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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: T. R. QUAY

SUBJECT: **SUMMARY OF AP600 THERMAL-HYDRAULIC UNCERTAINTY AND MAAP4 BENCHMARKING PLAN AS DISCUSSED AT FEBRUARY 29, 1996 MEETING**

Dear Mr. Quay:

A meeting was held on February 29, 1996 between Westinghouse and NRC staff to discuss the AP600 Thermal-Hydraulic Uncertainty and MAAP4 Benchmarking plan that was submitted by Westinghouse on December 8, 1995 and the staff's response to the plan in a letter dated January 18, 1996. As explained in the Westinghouse December 8 cover letter and at the February meeting, the plan continues to evolve in order to accommodate NRC staff comments presented to us during several meetings and provided in NRC correspondence. At the February 29 meeting, the staff committed to provide feedback to Westinghouse of what was presented at the meeting.

As requested by the staff at the March 19, 1996 Westinghouse/NRC senior management meeting, Westinghouse agreed to provide the staff with a written summary of what was presented at the February 29 meeting. Enclosed please find the Westinghouse summary of the February 29, 1996 Thermal-Hydraulic Uncertainty and MAAP4 Benchmarking meeting. The enclosed material fulfills the action Westinghouse took at the March 19, 1996 senior management meeting.

The staff was informed at both the February 29 and the March 19 meetings, that Westinghouse is currently working on the activities as they were spelled out in February meeting. Feedback from the staff is essential to appropriately expend resources and maintain momentum on the path to resolving this issue.

Westinghouse would like to meet with the staff the week of April 22 to continue discussions on the T-H uncertainty and MAAP4 benchmarking issues. Specifically, we would like to discuss the process Westinghouse is currently pursing to resolving these issues and to discuss key technical issues to be addressed in benchmarking. Prior to this meeting the staff should review the enclosed material. Cindy Haag will contact Mr. Bill Huffman to set up the proposed meeting.

Please contact Cynthia L. Haag on (412) 374-4277 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Enclosure

cc: B. Huffman, NRC
D. Jackson, NRC
N. J. Liparulo, Westinghouse (w/o Enclosure)

Enclosure 1 to Westinghouse
Letter NSD-NRC-96-4691

April 12, 1996

SUMMARY OF AP600 THERMAL-HYDRAULIC UNCERTAINTY AND MAAP4 BENCHMARKING PLAN AS DISCUSSED AT FEBRUARY 29, 1996 MEETING

A meeting was held between Westinghouse and the NRC on February 29, 1996 to discuss the MAAP4 Benchmarking and T&H Uncertainty resolution plans. This document describes the plans as they were described at the meeting, with annotations regarding issues that were discussed or issues that require further discussion.

1.0 BACKGROUND

1.1 Summary of Meetings and Proposed Plans

The mission statement describing the tasks to be accomplished is:

> *To provide a higher level of comfort that AP600 success criteria have been defined "robustly," so that PRA results are not significantly impacted by:*
>
> - *T/H uncertainty in the behavior of the passive systems*
> - *MAAP4's simplified models*

This mission statement was first formulated for the July 27, 1995 meeting, and remains unchanged.

The July 27 meeting described an integrated process by which the MAAP4 benchmarking issue and T/H uncertainty issue would be resolved. The plan identified four accident scenarios that were chosen because they are the only ones in the PRA success criteria with core uncovery. The cases represented a range of break sizes (0.5", 2.0", 4.0" and 8.75"), break locations (hot leg, cold leg, DVI line), CMT or accumulator actuation, and the most important sequence in respect to core damage frequency (CDF). The plan identified that the NOTRUMP analyses would be performed with the DBA-like assumptions, including:

- Appendix K decay heat (1971 ANS +20%)
- 102% Initial Power
- Initial water temperatures at Tech Spec maximums
- ADS minimum valve area
- IRWST line maximum resistances
- Maximum Tech Spec peaking factors

The MAAP4 analysis assumptions would match the NOTRUMP assumptions in the extremely important boundary condition of decay heat and the initial power level. Other MAAP4 analysis assumptions would remain at previously analyzed (usually nominal) conditions. The MAAP4 input changes were limited so that applicability to previous MAAP4 analyses performed for the PRA would be clear.

The July 27 integrated MAAP4 benchmarking and T&H uncertainty plan identified the closure process for each of the issues:

- The T/H uncertainty issue will be closed by showing that NOTRUMP (and LOCTA) calculation of PCT meets the 2200°F criterion for all four cases.

- The MAAP4 benchmarking effort consists of comparing system responses from the NOTRUMP and MAAP4 analyses. All differences in the following system responses will be investigated and explained:

  - RCS Pressure
  - Break Flowrate
  - CMT Flowrate
  - CMT Level
  - Accumulator Flowrate
  - IRWST Flowrate
  - RCS Inventory Mass
  - Core Mixture Level
  - Peak Clad Temperature
  - ADS Flowrate

NRC comments on the July 27 plan were expressed in a letter dated August 14, 1995 and in meetings held between Westinghouse and the NRC in August, September and October. The major comments were:

- The NRC cannot concur on the sufficiency of the number of cases or the selection of cases without the identification of the important phenomena.

- Westinghouse needs to provide basis for why MAAP4 is good enough to have chosen the most limiting cases.

- PRA sensitivities that support the resolution of T&H uncertainty need to consider the focused PRA rather than the baseline PRA.

- Comparison of MAAP4 and NOTRUMP should be done with exactly the same set of analysis assumptions.

- MAAP4 needs to be compared to data from tests.

On December 8, 1995, Westinghouse submitted a written plan to the NRC for the resolution of MAAP4 benchmarking and T/H uncertainty issues. The plan was based on the July 27 presentation, with modifications to incorporate NRC comments to date. The major differences in the December 8 plan from the July 27 plan were:

1) Key models for the PRA scenarios were defined. The definition of key models was done in a table that includes the reason of importance, potential reasons for concerns, and the parameters that will be used to confirm the key models. In addition, the plan described three types of core uncovery that occur in the PRA scenarios. Many of the key models were discussed in context of how they are important for these types of cases.

2) The cases for comparison were modified. This was done to better exhibit the key models.

3) An OSU assessment was added.

4) A final set of success criteria analyses will be done, based on the benchmarked parameter file and the final AP600 design.

5) The pathway for T&H uncertainty resolution changed. In the July 27 plan, there were three curves that would be compared for each parameter:

    - Nominal MAAP4 run
    - MAAP4 + Higher Decay Heat run
    - DBA-like NOTRUMP run

    In the December 8 plan, the curves would be:

    - Nominal MAAP4 run
    - Nominal NOTRUMP run
    - Sensitivities that encompass the DBA-like assumptions from the July plan (performed with MAAP4 and LOCTA)

The T&H uncertainty resolution process is one that requires further discussion between Westinghouse and the NRC. The NRC has stated a number of different concerns that sometimes appear to Westinghouse to be contradictory in nature. On one hand the July 27 plan was "approved," yet the caveats to that approval seem major. There is more discussion within this document on the T&H uncertainty resolution plan, but this issue remains one that is in need of clarification of NRC concerns. Comments on this subject that were transmitted in August 1995 and January 1996 include:

- "Westinghouse has assumed that ... Appendix K inputs provide sufficient margin to bound the effects of passive system thermal hydraulic uncertainties on the PRA success criteria.... Westinghouse must justify why the use of Appendix K inputs and models is sufficient to bound the thermal hydraulic uncertainties for all AP600 PRA sequences." (August 14, 1995)

- "In an August 14, 1995, letter from the NRC to Westinghouse, the staff approved the Westinghouse bounding approach provided five concerns could be satisfied. The plan approval received high level review and concurrence within the NRC." (January 18, 1996)

- "Since passive systems rely on natural forces such as gravity and stored energy to perform their functions, the net driving forces are small compared to active systems and are subject to large uncertainties - especially when considering multiple system failure scenarios contained in the PRA." (Jan 18)

- "The MAAP4 sensitivity study of the few parameters indicated in the report, including the sensitivity study using LOCTA to show the effect of varying the core peaking factors, appear to be too limited in scope, and do not necessarily cover the T/H uncertainty." (Jan. 18)

    - Core peaking factors
    - Minimum and maximum accumulator flowrate
    - Minimum and maximum IRWST flowrate
    - Maximum ADS flowrate
    - 1971 ANS + 20% Decay Heat

1.2 Major Issues

Based on the preceding history of plans, meetings and NRC comments, there are three areas of discussion on which to focus.

- Need more than four MAAP4 benchmarking cases.

- T&H uncertainty issues cannot be resolved solely with MAAP4.

- December 8 proposed OSU assessment is not acceptable.

1.3 PRA, Success Criteria, and MAAP4 Analyses

Because the mission of this work is to focus on the PRA impact, the scope must be viewed in context of the PRA purpose. The purpose of a PRA is to quantify the core-damage frequency (CDF) and large-release frequency (LRF), while gaining insights into any risk-significant vulnerabilities of the plant. One of the elements in performing a PRA is to define success criteria, which refer to a minimum set of equipment needed to prevent core damage.

Safety analyses performed for Chapter 15 of the SAR are done in a conservative manner to justify the safety of the plant design. The resulting accident analyses can sometimes deviate from reality, due to the conservatisms that are stacked upon one another. For the PRA, definitions of success criteria are done considering the nominal performance of the plant. Conservatism in success criteria (requiring more equipment) can potentially mask risk-significant insights in the plant. Overly conservative success criteria are not desirable when trying to gain PRA insights.

There is a need for additional discussion on this topic between Westinghouse and the NRC. Westinghouse believes that understanding the role of PRA will be fundamental to resolution of the outstanding issues.

The MAAP4 code enters the picture because it was used to support some of the AP600 success criteria definitions. Accident scenarios that require ADS actuation as part of the successful sequence of events were considered in MAAP4 analyses. Scenarios were grouped, and "baseline" cases were defined as the most limiting cases for a range of accidents. The baseline cases include the most restrictive set of hardware assumptions and the most restrictive break location and size.

Appendix A of the PRA documents MAAP4 analyses that support the ADS success criteria. This documentation was submitted to the NRC in January of 1995. Since then, the AP600 success criteria definitions have continued to evolve. Through work being performed within Westinghouse, and discussions with the NRC, issues have been raised that have caused the success criteria to be 1) more conservative (more equipment is required), 2) simpler, because the same equipment is required across a broad spectrum of events, and 3) there is more T&H margin. In addition, success sequences with PRHR are not based on MAAP4 analyses.

Because of the ADS success criteria evolution described above, there are now two basic accident scenarios.

Automatic ADS	Manual ADS
- Initiating Event	- Initiating Event
- No startup feedwater	- No startup feedwater
- No PRHR	- No PRHR
- **No accumulators**	- **1 accumulator**
- **1 CMT**	- **No CMTs**
- 2 stage 4 ADS **(on lo-lo CMT level)**	- 2 stage 4 ADS **(operator action)**
- 1 IRWST line	- 1 IRWST line
- Containment isolation failure	- Containment isolation failure

Both scenarios involve a complete loss of heat removal capability except for the break and ADS. These accident scenarios have been studied for a range of break sizes and initiating events. The minimum RCS inventory over a spectrum of break sizes is shown in Figure 1 from the automatic ADS cases. Observations from studying the automatic ADS cases are:

- The CMT is an effective safety feature of the AP600 plant.
  - 1 CMT contains a large amount of water that is able to provide make-up for the Transients and LOCAs of interest.
  - The CMT level setpoints have been defined to provide ADS actuation in time to get IRWST gravity injection to cool the core, even without credit for accumulator injection.
- CMTs have a recirculation and a draining phase of injection.
  - Recirculation of the CMTs occurs for a longer period of time in the smaller breaks.
- Most cases do not experience core uncovery.
- Core uncovery can occur in Transients and Small LOCAs.
  - The depth and duration of core uncovery are limited.
  - Maximum uncovery of 30% for 500 seconds.
- Core uncovery occurs at the small end of the NLOCA spectrum.
  - The depth and duration of core uncovery are limited.
  - Maximum uncovery of 10% for 100 seconds.

The minimum RCS inventory over a spectrum of break sizes is shown in Figure 2 from the manual ADS cases. Figure 3 also summarizes plant behavior for this accident scenario over a range of break sizes. Figure 3 illustrates the time that core uncovery starts, the time the accumulator injection starts and depletes, and how the interplay of these items changes over the break spectrum. Although operator action time is not explicitly shown, Figure 3 allows one to obtain information of when operator action would be needed to prevent core uncovery. Observations from these cases are:

- Because there is no CMT, the response of the plant is dependent on the depressurization due to the break and operator action time to actuate ADS.

- Transients and SLOCAs are slow-acting, and have small to no inventory loss before the operator action is anticipated.

- For NLOCAs, the core uncovers before accumulators can inject.

  - RCS pressure decreases after core uncovery, allowing accumulator injection

  - Accumulator injection is relatively slow

  - Accumulator injection limits the depth of uncovery

  - Duration of core uncovery is a function of operator action time

- For MLOCAs, the accumulators inject and empty before the core uncovers.

  - Depth and duration of core uncovery is a function of operator action time

  - Hot leg break location is a significant factor at the largest breaks

2.0 MAAP4 BENCHMARKING

There is a need to benchmark MAAP4 to provide a higher level of comfort that the success criteria in the PRA are valid.

2.1 Purpose

The purpose of MAAP4 benchmarking is to support the baseline PRA success criteria. The benchmarking of MAAP4 will be done against NOTRUMP analysis results, performed with nominal assumptions. The benchmarking will focus on MAAP4's ability to track inventory losses and gains, and to predict the system depressurization. The goal of the benchmarking is to demonstrate an understanding of the behavior of the AP600 plant:

- as break size changes,
- as break location changes, and
- as another tank (CMT or accumulator) is credited.

As discussed in the February 29, 1996 meeting, the MAAP4 benchmarking is not just an exercise of comparing codes, but it is to demonstrate the AP600 plant response to different accident scenarios.

2.2 Key Models

Before benchmarking cases can be defined, the key behaviors of interest must be identified. Based on the plant response discussed in Section 1.3, a set of key models were defined. These key models are from the December 8, 1995 proposed plan, and are listed in Table 1.

Table 1 also identifies the parameters of interest that will be used to compare the system response as predicted by MAAP4 and NOTRUMP. Differences in the responses will be investigated and explained. Within this effort, there is no plan to tune MAAP4. Identical responses are not expected nor necessary to support MAAP4 as a scoping tool for PRA. However, if a MAAP4 parameter is changed, it will be done in a systematic manner that either changes the value for all cases, or is based on phenomena that are specific to a set of cases.

The applicability of NOTRUMP to the PRA scenarios is an outstanding issue to be discussed later.

2.3 Benchmarking Cases

The benchmarking cases are chosen to cover the key models listed in Section 2.2, to address the system behavior illustrated in Section 1.1, and to cover a spectrum of conditions. The cases that were identified in the February 29, 1996 meeting are:

Automatic ADS Actuation

0.5" hot leg break
2.0" hot leg break
5.0" hot leg break
8.75" hot leg break
0.5" hot leg break with 1 CMT, 1 Accumulator
2.0" hot leg break with 2 CMTs
2.0" hot leg break with delayed ADS

Manual ADS Actuation

3.0" hot leg break
6.0" hot leg break
8.75" hot leg break
8.75" cold leg break
DVI line break

An additional issue that was raised at the February meeting is to address whether the inventory loss from more ADS valves could outweigh the benefit of the faster depressurization that is achieved. A benchmarking case will be added to address this issue. Westinghouse is proceeding with the benchmarking of these cases. NRC comments on the adequacy of these cases are needed immediately.

2.4 Comparison to Test Data

The NRC August 14, 1995 letter stated that MAAP4 comparison to test data should be performed. Westinghouse has expressed concerns about the value added. The concerns include:

- Establishing values for MAAP4 OSU parameter file would not show validity of MAAP4 AP600 parameter file.
- OSU "PRA" test scenarios are counted as failure in the PRA.
- Although two OSU tests experience core uncovery, they do not necessarily exercise the phenomena that are of interest.
- Data from "PRA" test scenarios were not documented in the OSU Test Analysis Report.

Nevertheless, in the December 8, 1995 plan, Westinghouse proposed an "OSU assessment" to compare MAAP4 AP600 results with OSU test data. The OSU assessment would focus on a few parameters (primarily mass flow rate predictions) and would provide a <u>higher level of comfort</u> that MAAP4 predicts similar trends. Westinghouse had performed a blind feasibility study prior to the proposal of the OSU assessment, and Figure 4 shows a sampling of some of the results. The MAAP4 data is scaled from a full-scale AP600 analysis that is run for the same accident scenario (equipment failures) modelled in the OSU test.

In the January 18, 1996 NRC comments, the proposed "OSU assessment" was rejected due to:

- Distortions in loop response due to the reduced size of the test facility.
- Appropriate scaling ratios change as a function of time.
- Response of OSU fuel rod simulators does not represent AP600 fuel rods.
- Initial conditions cannot be scaled.
- Test scenarios should not be expected to provide global coverage of phenomena that might be encountered in the multiple failure PRA sequences.

Westinghouse is no longer planning to do a comparison between MAAP4 and test data because it is not expected to improve the understanding of plant response for the PRA scenarios.

3.0 T&H UNCERTAINTY

The resolution of T&H uncertainty issues needs to be performed as a separate effort, after MAAP4 benchmarking is completed. The plan that is proposed in this section establishes a structure for the resolution, more discussion between Westinghouse and the NRC is needed. NRC T&H uncertainty concerns need to be clarified.

3.1 Purpose

The purpose of the T&H uncertainty resolution plan is to determine whether uncertainty in the T&H performance of passive systems has an acceptable impact on the focused PRA. There are two major components to the plan:

1) PRA sensitivity to the focused PRA to determine if there are risk-significant, low-margin accident scenarios.

2) T&H analyses to examine risk-significant, low-margin accident scenarios.

3.2 PRA Sensitivity

The purpose of an AP600 PRA sensitivity is to determine if the low-margin accident scenarios are risk-significant to the focused PRA. Applicable event tree paths will be evaluated to further define the frequency of the low-margin scenarios

- Number of CMTs and accumulators
- Break size
- Break location
- Operator action time
- Credit for additional operator actions not considered

Determine if focused PRA CDF and LRF goals can be met if low-margin sub-sequences are counted as failure. From this sensitivity, determine if the low-margin sequences are risk significant

3.3 T&H Analyses Supporting T&H Uncertainty

If there are risk-significant, low-margin sequences, further T&H analyses will be performed with NOTRUMP. The NOTRUMP analyses will consider the uncertainty associated with the small net driving forces of passive systems. Further details of the NOTRUMP analyses can only be discussed after it is known which accident scenario will be examined.

4.0 SUMMARY

- The MAAP4 benchmarking and T&H uncertainty issues continue to evolve as Westinghouse and the NRC exchange ideas.
- The MAAP4 benchmarking plan has been separated from T&H uncertainty resolution.
- The MAAP4 benchmarking plan is a comprehensive set of cases for comparison to NOTRUMP.
- The framework for T&H uncertainty resolution is established; the details will require further discussion.

Figure 1

Automatic ADS

1 CMT, 2 Stage 4 ADS

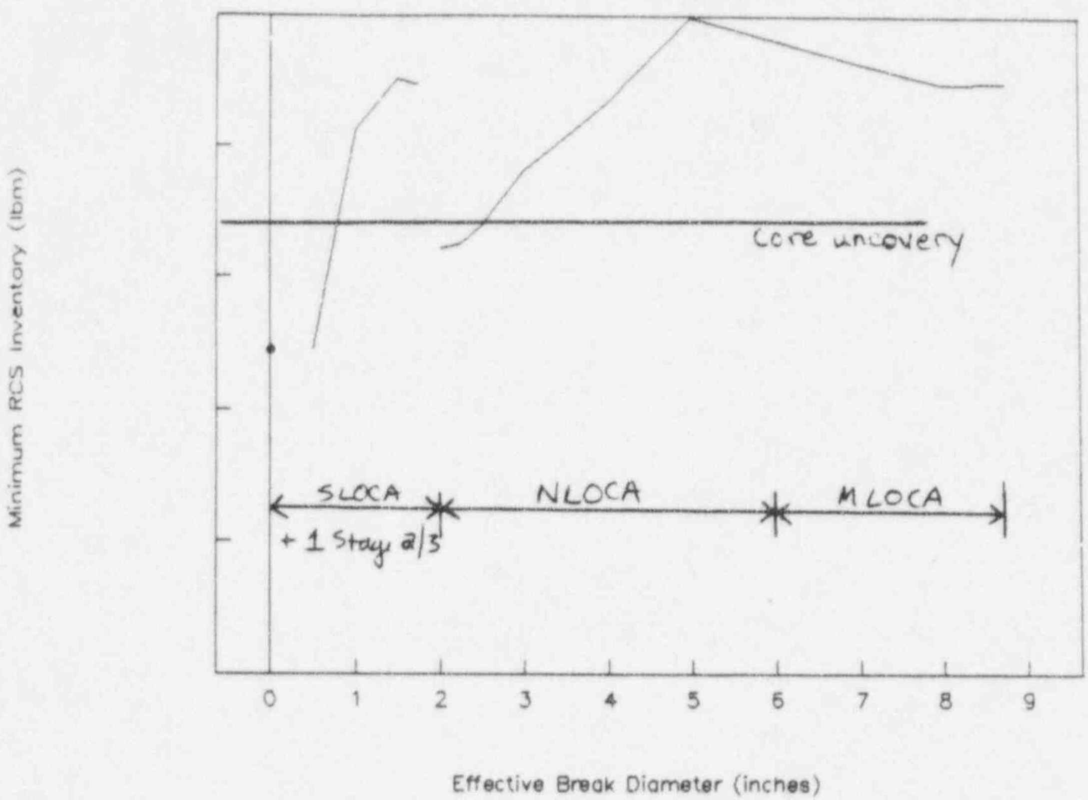
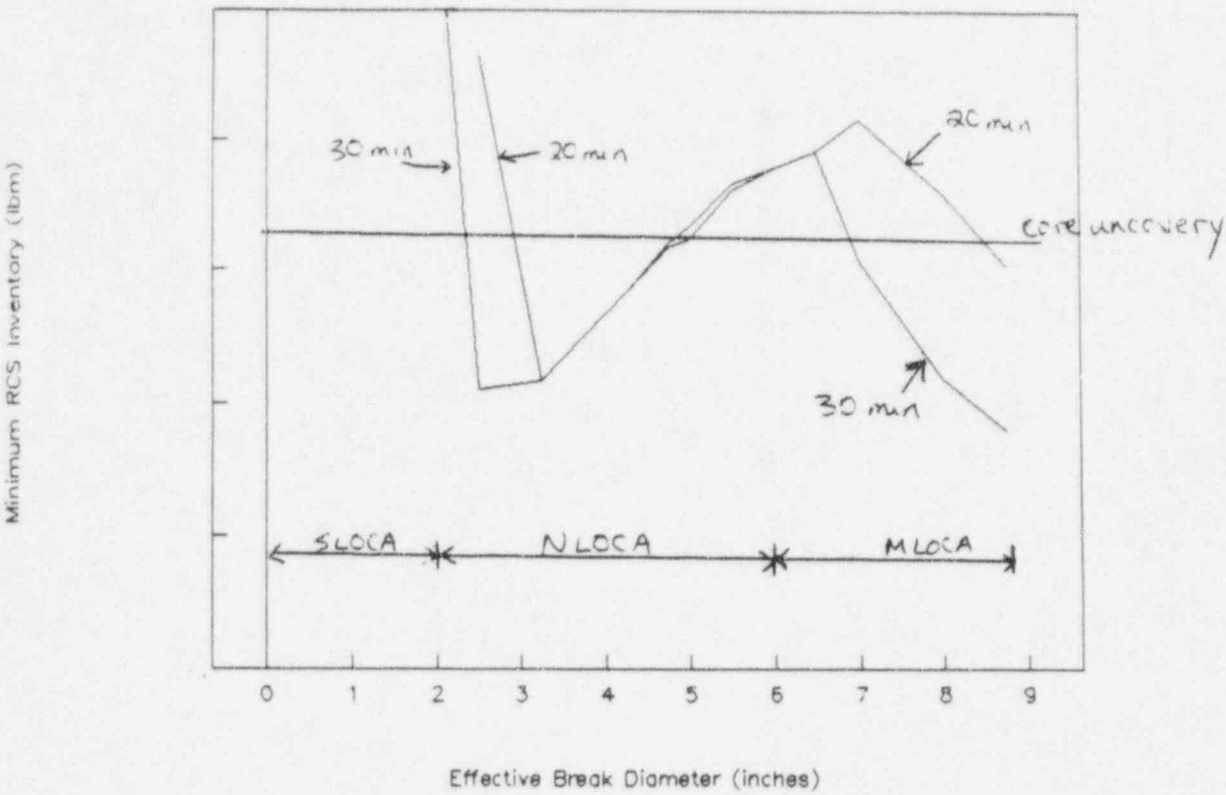


Figure 2

Manual ADS

1 Accumulator, 2 Stage 4 ADS



20 min and 30 min refers to operator action time to open ADS

Figure 3

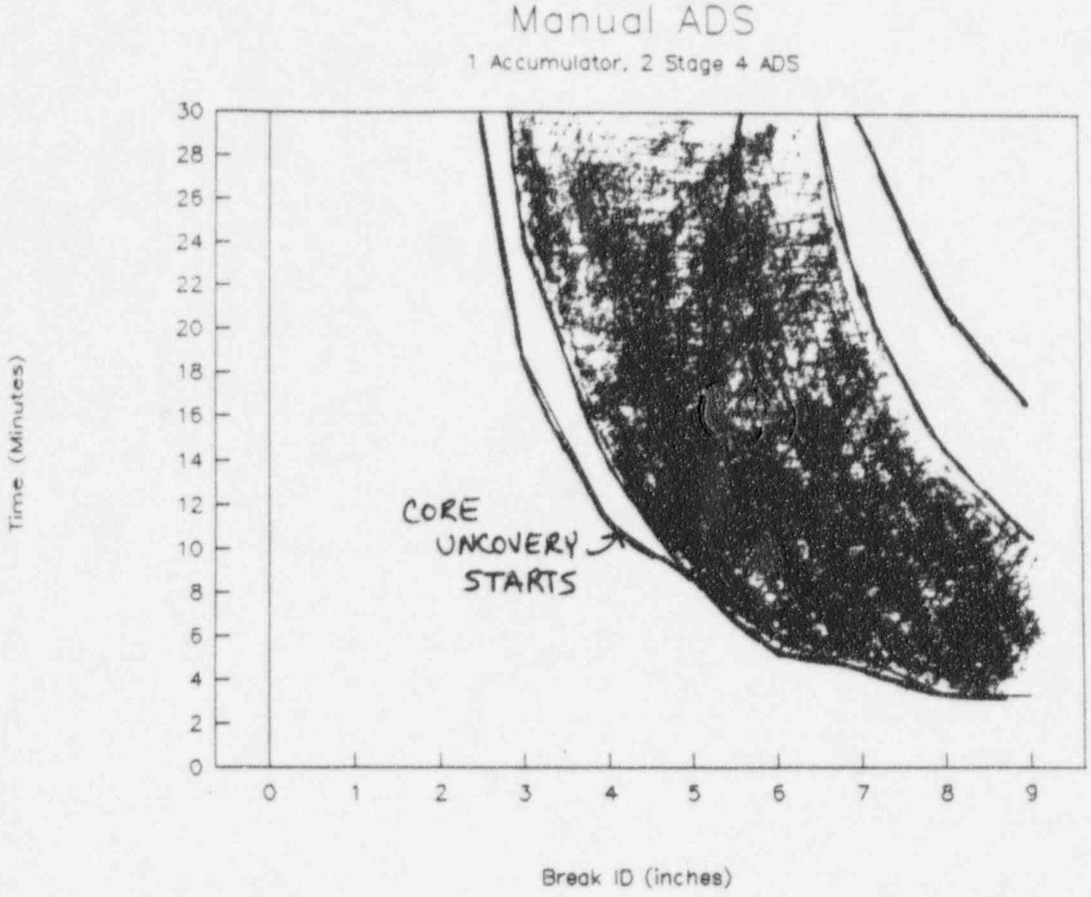

Manual ADS
1 Accumulator, 2 Stage 4 ADS
Time (Minutes)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
Break ID (inches)
CORE UNCOVERY STARTS

Figure 4

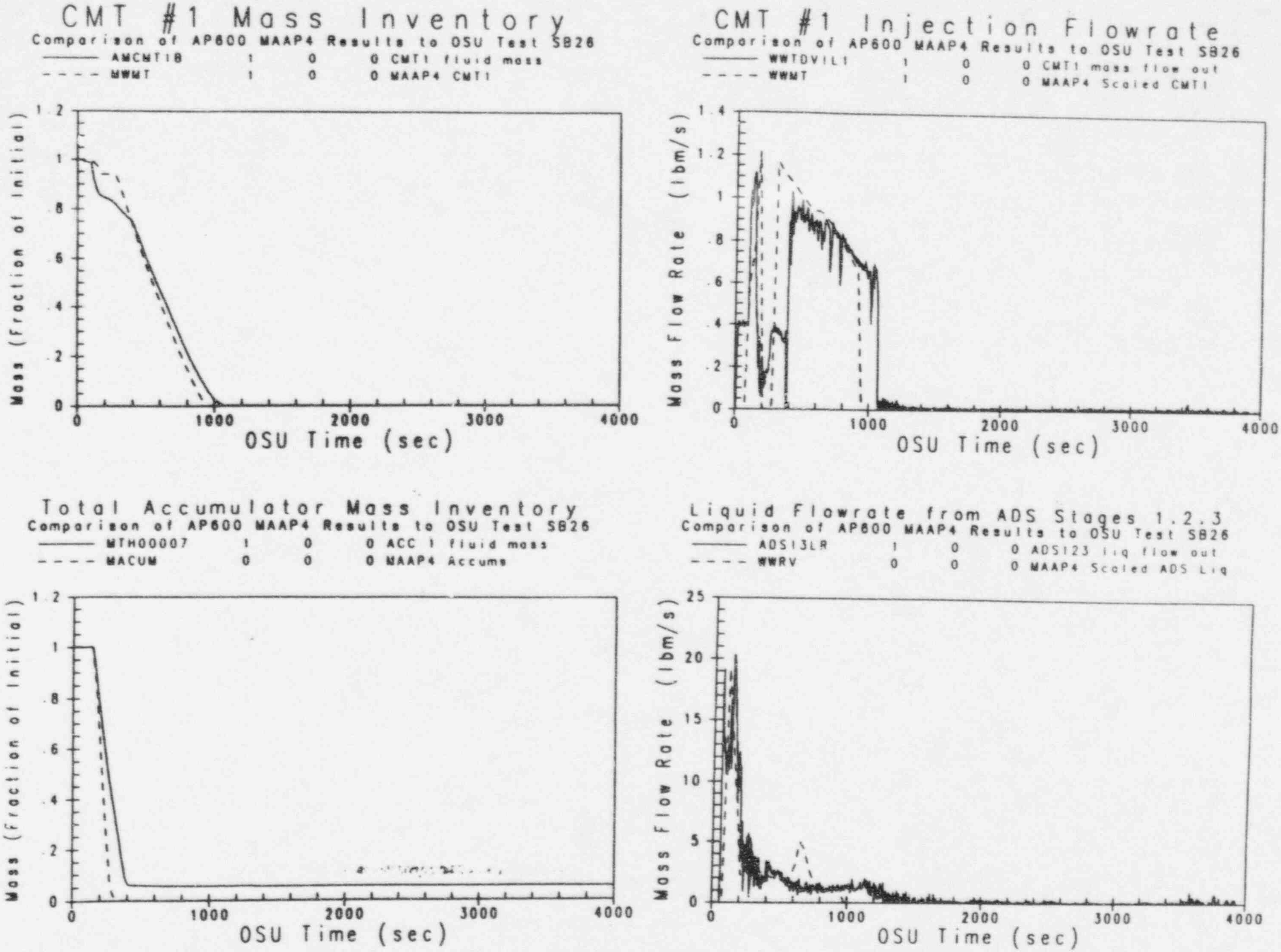

CMT #1 Mass Inventory
Comparison of AP600 MAAP4 Results to OSU Test SB26
AMCMT1B 1 0 0 CMT1 fluid mass
WWMT 1 0 0 MAAP4 CMT1
Mass (Fraction of Initial)
OSU Time (sec)
CMT #1 Injection Flowrate
Comparison of AP600 MAAP4 Results to OSU Test SB26
WWTDVIL1 1 0 0 CMT1 mass flow out
WWMT 1 0 0 MAAP4 Scaled CMT1
Mass Flow Rate (lbm/s)
OSU Time (sec)
Total Accumulator Mass Inventory
Comparison of AP600 MAAP4 Results to OSU Test SB26
MTH00007 1 0 0 ACC 1 fluid mass
MACUM 0 0 0 MAAP4 Accums
Mass (Fraction of Initial)
OSU Time (sec)
Liquid Flowrate from ADS Stages 1,2,3
Comparison of AP600 MAAP4 Results to OSU Test SB26
ADS13LR 1 0 0 ADS123 liq flow out
WWRV 0 0 0 MAAP4 Scaled ADS Liq
Mass Flow Rate (lbm/s)
OSU Time (sec)

Table 1 Key MAAP4 Models Used in Success Criteria Analysis		
Model	Importance Concerns	Parameters of Interest
Core Uncovery and Heatup	• The peak core temperature is used to determine whether a sequence is defined as "success" or "damage." • MAAP4's core model does not simulate the hot pin, therefore MAAP4's peak temperature prediction needs to be compared to a more detailed model. • Approximately half of the success criteria analyses result in partial core uncovery. They are primarily manual ADS scenarios that rely on operator action.	• Core mixture level • Peak core temperature • Decay heat
ADS Stage 4	• Credited in full depressurization cases to depressurize the RCS so that IRWST gravity injection can occur. 2 out of 4 stage 4 ADS lines is the success criterion for all full depressurization cases.	• ADS liquid flow rate • ADS vapor flow rate • RCS pressure
CMT	• CMT provides cooling and inventory make-up for LOCAs • CMT level determines the time of ADS actuation	• CMT injection flow rate • CMT recirculation flow rate • CMT level • Time CMT recirculation transitions to CMT injection • Time CMT low level setpoints are reached
IRWST Injection	• IRWST injection is the mechanism for long-term cooling in the full depressurization cases • IRWST injection recovers the core, or keeps the core from uncovering • IRWST injection is sensitive to the ΔP between containment and the RCS.	• IRWST injection flow rate • RCS pressure • Containment pressure • Core mixture level
Break	• Inventory loss through the break determines whether core is covered • System depressurization defines break size ranges for LOCA categories • Location of break at bottom of hot leg was a major consideration in defining success criteria, particularly for larger breaks	• Liquid break flow rate • Vapor break flow rate • RCS water inventory • RCS pressure

RCS Natural Circulation	• MAAP4's VPSEP model can have an impact on:
	  - whether the break location is covered with water
	  - the end of CMT recirculation and the start of CMT injection
		• Liquid break flow rate
		• Vapor break flow rate
		• Time CMT recirculation transitions to CMT injection

Accumulator (1)	• The accumulator injection prevents core uncovery for larger (> 6") breaks. • The accumulator injection plays a role in limiting the PCT for breaks around 3" to 5" • The accumulator and CMT share the DVI line, and interaction between the tanks must be considered. • The MAAP4 accumulator model is isothermal.	• Accumulator injection flow rate • Core mixture level • RCS pressure

Table 1 Key MAAP4 Models Used in Success Criteria Analysis		
Model	Importance / Concerns	Parameters of Interest
ADS Stage 1 - 3 (2)	• For high pressure scenarios, credited to reduce pressure so that stage 4 ADS can open • Credited in partial depressurization cases to depressurize the RCS below RNS shutoff head. • Location is at top of pressurizer, and entrainment of water into pressurizer could affect depressurization capability	• ADS liquid flow rate • ADS vapor flow rate • Pressurizer inventory • RCS pressure
SG Heat Transfer	• Heat transfer to SGs plays a role in Transients and SLOCAs; RCS inventory loss starts or increases when SGs dry out	• SG heat transfer
PRHR	• ADS success criteria with the PRHR operable are not directly supported by MAAP4 analyses.	Not Applicable

Notes:

(1) Interaction between accumulator and CMT will not be shown in MAAP4 / NOTRUMP comparison. The MAAP4 / OSU assessment will address this issue.

(2) The MAAP4 / NOTRUMP comparison will only examine ADS Stage 1 - 3 as a precursor to ADS Stage 4. The behavior of ADS 1 -3, by itself, can be seen through the MAAP4 / OSU assessment.