff in an August 14, 1995, letter to Westinghouse.

The meeting involved the review of numerous baseline accident sequence progressions. Specific system responses and the integrated system behavior and phenomenology, as predicted by MAAP4, were examined and evaluated in terms of what might be expected based on engineering judgement. Westinghouse also explained the process and sensitivity studies used to discard marginal success criteria and to sort the various accident sequences to a set of worst case, baseline, sequences.

The meeting was productive and the staff was in general agreement with the Westinghouse approach for selecting the success criteria and baseline sequences. Attachment 1 is the list of meeting attendees. Attachment 2 are discussion items which were focused on during the meeting. Attachment 3 contains handouts provided by Westinghouse during the meeting to supplement the presentation and discussions.

A commitment was made to have the next meeting in the T/H uncertainty resolution process on specific use and application of the MAAP4 code in analyzing the AP600 thermal-hydraulic phenomena. This meeting is scheduled for October 1995.

Original signed by
William C. Huffman, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office Of Nuclear Reactor Regulation

Docket No. 52-003

Attachments: As stated

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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AP600
THERMAL-HYDRAULIC UNCERTAINTY
MEETING ATTENDEES
SEPTEMBER 12 THROUGH 14, 1995

NAME	ORGANIZATION
Terry Schultz	Westinghouse
Debra Ohkawa	Westinghouse
Cindy Haag	Westinghouse
Bill Huffman	NRC
Tim Collins	NRC
Gene Hsii	NRC
Constantine Tzanos	ANL

Attachment 1

Meeting Discussion Items

1. The NRC staff agreed that the use of plots or graphs to illustrate sensitivity study results would be useful in the T/H uncertainty documentation.

2. The NRC staff questioned stopping success criteria analysis at stabilized IRWST injection conditions. Long term recirculation conditions could be subject to greater uncertainty due to the small head differences involved.

   Westinghouse staff indicated that they felt the long time interval to recirculation reduced decay heat levels to the point where recirculation thermal-hydraulics is not a significant concern.

3. The current PRA does not reflect some of the recent AP600 design changes (such as the increase in the volume of the pressurizer). Although Westinghouse noted that the changes will not affect the success path criteria, there may be some limited impact on sensitivity break points for such things a bounding break sizes between small breaks, intermediate breaks and medium break. The NRC staff did note that the PRA should represent the actual plant design for DCD purposes.

4. Westinghouse staff noted that many of the parameters used for the MAAP4 success criteria analyses are conservative in lieu of nominal values. For example, the ADS line and valve friction factors are bounding minimum allowable.

5. The NRC staff would like to better understand the sensitivity of MAAP4 analyses to the void fraction separation factor which is currently set to 0.6. The factors seems to has a large impact on the time that CMT draining starts, which in turn, impacts both automatic or manual ADS timing.

6. The operator action times for manual ADS cases was complicated by the possibility that ADS actuation too quickly could worsen the core peak temperature results. The NRC staff suggested that scenario success criteria be based only on a maximum wait time before manual operator ADS (e.g., less than 30 minutes). It would appear that early ADS actuation in these scenarios has a minor impact on PCT temperatures.

   Similarly, for automatic and manual actuation delays of other equipment, such as CMT's, the NRC staff suggested that Westinghouse concentrate on justifying operator action times that minimize PCT's rather than trying to determine the maximum PCT which the staff consider success in an effort to minimize the need to utilize operator intervention.

7. Westinghouse noted that they were considering revising the success criteria for a few accident scenarios to provide more margin to core damage. For example, changing the stage 4 valve interlock from 1000 psi to 1100 psi.

Attachment 2

8. The NRC staff requested more information on the success criteria analysis of large break LOCA and ATWS scenarios since these were not analyzed with MAAP4.

   Westinghouse stated that no additional LOFTRAN runs were performed for ATWS scenarios beyond DBA's. For large break LOCA's, the success crtieria was determined through engineering calculations. The staff plans to have followup discussions on these items in another meeting.

HANDOUTS PRESENTED

AT THE SEPTEMBER 12 THROUGH 14, 1995, MEETING

BETWEEN WESTINGHOUSE AND THE NRC ON

AP600 THERMAL-HYDRAULIC UNCERTAINTIES

Attachment 3

Topics of Discussion for 9/12 - 9/14 Meeting

INTRODUCTION: Discussion of Purpose

- Grouping of MAAP4 Cases
  - Event Trees
  - Definition of LOCA Groups
  - What is not covered by MAAP4 analyses
- Initial Analyses
  - Break size and location
  - Containment isolation
  - Sensitivities
- Baseline Cases
  - Task 3
  - Revised Task 3
- System response for Automatic ADS cases
- System response for Manual ADS cases
  - Operator action timing
  - Break size
- Cases with PRHR
- Effect of delays:
  - CMT
  - ADS
  - RNS
  - PRHR
- Sensitivity analyses
- Discussion of remaining questions

CONCLUSION: Summary of meeting accomplishments and action items

Table A-4

SUMMARY OF ADS SUCCESS CRITERIA DEFINITIONS SUPPORTED BY MAAP4 ANALYSES

Depress. Method	Success Criteria Name	Description of Success Criteria	Heat Removal/ Injection Method		MAAP4 Case Name for Applicable Initiating Events				
			Short Term	Long Term	MLOCA	NLOCA	SLOCA	SGTR	Trans
PARTIAL	ADU	Automatic Actuation: 2/2 stage 1 OR 1/8 stage 2,3,4	CMT	NRHR		x1b			
	ADIA ADRA	Automatic Actuation: 2/2 stage 1 OR 1/4 stage 2,3	CMT	NRHR			s16t	g10a	t1
	ADV	Automatic Actuation: 1/10 stage 1,2,3,4	CMT	PRHR NRHR			s10	g11	
	ADUM ADI ADR	Manual Actuation: 2/2 stage 1 OR 1/8 stage 2,3,4	Accum	NRHR		x2h	s19b2	g12d	t3h
	ADZ	Manual Actuation: 1/10 stage 1,2,3,4	Accum	PRHR NRHR			s13	g13	
FULL	ADM	Automatic Actuation: 2/4 stage 4	CMT	IRWST[1]	m3g4	x3d4			
	ADAB ADAL ADA	Automatic Actuation: 3/4 stage 2,3 OR 1/4 stage 2,3 and 1/4 stage 4	CMT	IRWST[1]			s1t2		t5t
	ADAG	Automatic Actuation: 1/4 stage 2,3 and 1/4 stage 4	CMT	IRWST[1]				g14e	
	ADS	Automatic Actuation: 3/4 stage 2,3 OR 1/4 stage 4	CMT	PRHR IRWST[1]			s4z	g15	
	ADQ	Manual Actuation: 2/4 stage 4	Accum	IRWST[1]	m6e5	x4g			
	ADB ADL ADT	Manual Actuation: 2/4 stage 4	Accum	IRWST[1]			s6e4	g16	t9a3
	ADT	Manual Actuation: 2/4 Stage 4	Accum	PRHR IRWST[1]			s8e4	g17	

Note:

1. IRWST gravity drain or normal residual heat removal can provide long term injection and heat removal, but IRWST gravity drain is more limiting for ADS success criteria, and therefore is modeled in the MAAP4 analyses.

Table 1
MAAP4 Baseline Cases Supporting PRA Rev 2

Base-line Case	Input Assumptions			Output			
	Break	ADS Assumption	Other Assump-tion	Peak Core Temp (°F)	Core Uncovery		
					Start (sec)	Min Level (%)	Dura-tion (sec)
s1t2	1.75" cold leg	3 stage 2/3	1 CMT	1534	4617	59%	5400
t5t	trans	3 stage 2/3	1 CMT	1262	9272	50%	4500
g14e	SGTR	1 stage 2/3, 1 stage 4	1 CMT	685	16080	81%	1400
x3d4	2" hot leg	2 stage 4	1 CMT	959	3792	45%	700
m3g4	5" cold leg	2 stage 4	1 CMT	No Uncov.	--	--	--
s4z	1.75" hot leg	3 stage 2/3	1 CMT, PRHR	1273	6203	73%	4500
g15	SGTR	3 stage 2/3	1 CMT, PRHR	No Uncov.	--	--	--
m6e5	8.75" hot leg	2 stage 4 - 30 min	1 Acc	1554	1122	40%	1000
x4g	4.75" hot leg	2 stage 4 - 30 min	1 Acc	969	925	82%	1000
s6a4	0.5" cold leg	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--
g16	SGTR	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--
s8a4	0.5" cold leg	2 stage 4 - 15 min	1 Acc, PRHR	No Uncov.	--	--	--
g17	SGTR	2 stage 4 - 15 min	1 Acc, PRHR	No Uncov.	--	--	--
t9a3	trans	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--

PRELIMINARY

Table 2
MAAP4 Cases Supporting PRA Sensitivity

Case	Input Assumptions			Output			
	Break	ADS Assumption	Other Assump-tion	Peak Core Temp (°F)	Core Uncovery		
					Start (sec)	Min Level (%)	Dura-tion (sec)
ts1a	1.75" cold leg	1 stage 2/3, 2 stage 4	1 CMT	No Uncov.	--	--	--
ts1b	0.5" cold leg			835	13940	50%	600
tt5a	trans	1 stage 2/3, 2 stage 4	1 CMT	826	9374	58%	800
tg14a	SGTR	1 stage 2/3, 2 stage 4	1 CMT	No Uncov.	--	--	--
x3d4	2" hot leg	2 stage 4	1 CMT	959	3792	45%	700
m3g4	5" cold leg	2 stage 4	1 CMT	No Uncov.	--	--	--
ts4a	1.75" hot leg	2 stage 4	1 CMT, PRHR	No Uncov.	--	--	--
ts4b	0.5" hot leg			No Uncov.	--	--	--
g15	SGTR	2 stage 4	1 CMT, PRHR	No Uncov.	--	--	--
tm6a	8.75" hot leg	2 stage 4 - 30 min	2 Acc	982	1522	63%	500
tm6b	5" hot leg		2 Acc	No Uncov.	--	--	--
tm6c	4" DVI		1 Acc	934	1338	78%	500
tx4a	4.75" hot leg	2 stage 4 - 30 min	2 Acc	No Uncov.	--	--	--
tx4b	2" hot leg			No Uncov.	--	--	--
s6a4	0.5" cold leg	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--
g16	SGTR	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--
s8a4	0.5" cold leg	2 stage 4 - 15 min	1 Acc, PRHR	No Uncov.	--	--	--
g17	SGTR	2 stage 4 - 15 min	1 Acc, PRHR	No Uncov.	--	--	--
t9a3	trans	2 stage 4 - 15 min	1 Acc	No Uncov.	--	--	--

Summary of NRC Task 3 Comments

Systematic Method

- No systematic analysis was performed to identify for each LOCA category the limiting break size and location. Some tables show runs only with cold leg breaks while others show runs with hot leg breaks. The identification of the limiting break size and location is not systematic and complete. (SPSB,#2)

- How do you conclude that for a 2" hot leg break a 15 minute delay gives a higher temperature than a 30 minute delay without having analyzed a 2" hot leg break with a 30 minute delay? (SPSB, #11)

- Why is the extrapolation from a 2" cold leg break to a 2" hot leg break correct, but the inference from a 4.75" hot leg break to a 2" hot leg break is not correct? (SPSB, #11)

- The boundary break size of the LOCAs is defined based on the system depressurization. Has the uncertainty in this calculation been considered in the determination of success criteria? (SPSB, #9)

- No runs with ADS stage 2, 3 and 4 are provided in Table A-4.11a (SGTR with PRHR and RNS). (SPSB, #14)

- Not enough runs to support limited break size and location for NLOCA and SLOCA (Tables A4-14 and A4-15) (SPSB, #15)

Sensitivity Analyses

- The section on system interaction and passive system performance sensitivities indicate that they'll be provided in the future. Will this section address sensitivities only if the PCT is above 1000°K? Will this section address only "one-at-a-time" variations? (SPSB, #3c, #3d)

- Section A.9 does not discuss how the sensitivity analyses will be done. (SRXB, #3)

- The list of sensitivities identified in Westinghouse's Task 3 submittal is: ADS minimum flow, CMT minimum flow, accumulator minimum flow, PRHR minimum heat removal, RNS minimum flow, IRWST minimum flow. The staff has repeatedly stressed that uncertainties must be combined. It has many times been stressed by the staff that many other parameters must be considered, and justification must be provided for their reduction to a list of a few important variables. (SPSB, #3c, #3d)

- The staff believes that all uncertainties including code parameters, T/H uncertainties, and plant parameter uncertainties, should be addressed at the same time. This is particularly important because of interdependent, synergistic effect of certain phenomena. Therefore, the sensitivity analysis should be performed either deterministically assuming all plant parameters at their bounding values, or using Monte-Carlo-like approach. (SRXB, #3)

Summary of NRC Task 3 Comments

- Minimum CMT (runs s1t7 and s1t2) and ACC flows (runs m6e5a and m6e5) gave lower PCT than their baseline values? (SPSB, #3f)

- Minimum IRWST flow (runs m6e5b and m6e5) gave a PCT of 2°F higher than the baseline flow. (SPSB, #3f)

System Response/Operator Action

TIMING OF MANUAL ADS (CASES WITHOUT CMTs):

- If earlier depressurization gives higher PCTs, should also depressurization with more ADS lines have a similar effect? (SPSB, #11)

- If higher decay heat is the reason for worse results with shorter operator actions, then why is a 30 minute delay worse than a 15 minute delay for 4.75" break (Table A-4.7a)? (SPSB, #11)

- Why are delays (in manual ADS) shorter than 15 minutes not considered? (SPSB, #11, #12)

- Further analysis with even shorter delay time may be needed to determine if they could produce even more severe results. (SRXB, #4)

CMT DELAYS:

- Why is a NLOCA (case x1bop2) with a 10 min CMT delay more limiting than a MLOCA (case m3g4op2) with the same delay, when p. A-40 states that larger breaks are more limiting? (EXTRA, #2b)

- Why does a 10 minute CMT delay result in lower PCT than no CMT delay (x1bop2: 1128°F vs. x1b: 1147°F; x3d4op2: 846°F vs. x3d4: 959°F) (EXTRA, #2c)

- Why does a 30 minute CMT delay result in lower PCT than no CMT delay? Would delay times between 0 and 30 minutes lead to higher PCTs than the baseline? (EXTRA, #2d)

PRHR DELAYS:

- Why does delaying PRHR by 30 minutes result in a lower PCT (1043°F vs. 1273°F)? If the system behavior is nonlinear, how does the PCT vary with shorter than 30 minute delays? (EXTRA, #3a)

RNS DELAY:

- What is the basis for the 30 minute delay time for RNS actuation from CMT injection signal? (SPSB, #18)

Summary of NRC Task 3 Comments

ADS DELAY (CASES WITH A CMT):

- In sub-sections of A.4.2 (manual ADS cases), a 15 minute delay results in higher PCT than a 30 minute delay. Why is only one time delay of 30 minutes presented in Table A.4.27a (ADS delay for cases with a CMT)? (EXTRA, #1a)

- Is the relation between PCT and ADS time delay linear? (EXTRA, #1a)

- Will the effect of the ADS delay time on PCT for different break sizes be analyzed? (EXTRA, #1b)

- There are inconsistences in comparing the results from ADS delay cases with the corresponding baseline cases. PCT for runs x1b and x1bop1 are the same; does this mean that PCT is independent of ADS delay time? A 30 minute ADS delay time (case t1op1) gave a significantly lower temperature (1109°F) than the base case, t1 (1305°F). Does depressurization lead to a worse transient? The baseline transient run t5t predicted a PCT of 1262°F while run t5top1 (30 min ADS delay) gave a lower temperature of 1047°F. Why is there a drastic difference between the Transient and SLOCA responses? (EXTRA, #1b, #1c, #1d)

MAAP4 Model

- How is the clad modeled, while no clad temperature is computed? Are the 5 radial rings fuel-pin rings or core rings? (SPSB, #4)

- Why is the clad temperature not easily summarized? (SRXB, #1b)

- Clarifications are needed on whether the core temperature is based on the average fuel pellet or fuel centerline temperature, and whether the PCT is at the hottest spot within the core. (SRXB, #1b)

Technical Questions

- The staff did not accept the assumption that there is adequate margin if the predicted PCT does not exceed 1000°K. No justification has been provided for this assumption. (SPSB, #3a)

- Section A.1.4.2 should be modified to reflect the possibility that core damage may occur due to extended core uncovery. (SRXB, #1a)

- The discussion about sufficient water inventory for core cooling without containment isolation is confusing. Is this calculation based on the simple assumption that all IRWST water boils off by decay heat? (SPSB, #20)

- The 2.7 days of sufficient water inventory to keep the core covered is inconsistent with the 3-day design basis for the passive safety systems. (SRXB, #5)

Summary of NRC Task 3 Comments

- How does the probability of producing elevated core temperature compare with the low probability from hardware and human failures? (SPSB, #8)

Documentation

- Westinghouse must provide a direct response to the March review comments and explain how Appendix A was accordingly revised. (SPSB,#1)

- The documentation does not include: details of baseline calculations (plots of system parameters or equipment actuation times), information on initial and boundary analysis assumptions, details of input models or code input parameters. (SASG, #1)

- Sensitivities in the original Appendix A on VFSEP and the ADS and IRWST discharge coefficients were removed. Why? (SPSB, #3e)

- There are no VFSEP sensitivity analyses presented in Section A.8. (SPSB, #5)

- Table A-9 (Approximate Times that RNS is Credited in MAAP4 Analyses) is confusing. (SPSB, #18)

- Table A-4.29a does not cover all the success criteria with PRHR. (SPSB, #17)

- Table A-4.30a (RNS Manual Action Delay Time) does not cover all the relevant success criteria. (SPSB, #19)

Other

- There are best-estimate codes which can differ drastically in their predictions. If one of them predicts damage and the other no damage, would you consider the core damaged or not damaged? (SPSB, #7)

- The presentation of this material makes its review very difficult. The review is not considered complete. (SPSB, #21)

- The staff should not be reviewing DRAFT submittals. (SASG, #2)

- How does the operator know that the CMTs are not injecting? (SPSB, #10)

- What other systems, in addition to containment isolation, are considered that adversely impact the response to a sequence? (SPSB, #6)

Summary of NRC Task 3 Comments

Typographical / Wording Errors

- 2" cold leg versus 2" hot leg (SPSB, #11)
- References to core uncovery in discussion of success criterion ADZ. (SPSB, #13)
- Reference to 0.5" break in Transient discussion (SPSB, #16)
- Low pressurizer level is listed (p. A-2 and Table A-1) as a reactor trip. (SRXB, #2)
- The definition of baseline cases with "longest operator action time" needs to be modified since 15 minutes is worse than 30 minutes. (SRXB, #4)
- Success criteria names in Table A-4.29a are wrong. (EXTRA, #3a, #3b)
- 1.75" cold leg versus 1.75" hot leg (EXTRA, #3a)

System Response for Automatic ADS
(Partial Depressurization)

Section A.4.1

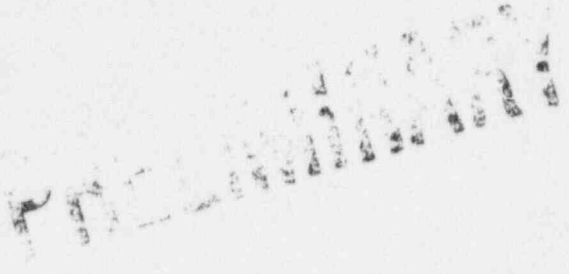
- Success criteria ADU, AD1A, ADRA:
  - 2 stage 1 ADS lines

    OR
  - 1 stage 2,3 ADS lines (or 1 stage 4 for NLOCA)

- Initiating events:

Initiating Event	Baseline Break	PCT (°F)
NLOCA	2" cold leg	1119
SLOCA	0.5" hot leg	1307
SGTR	--	1111
Transient	--	1345

- System assumptions:
  - 1 or more CMTs
  - No accumulators credited
  - No PRHR
  - 1 RNS pump



- Limiting conditions:
  - 2 stage 1 ADS
  - Small end of break spectrum
  - 1 CMT

- Observations:
  - Additional CMT or accumulators provides some improvement.
  - Cold leg and hot leg breaks produce similar results.

Table A-4.1
MAAP4 Analyses Supporting NLOCA Success Criterion ADU

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	x1b	Baseline: 2 stage 1 ADS lines 2" cold leg break 1 CMT 1 RNS pump	1119
ADS Line Assumption	x1c	1 stage 2/3 ADS line	no uncov
	x1d	1 stage 4 ADS line	no uncov
Break Size and Location	x1b4	2" hot leg break	1065
	x1a	4.75" cold leg break	no uncov (1)
	x1e	4.75" hot leg break	no uncov (1)
	x1b3	Stuck-open Pressurizer SV	931
# of CMTs and Accumulators	x1f1	2 CMTs	1111
	x1f2	1 CMT, 1 Acc	705
Containment Isolation	Not Applicable		
Operator Action Time	Not Applicable		
Other Sensitivities (2)	x1d2	2" hot leg break with 1 stage 4 ADS line	774

Notes:

(1) Includes more restrictive assumption of 1 stage 1 ADS

(2) Additional sensitivity is run because the delay before stage 4 ADS opens (due to the 1000 psia RCS pressure interlock) may have more adverse impact on hot leg break than on a cold leg break.

Table A-4.2
MAAP4 Analyses Supporting SLOCA Success Criterion AD1A

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	s16k	Baseline: 2 stage 1 ADS lines 0.5" hot leg 1 CMT 1 RNS pump	1307
ADS Line Assumption	s17a	1 stage 2/3 ADS line	889
Break Size and Location	s16	0.5" cold leg break	1301
	s16c	1.75" cold leg break	1122
	s16c3	1.75" hot leg break	1102
	s16c4	PRHR Tube Rupture	
# of CMTs and Accumulators	s16k1	2 CMTs	1037
	s16k2	1 CMT, 1 Acc	1286
Containment Isolation	Not Applicable		
Operator Action Time	Not Applicable		
Notes:			

Table A-4.4
MAAP4 Analyses Supporting SGTR Success Criterion AD1A

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	g1a	Baseline: 2 stage 1 AD lines SGTR 1 CMT 1 RNS pump	1111
ADS Line Assumption	g1f2	1 stage 2/3 ADS line	no uncov
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	g1a2	2 CMTs	1080
	g1a3	1 CMT, 1 Acc	404
Containment Isolation	Not Applicable		
Operator Action Time	Not Applicable		

Table A-4.6
MAAP4 Analyses Supporting Transient Success Criterion AD1A

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	t1	Baseline: 2 stage 1 ADS lines Loss of Feedwater Transient 1 CMT 1 RNS pump	1345
ADS Line Assumption	t2	1 stage 2/3 ADS line	799
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	t1a2	2 CMTs	1133
	t1a	1 CMT, 1 Acc	764
Containment Isolation	Not Applicable		
Operator Action Time	Not Applicable		

PRELIMINARY

Section A.4.3

System Response for Automatic ADS

(Full Depressurization)

- Success criteria ADM, ADAB, ADAL, ADA
  - 2 stage 4 ADS lines (with 1 stage 2,3 ADS line for SLOCA, SGTR, and Transients)

- Initiating events:

Initiating Event	Baseline Break	PCT (°F)
MLOCA	5" hot leg	no uncovery
NLOCA	2" hot leg	1030
SLOCA	0.5" hot leg	860
SGTR	--	no uncovery
Transient	--	796

- System assumptions:
  - 1 or more CMTs
  - No accumulators credited
  - No PRHR
  - 1 line of IRWST gravity injection
  - Containment isolation failure

- Limiting conditions:
  - 2 stage 4 ADS (+ stage 1,2,3 line for high pressure scenarios)
    Small end of break spectrum
  - Hot leg breaks
  - 1 CMT

- Observations:
  - Additional CMT or accumulators provides some improvement.
  - The hot leg is at a lower elevation and the break remains covered for a longer period of time. Therefore, hot leg breaks lose more inventory and produces higher PCT.
  - The containment isolation failure has only a small impact on the PCT (~100°F) with the 2 stage 4 ADS criterion. However, preliminary cases with only 1 stage 4 ADS line showed a strong sensitivity to containment isolation.
  - The NLOCA (2") case gets the most limiting results. For this case, ADS is substantially delayed (~ 1000 seconds) until the RCS pressure drops below 1000 psia. This is because the break sizes for each LOCA were defined based on the RCS pressure at the time of core uncovery.

Table A-4.13
MAAP4 Analyses Supporting MLOCA Success Criterion ADM

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	m3n3	Baseline: 2 stage 4 ADS lines 5" hot leg break 1 CMT Containment Isolation Failure 1 line IRWST	no uncov
ADS Line Assumption	Not Applicable		
Break Size and Location	m3g4	5" cold leg break	no uncov
	m3r4	8.75" cold leg break	no uncov (1)
	m3r3	8.75" hot leg break	no uncov (1)
	m4a3	DVI Line Break (4") (2)	no uncov
	m4b3	DVI Line Break (4" + 3.7")	no uncov
	m4c3	DVI Line Break (4" + 8")	no uncov
# of CMTs and Accumulators	m3x1	2 CMTs	no uncov
	m3x2	1 CMT, 1 Acc	no uncov
Containment Isolation	m3n	With Containment Isolation	no uncov (1)
Operator Action Time	Not Applicable		

Notes:

(1) Includes more restrictive assumption of 1 stage 4 ADS

(2) The 4" DVI line break is smaller than the defined MLOCA break range, but is grouped within the MLOCA category because of the other DVI line break scenarios.

Table A-4.14
MAAP4 Analyses Supporting NLOCA Success Criterion ADM

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	x3d4	Baseline: 2 stage 4 ADS lines 2" hot leg break 1 CMT Containment Isolation Failure 1 line IRWST	1030
ADS Line Assumption	Not Applicable		
Break Size and Location	x3d5	2" cold leg break	no uncov
	x3j5	4.75" cold leg break	no uncov
	x3j6	4.75" hot leg break	no uncov
	x3c2	Stuck-open Pressurizer SV	no uncov
# of CMTs and Accumulators	x3k1	2 CMTs	no uncov
	x3k2	1 CMT, 1 Acc	no uncov
Containment Isolation	x3b3	With Containment Isolation	943
Operator Action Time	Not Applicable		

Notes:

PRELIMINARY

Table A-4.15 MAAP4 Analyses Supporting SLOCA Success Criterion ADA			
Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	s2c	Baseline: 1 stage 2/3 + 2 stage 4 ADS lines 0.5" hot leg break 1 CMT Containment Isolation Failure 1 line IRWST	860
ADS Line Assumption	Not Applicable		
Break Size and Location	s2a	0.5" cold leg break	840
	s2b2	1.75" hot leg break	no uncov
	s2b	1.75" cold leg break	no uncov
	s2e	PRHR Tube Rupture	
# of CMTs and Accumulators	s2c2	2 CMTs	353
	s2c3	1 CMT, 1 Accumulator	no uncov
Containment Isolation	s2d	With Containment Isolation	696
Operator Action	Not Applicable		
Other Sensitivities			
Notes:			

Table A-4.17
MAAP4 Analyses Supporting SGTR Success Criterion ADAG

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	g4m	Baseline: 1 stage 1 + 2 stage 4 ADS lines SGTR 1 CMT Containment Isolation Failure 1 line IPWST	no uncov
ADS Line Assumption	g4p	1 stage 2/3 + 2 stage 4 ADS lines	no uncov
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	g4m2	2 CMTs	no uncov
	g4m3	1 CMT, 1 Acc	no uncov
Containment Isolation	g4m1	With Containment Isolation	no uncov
Operator Action Time	Not Applicable		
Other Sensitivities			

Notes:

Table A-4.19
MAAP4 Analyses Supporting Transient Success Criterion ADA

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	t7	Baseline: 1 stag. 2/3 + 2 stage 4 ADS lines Loss of Feedwater Transient 1 CMT Containment Isolation Failure 1 line IRWST	796
ADS Line Assumption	Not Applicable		
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	t7b1	1 CMT, 1 Accumulator	519
	t7b2	2 CMTs	no uncov
Containment Isolation	t7c	With Containment Isolation	691
Operator Action Time	Not Applicable		
Other Sensitivities			
Notes:			

PRELIMINARY

Section A.4.2

System Response for Manual ADS

(Partial Depressurization)

- Success criteria AD1, ADY, ADR
  - 2 stage 1 ADS lines
    OR
  - 1 stage 2,3,4 ADS lines

- Initiating events:

Initiating Event	Baseline Break	Time of Manual ADS	PCT (°F)
NLOCA	2" hot leg	15 min after failed CMT	1145
SLOCA	0.5" hot leg	15 min after failed CMT	1270
SGTR	--	15 min after failed CMT	1194
Transient	--	15 min after failed PRHR	1276

- System assumptions:
  - No CMT
  - 1 or more accumulators
  - No PRHR
  - 1 RNS pump

- Limiting conditions:
  - 2 stage 1 ADS
  - Small end of break spectrum
  - 1 Accumulator

- Observations:
  - System response is less dependent on initiating event.
  - Accumulator does not inject until ADS lines are opened.
  - Earlier manual actuation is worse due to higher decay heat.
  - Cold leg and hot leg breaks produce similar results, although hot leg is consistently slightly more limiting.

Table A-4.7
MAAP4 Analyses Supporting NLOCA Success Criterion ADUM

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	x2h	Baseline: 2 stage 1 ADS lines - manual op action 15 min after failed CMT 2" hot leg break 1 Accumulator 1 RNS pump	1145
ADS Line Assumption	x2f2	1 stage 2/3 ADS line	no uncov
	x2g2	1 stage 4 ADS line	no uncov
Break Size and Location	x2e	2" cold leg break	1099
	x2j1	4.75" cold leg break	no uncov
	x2h2	4.75" hot leg break	867
	x2j2	Stuck-open Pressurizer SV	800
# of CMTs and Accumulators	x2k	2 Accumulators	no uncov
Containment Isolation	Not Applicable		
Operator Action Time	x2m1	op action 30 min after failed CMT	761
Other Sensitivities (1)	x2m2	4.75" hot leg break with op action 30 min after failed CMT	1099
	x2j3	Stuck-open Pressurizer SV with op action 30 min after failed CMT	1230 (2)

Notes:

(1) Additional sensitivities are done to show the impact of the maximum delay for the large end of this break spectrum and for the stuck-open SV scenario.

(2) If the operator does not take action until 30 minutes after the CMT actuation fails when the pressurizer safety valve sticks open after an initiating Transient, the maximum core temperature is slightly higher than the baseline case. However, the stuck open SV scenario is not chosen as the baseline case because of the differences in timing of the event. The failed CMT actuation signal occurs 30 minutes later in the stuck SV scenario compared with the initiating LOCA scenario. Therefore, before the SV sticks open, the operator has additional time to recognize that action may be necessary due to the loss of heat sink.

PRELIMINARY

Table A-4.8
MAAP4 Analyses Supporting SLOCA Success Criterion AD1

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	s19b2	Baseline: 2 stage 1 ADS lines - manual op action 15 min after failed CMT 0.5" hot leg break 1 Accumulator 1 RNS pump	1270
ADS Line Assumption	s20a	1 stage 2/3 ADS line	no uncov (2)
	s20b	1 stage 4 ADS line	no uncov (2)
Break Size and Location	s19b	0.5" cold leg break	1264
	s19n	1.75" cold leg break	1163
	s19k	1.75" hot leg break	1177
	s19p	PRHR Tube Rupture	
# of CMTs and Accumulators	s19m	2 Accumulators	943 (2)
Containment Isolation	Not Applicable		
Operator Action Time	s19	op action 30 min after failed CMT	1145 (2)
Other Sensitivities (1)	s19k2	1.75" hot leg break with op action 30 min after failed CMT	1031

Notes:

(1) Additional sensitivities are done to show the impact of the maximum delay for the large end of this break spectrum.

(2) These supporting cases model the break on the cold leg rather than the hot leg. Cold leg break and hot leg break system response is very similar.

PRELIMINARY

Table A-4.8
MAAP4 Analyses Supporting SLOCA Success Criterion AD1

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	s19b2	Baseline: 2 stage 1 ADS lines - manual op action 15 min after failed CMT 0.5" hot leg break 1 Accumulator 1 RNS pump	1270
ADS Line Assumption	s20a	1 stage 2/3 ADS line	no uncov (2)
	s20b	1 stage 4 ADS line	no uncov (2)
Break Size and Location	s19b	0.5" cold leg break	1264
	s19n	1.75" cold leg break	1163
	s19k	1.75" hot leg break	1177
	s19p	PRHR Tube Rupture	
# of CMTs and Accumulators	s19m	2 Accumulators	943 (2)
Containment Isolation	Not Applicable		
Operator Action Time	s19	op action 30 min after failed CMT	1145 (2)
Other Sensitivities (1)	s19k2	1.75" hot leg break with op action 30 min after failed CMT	1031

Notes:

(1) Additional sensitivities are done to show the impact of the maximum delay for the large end of this break spectrum.

(2) These supporting cases model the break on the cold leg rather than the hot leg. Cold leg break and hot leg break system response is very similar.

PRELIMINARY

Table A-4.10
MAAP4 Analyses Supporting SGTR Success Criterion AD1

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	g6b	Baseline: 2 stage 1 ADS lines - manual op action 15 min after failed CMT SGTR 1 Accumulator 1 RNS pump	1194
ADS Line Assumption	g6d	1 stage 2/3 ADS line	no uncov
	g6e	1 stage 4 ADS line	no uncov
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	g6f	2 Accumulators	740
Containment Isolation	Not Applicable		
Operator Action Time	g6	op action 30 min after failed CMT	1121
Other Sensitivities	g6e2	1 stage 4 ADS line with op action 30 min after failed CMT	no uncov

Table A-4.12
MAAP4 Analyses Supporting Transient Success Criterion AD1

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	t3h	Baseline: 2 stage 1 ADS lines - manual op action 15 min after failed PRHR Loss of Feedwater Transient 1 Accumulator 1 RNS pump	1276
ADS Line Assumption	t4a	1 stage 2/3 ADS line	no uncov
	t4c	1 stage 4 ADS line	no uncov
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	t3h2	2 Accumulators	961
Containment Isolation	Not Applicable		
Operator Action Time	t3i	op action 30 min after failed PRHR	1167
	t3i2	op action 60 min after failed PRHR	1220
Other Sensitivities (1)	t4c2	1 stage 4 ADS line with op action 30 min after failed PRHR	no uncov
	t4c3	1 stage 4 ADS line with op action 60 min after failed PRHR	no uncov

Notes:

(1) Other sensitivites are performed to show the impact of operator action time when stage 4 ADS lines are used.

PRELIMINARY

Section A.4.4

System Response for Manual ADS

(Full Depressurization)

- Success criteria ADQ, ADB, ADC, ADL, ADT
  - 2 stage 4 ADS lines

- Initiating events:

Initiating Event	Baseline Break	Time of Manual ADS	PCT (°F)
MLOCA	8.75" hot leg	30 min after failed CMT	1554
NLOCA	4.75" hot leg	30 min after failed CMT	1095
SLOCA	1.75" hot leg	15 min after failed CMT	no uncovery
SGTR	--	15 min after failed CMT	no uncovery
Transient	--	15 min after failed PRHR	no uncovery

- System assumptions:
  - No CMT
  - 1 or more accumulators
  - No PRHR
  - 1 line IRWST injection

- Limiting conditions:
  - 2 stage 4 ADS
  - Large end of break spectrum
  - Hot leg breaks
  - 1 Accumulator

- Observations:
  - Larger hot leg breaks get significantly more limiting results than cold leg.
  - Additional accumulator for larger breaks provides substantial improvement.
  - Key to understanding results:
    1) Whether the break is large enough to uncover core in time frame of interest
    2) The impact of the accumulator

Table A-4.20
MAAP4 Analyses Supporting MLOCA Success Criterion ADQ

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	m6e5	Baseline: 2 stage 4 ADS lines - manual op action 30 min after failed CMT 8.75" hot leg break 1 Accumulator Containment Isolation Failure 1 line IRWST	1554
ADS Line Assumption	Not Applicable		
Break Size and Location	m6e2	5" cold leg break	484
	m6e	5" hot leg break	964
	m6e7	8.75" cold leg break	no uncov
	m5f3	DVI Line Break (4") (2)	1484 (1)
# of CMTs and Accumulators	m6f1	2 Accumulators	478
Containment Isolation	m6g	With Containment Isolation	1316
Operator Action Time	m6e6	op action 15 min after failed CMT	no uncov

Notes:

(1) Includes more restrictive assumption of 1 stage 4 ADS.

(2) The 4" DVI line break is smaller than the defined MLOCA break range, but is grouped within the MLOCA category because of the other DVI line break scenarios. However, when both CMTs fail, there are no other DVI line break scenarios.

Table A-4.21
MAAP4 Analyses Supporting NLOCA Success Criterion ADQ

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	x4g	Baseline: 2 stage ADS lines - manual op action 30 min after failed CMT 4.75" hot leg break 1 Accumulator Containment Isolation Failure 1 line IRWST	1095
ADS Line Assumption	Not Applicable		
Break Size and Location	x4h1	2" cold leg break	no uncov
	x4m	2" hot leg break	no uncov
	x4h2	4.75" cold leg break	682
	x4s	Stuck-open Pressurizer SV	908
# of CMTs and Accumulators	x4j	2 Accumulators	580
Containment Isolation	x4k	With Containment Isolation	1087
Operator Action Time	x4g2	op action 15 min after failed CMT	840
Other Sensitivities (1)	x4e4	2" hot leg break with op action 15 min after failed CMT	no uncov
	x4s2	Stuck-open Pressurizer SV with op action 15 min after failed CMT	no uncov

Notes:

(1) Additional sensitivities are done to show the impact of a shorter delay for the small end of this break spectrum and for the stuck-open SV scenario.

PRELIMINARY

Table A-4.22
MAAP4 Analyses Supporting SLOCA Success Criterion ADT

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	s7d	Baseline: 2 stage 4 ADS lines - manual op action 15 min after failed CMT 1.75" hot leg break 1 Accumulator Containment Isolation Failure 1 line IRWST	no uncov
ADS Line Assumption	Not Applicable		
Break Size and Location	s7a	0.5" cold leg break	no uncov
	s7b	0.5" hot leg break	no uncov
	s7c	1.75" cold leg break	no uncov
	s7e	PRHR Tube Rupture	
# of CMTs and Accumulators		2 Accumulators	
Containment Isolation		With Containment Isolation	
Operator Action Time	s7f	op action 30 min after failed CMT	no uncov

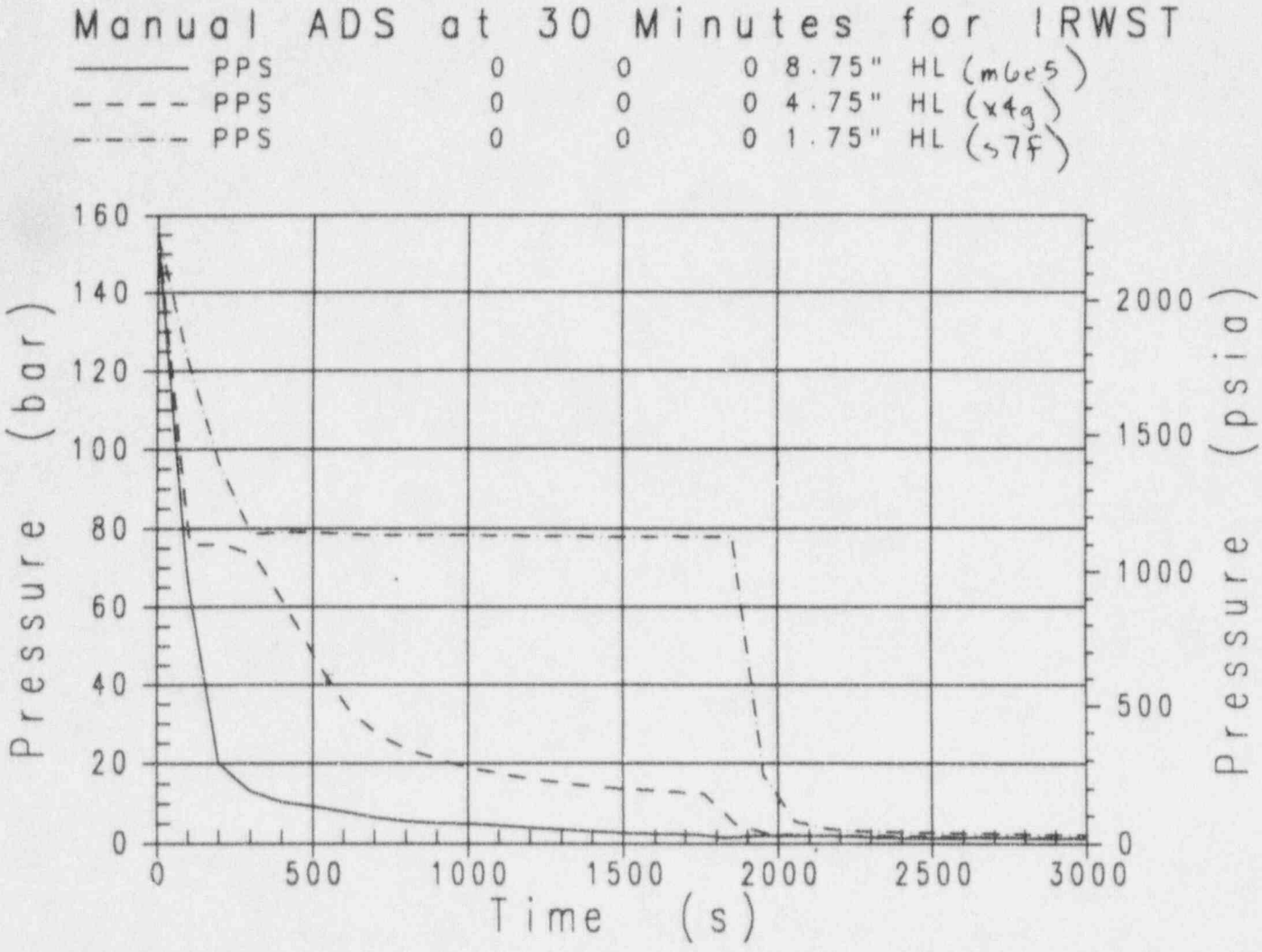
PRELIMINARY

Table A-4.24 MAAP4 Analyses Supporting SGTR Success Criterion ADT			
Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	g7d	Baseline: 2 stage 4 ADS lines - manual op action 30 min after CMT fails SGTR 1 Accumulator Containment Isolation Fails 1 line IRWST	no uncov
ADS Line Assumption	Not Applicable		
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	g7f2	2 Acc	no uncov
Containment Isolation	g7d2	With Containment Isolation	no uncov
Operator Action Time	g7c	op action 15 min after CMT fails	no uncov

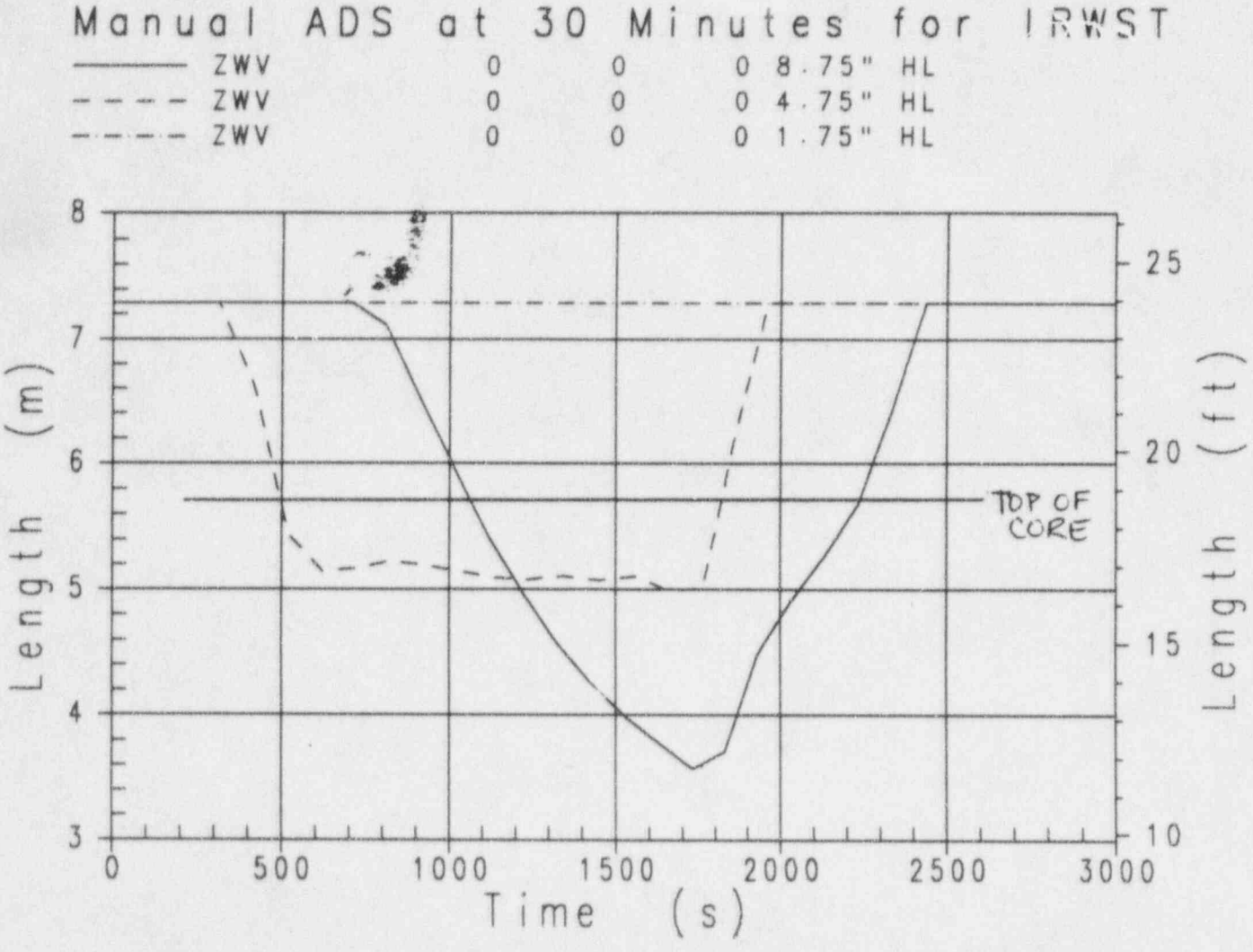
Table A-4.26
MAAP4 Analyses Supporting Transient Success Criterion ADT

Purpose of Case	Case Name	Change From Baseline	Max Core Temp (°F)
Baseline	t9a1	Baseline: 2 stage 4 ADS lines - manual op action 15 min after PRHR fails 1 Accumulator Containment Isolation Fails 1 line IRWST	no uncov
ADS Line Assumption	Not Applicable		
Break Size and Location	Not Applicable		
# of CMTs and Accumulators	t9n	2 Accumulators	no uncov
Containment Isolation	t9o	With Containment Isolation	no uncov
Operator Action Time	t9a2	op action 30 min after PRHR fails	no uncov
	t9p	op action 60 min after PRHR fails	no uncov

PRELIMINARY



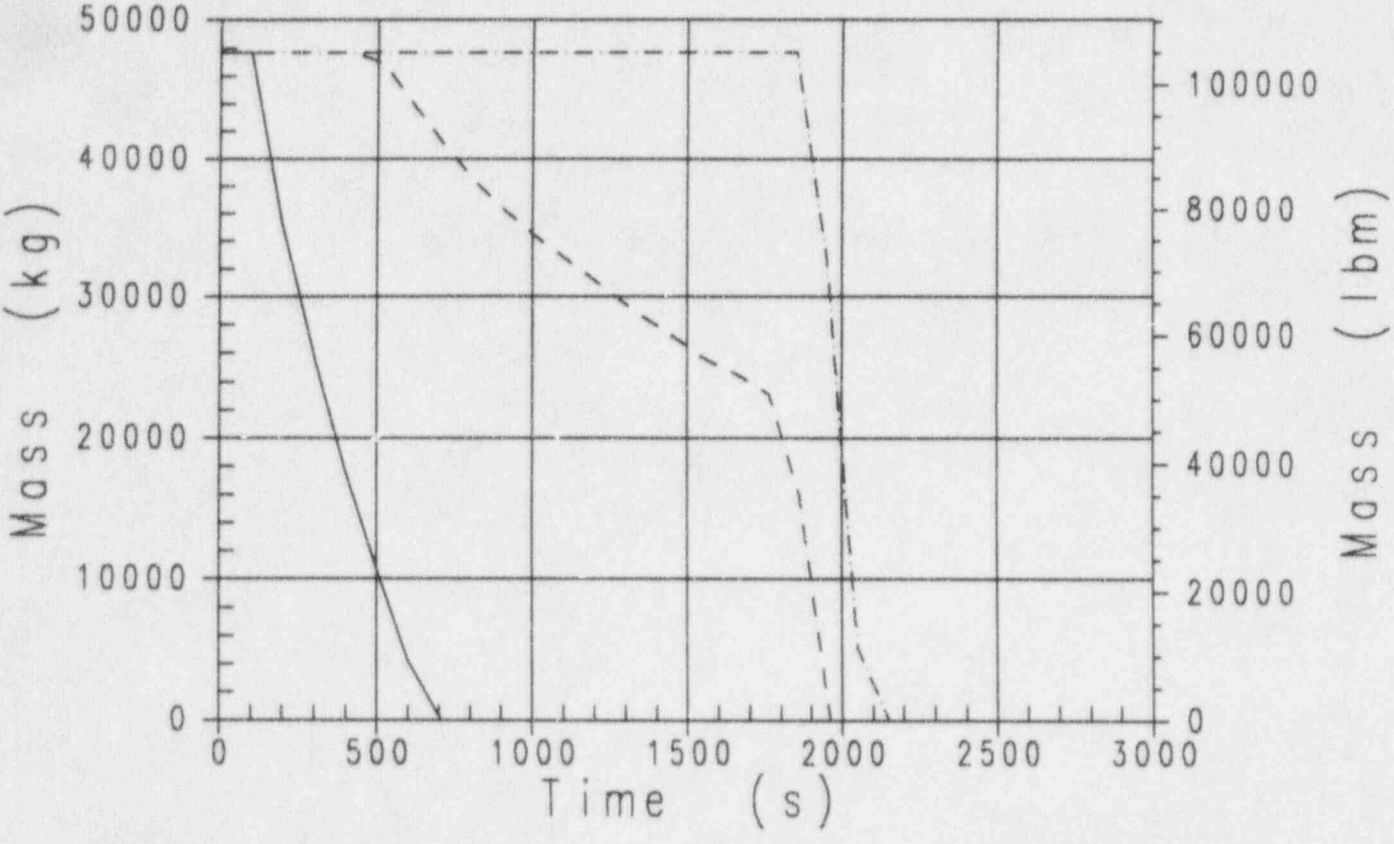
PRELIMINARY



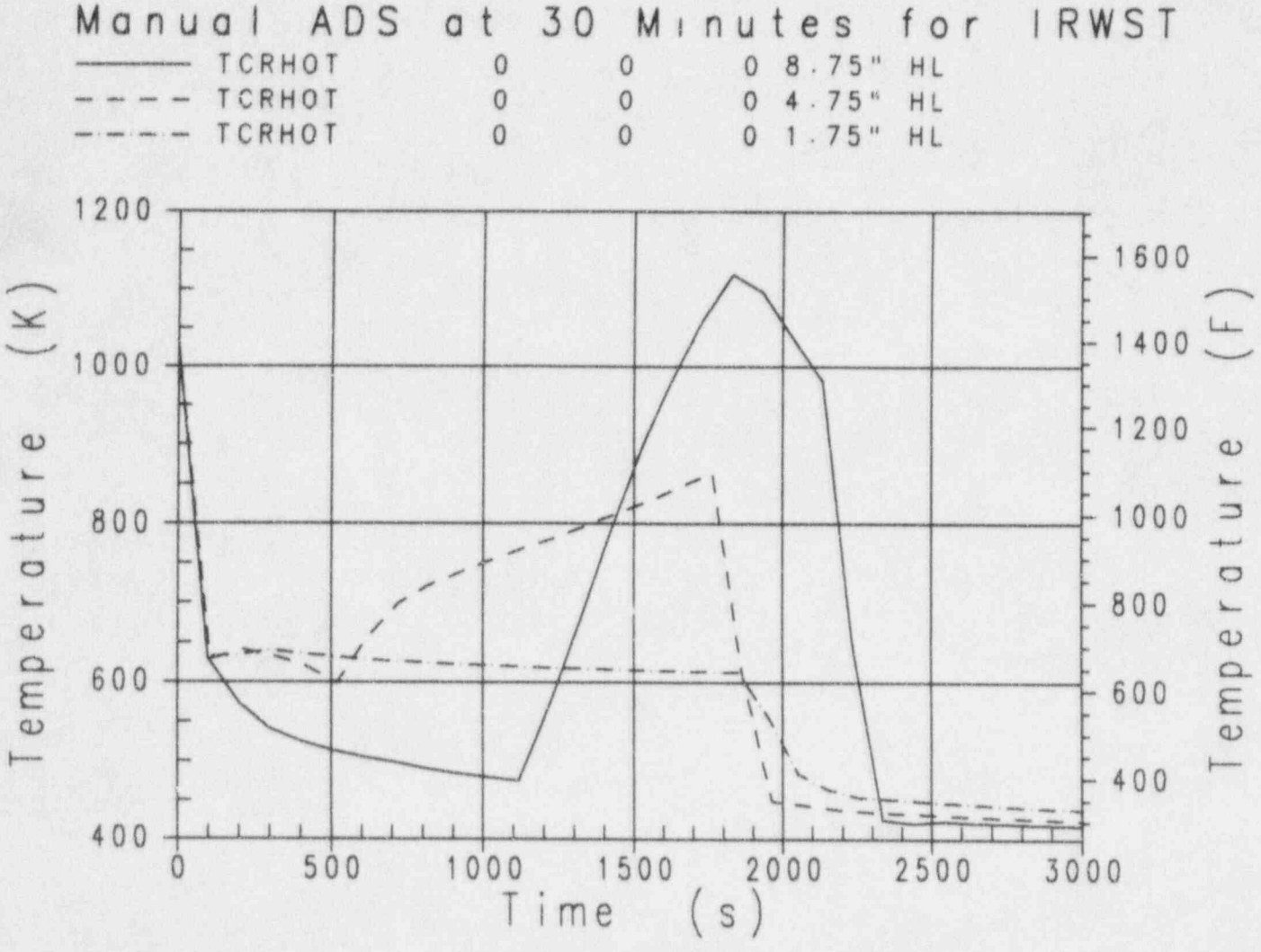
PRELIMINARY

Manual ADS at 30 Minutes for IRWST

———	MACUM	0	0	0 8.75" HL
- - - -	MACUM	0	0	0 4.75" HL
- - - -	MACUM	0	0	0 1.75" HL



PRELIMINARY



PRELIMINARY