APPENDIX A

MAAP4 ANALYSIS TO SUPPORT SUCCESS CRITERIA

A.1 Introduction

The success criteria that define the event tree paths that do not result in core damage have been identified and discussed in Chapter 6. Supporting analyses for the success criteria and success paths can sometimes be found within the licensing basis analyses in the *Standard Safety Analysis Report* (SSAR). However, when there are multiple system failures, other analyses are necessary to support the success criteria definitions. Most of the success paths involve multiple failures and include the actuation of the automatic depressurization system (ADS). The additional system analyses are performed with the Modular Accident Analysis Program, version 4.0 (MAAP4) and are described in the following subsections.

A.1.1 MAAP4 Overview and Limitations

MAAP4 is a computer code that simulates the response of light water reactor systems to initiating events. It was originally developed to investigate the physical phenomena that may occur in the event of a severe accident after significant core damage. Although the emphasis in the code development has been on the severe fuel damage phase of the accident, the code can also be used to predict the thermal-hydraulic behavior prior to core damage.

MAAP4 is a fully integrated, systems accident code and includes models for important thermal-hydraulic and fission-product phenomena which may occur during a postulated accident in a pressurized water reactor plant. The models in MAAP4 relevant to success criteria are the following:

- Reactor coolant system thermal-hydraulics
- Cladding water reaction
- Reactor core heatup
- Containment thermal-hydraulics

The version of MAAP4 used for these analyses is documented in Reference A-1, which provides details of the code models, the benchmarking performed, and users guidance. MAAP4 has improved capability, compared to MAAP3B, to model the following in-vessel and advanced reactor systems:

- Detailed core model nodalization includes the fuel, clad, control rod and coolant. Up to 175 nodes can be modelled; the AP600 model has 85 nodes, with 5 radial rings and 17 axial rows.

- Improved pressurizer and surge line thermodynamic calculations for modeling the large valves used in the automatic depressurization system

- Generalized containment model
- Passive safety system models, including passive residual heat removal (PRHR) heat exchanger, core makeup tanks (CMTs), and passive containment cooling system (PCS)

MAAP4 was chosen as the code to support the success criteria because of its flexibility and ease of use. MAAP4 integrates the effects from the primary system, the secondary system, and the containment. The code is fast-running, making it feasible to analyze a large number of scenarios, variations of the scenarios, and sensitivities. The flexibility of the code includes the capability to model a wide range of initiating events and the capability to model operator intervention based on times or "trigger" events.

When applied to pre-core damage success criteria analyses, MAAP4 has limitations due to the model simplifications that make MAAP4 a fast-running code. The model simplifications have been considered in the analyses and are discussed below.

Core Power

The core power in MAAP4 is based on the full power input value before the reactor trips, and 1979 ANS decay heat after the reactor trips. The MAAP4 core power model is an adequate best estimate prediction of the core heat for the majority of the accident scenarios.

MAAP4 does not have a neutronics model and, therefore, cannot be used to determine the short-term reactivity transients or the potential for return to power after reactor trip that can be a concern for transients. Therefore, MAAP4 is only used for the longer thermal-hydraulic system response in transients, and is not used for anticipated transient without scram (ATWS) events.

For loss-of-coolant-accident (LOCA) initiating events, the plant remains at steady-state full power conditions until sufficient coolant inventory is lost through the break to cause the reactor to trip on a low pressurizer level or low pressurizer pressure signal. Since any make-up flow to the reactor coolant system (RCS) is borated, there are no power excursion concerns for loss-of-coolant accidents. For most loss-of-coolant accidents, the reactor trips within the first minutes of the accident and the core power model is based on decay heat. However, for small breaks in the reactor coolant system, the reactor can remain at full power on the order of 10 minutes until a reactor trip signal is reached. The absence of a neutronics model in MAAP4 is not a concern because power excursions are not a part of the expected plant response for the cases modelled with MAAP4.

Core Heat Transfer

There are also limitations for loss-of-coolant accident events, if the break is large and depletes the reactor coolant system inventory rapidly. MAAP4 can not handle the possibility of exceeding the critical heat flux during the blowdown, nor can it handle reflood while considerable stored heat remains within the fuel. If core uncovery occurs after the initial stored energy in the core has been removed, and the core heat is down to decay heat levels, the code simplifications do not significantly impact the results (Reference A-2). Therefore,

for "smaller" break sizes that do not involve a competition between reflood and clad heat-up rates, MAAP4 calculations are good at predicting the system response. As a result, the code is not used to analyze large loss-of-coolant accidents.

Two-Phase Flow Model

To maintain MAAP4 as a relatively small, fast-running code, the treatment of two-phase (water and steam) natural circulation in the primary system has been simplified. A thorough model would include the detailed treatment of void fraction distribution, a non-equal velocity model, and detailed pressure distribution through the reactor coolant system. Instead, a much simpler model was adopted for MAAP4, in which the primary system is assumed to have a spatially constant, homogeneous void fraction until phase separation occurs.

When the reactor coolant pumps (RCPs) are running, the voids are assumed to be uniformly distributed throughout the reactor coolant system. When the reactor coolant pumps are tripped, the MAAP4 model includes two options; natural circulation may be assumed, with the voids uniformly distributed; or the phases may be assumed to instantly separate into a stable gas-over-water configuration. The determination of which assumption is made is controlled by a user input, VFSEP. If the average void fraction is smaller than VFSEP, natural circulation is assumed, while the gas-over-water assumption occurs if the void fraction is greater than VFSEP.

Prior to phase separation, the homogeneous natural circulation model may not accurately predict the details of the internal situation in the reactor coolant system. T&H benchmarking of MAAP3B (Reference A-2) found little sensitivity to the value of VFSEP. However, sensitivity analyses on the value of VFSEP are performed in Section A.8.

Break Flow Model

The break flow rate in MAAP4 is determined by considering the pressure difference across the break, the fluid properties, and the void fraction entering the break. When the break location is totally submerged, the void fraction is based on the reactor coolant system void fraction. When the break location is partially submerged, the MAAP4 model considers the entrainment of the liquid into the overlying gas. The entrainment model is limited to only considering the entrainment of liquid that is contained within the break node. Therefore, the MAAP4 break model is not sufficient to address large breaks in the reactor coolant system in which the entrainment of water would extend beyond the immediate break location. As a result, the code is not used to analyze large loss-of-coolant accidents.

A.1.2 MAAP4 Model for AP600

The AP600 MAAP4 model is defined in a parameter file and an input deck. The parameter file contains the majority of the AP600 model, while the input deck is used to model the event-specific parameters. In addition, the input deck can be used to supersede any input in the parameter file, so that sensitivity studies can easily be performed. The purpose of this

section is to identify the general assumptions and models that are consistent in all of the analyses to support the success criteria.

The AP600 systems for core heat removal and reactor coolant system coolant inventory replacement that are modelled in MAAP4 are the steam generators, the passive residual heat removal, the core makeup tanks, the accumulators, gravity draining of the in-containment refueling water storage tank (IRWST), and the normal residual heat removal system (RNS). The steam generators and accumulators are a part of the MAAP4 model for conventional plants. The core makeup tank, passive residual heat removal and in-containment refueling water storage tank models were added to the general version of MAAP4 specifically for AP600. The normal residual heat removal model was added to the MAAP4 parameter file by defining low-pressure injection pumps drawing suction from the in-containment refueling water storage tank. The normal residual heat removal model does not take credit for any heat exchanger, which is a reasonable assumption for the limited time frame considered in these analyses. Startup feedwater and CVS are heat removal and inventory makeup sources that are not generally credited in the MAAP4 analyses.

All success criteria analyses with MAAP4 are terminated after a long term injection source is established to restore and maintain coolant inventory for the removal of decay heat.

All analyses include the consideration of the passive containment cooling system (PCS). For cases that rely on gravity injection from the in-containment refueling water storage tank, the time that the injection begins and the flow rate of the injection are a function of containment pressure. Therefore, a lower containment pressure is more limiting, and the operation of the passive containment cooling system is included in all the analyses. A lower containment pressure may also occur due to a failure in containment isolation. But this is not an assumption made in all the MAAP4 analyses since containment isolation is most likely to function as designed. However, the failure of containment isolation is considered in the definition of the success criteria through sensitivity analyses (Sections A.8 and A.9).

Because these analyses are to support the system response, the actuation signals and setpoints of the protection systems can be important to the timing and outcome of the results. Table A-1 summarizes the signals and other assumptions for the reactor trip, reactor coolant pump trip, automatic depressurization system actuation, core makeup tank actuation, accumulator actuation, passive residual heat removal actuation, normal residual heat removal operation, and the in-containment refueling water storage tank gravity drain.

A.1.3 MAAP4 Analysis Objectives and Considerations

The MAAP4 analyses identify the configurations and timing for automatic depressurization system, core makeup tanks and accumulators, passive residual heat removal, and normal residual heat removal and in-containment refueling water storage tank gravity drain that result in sufficient core heat removal and inventory control to prevent core damage. These configurations and timings constitute the success criteria for a given set of event sequences. The initiating events are grouped into five categories for the MAAP4 analyses, as discussed in Section A.2. The break sizes for the loss-of-coolant accident initiating events are defined in Section A.3.

The definition of the MAAP4 cases focus on the automatic depressurization system success criteria, as discussed in Section A.4. The automatic depressurization system success criteria are also considered with respect to whether the reactor coolant system depressurization is partial or full, and whether the automatic depressurization system lines are automatically or manually opened. Partial depressurization is defined as reducing the reactor coolant system pressure below the normal residual heat removal pump shut off head (~ 175 psia). Full depressurization is defined to be the condition at which the in-containment refueling water storage tank gravity drain can perform the long term injection and heat removal function. Automatic versus manual actuation of the automatic depressurization system is dependent on whether a core makeup tank is credited in the event sequence. A low core makeup tank level is the only signal that automatically actuates the automatic depressurization system, and therefore manual actuation of the automatic depressurization system is credited as a potential success path if no core makeup tanks successfully inject.

A.1.4 Systematic MAAP4 Analysis Methodology

The MAAP4 analyses to support the success criteria definitions are selected in a manner that adequately represents the applicable scenarios. To verify any given success criterion, both the initiating event and the system assumptions for the event tree sequence are considered. For each path on the event trees, conservative representative sequences, called baseline sequences, which do not result in core damage determine the success configuration for the systems. The definitions of baseline sequences and core damage are provided below. The steps in the systematic methodology are:

- define a success configuration for the event tree path
- define a baseline sequence to represent the event tree path
- perform MAAP4 analysis for the baseline sequence
- determine margin to core damage
- perform sensitivity analyses if insufficient margin exists
- redefine success configuration if necessary, and repeat process to obtain margin.

The details of the methodology are outlined in this section. Figure A-1 presents a flowchart of the methodology.

A.1.4.1 Baseline Sequences

To determine any given success criterion, the initiating event and the hardware and human action assumptions on the event tree are considered. Analyses consider the operation of plant systems, even those not modeled on the event tree, that could adversely impact the response to the sequence. An example of this consideration is the containment isolation system. Although not included on the event trees, the failure of the containment isolation system makes gravity injection from the in-containment refueling water storage tank more difficult to achieve (see section A.8.2). Therefore, the failure of the containment isolation system is included in gravity injection MAAP4 baseline sequence analyses.

A baseline sequence is one which includes the worst-case configuration associated with the variabilities in the event tree path to which the success criterion applies. Such variabilities exist because each path shown on an event tree actually represents additional possible hardware/human action combinations which have been bounded by the modeled sequence as a result of practical considerations for quantifying the PRA. These variabilities are:

- minimum injection capability defined for the path
- passive residual heat removal availability defined for the path
- worst break size for the initiating event
- worst break location in the reactor coolant system for the initiating event
- longest credited operator action time for manual actions
- containment isolation failure and passive containment cooling water success

Minimum Injection. The minimum injection is typically defined by the event tree path that the baseline sequence represents. Short-term injection can be provided by the two core makeup tanks and the two accumulators. Either one core makeup tank or one accumulator is credited for each path on the event tree. An accumulator is only credited in the paths with the failure of both core makeup tanks (except for Large LOCA which is not analyzed with the MAAP4 code or this methodology). Therefore, one core makeup tank or one accumulator is modeled in a baseline sequence.

Long-term injection can be provided by either the two normal residual heat removal (RNS) pumps or by the two lines of in-containment refueling water storage tank (IRWST) gravity injection. Event tree paths credit one RNS pump in the event that the primary system is not fully depressurized for gravity injection. If the reactor coolant system is fully depressurized, the event tree path credits either one RNS pump or one IRWST injection line. For partial depressurization, one normal RHR pump is modeled in the baseline sequence. For full depressurization, one IRWST injection line is modeled in the baseline sequence. The success of RNS in the fully depressurized case is bounded by the partially depressurized baseline sequence.

Passive Residual Heat Removal (PRHR). The availability of the passive RHR is defined by the event tree path modeled in the baseline sequence. One PRHR heat exchanger is credited for paths with PRHR success.

Worst Break Size. The worst break size for the success configuration cannot be directly discerned. The break size affects the timing of the sequence and decay heat considerations, reactor coolant system depressurization, and spillage of the injection. Therefore, supporting analyses are performed which vary the break size to determine the worst break size for the baseline sequences.

Worst Break Location. The worst break location cannot be directly discerned. The break location affects the elevation of the break, and pressurizer flooding. In LOCAs this can produce small effects in the reactor coolant system pressure and affect the gravity injection. Therefore, supporting analyses varying the break location are performed for gravity injection baseline LOCA sequences.

Operator Action Timing. For manual actuation sequences such as failure of the core makeup tanks which require manual action for reactor coolant system depressurization, the maximum time for operator action credited in the event trees is included in the baseline sequence. For systems that are normally actuated automatically but in which credit is taken for a backup manual actuation if the automatic actuation fails, sensitivity cases to the baseline case are performed to show timing limitations.

Containment Isolation and Passive Containment Cooling Water. The operation of the containment isolation and passive containment cooling water can affect gravity injection by creating small increases in the pressure differential between the reactor coolant system and the containment. At lower containment pressures it is more difficult to achieve successful gravity injection. Therefore, for baseline sequences that credit gravity injection for long-term heat removal, containment isolation is not credited and passive containment cooling water is credited to reduce the containment pressure. This assumption does not apply to normal residual heat removal baseline sequences. Normal RHR is a pumped system and is not affected significantly by small changes in the differential pressure between the containment and the reactor coolant system.

A.1.4.2 Core Damage Definition

Based on Reference A-3, the core is considered to be damaged if both of the following conditions occur:

- The collapsed water level in the reactor has decreased such that active fuel in the core has been uncovered.
- A fuel cladding temperature of 2200°F (1477°K) or higher is reached in any node of the core as defined in a best-estimate thermal-hydraulic calculation.

The criterion refers to the peak clad temperature. The clad temperature is not a parameter that is easily summarized in MAAP4 output, and therefore the core temperature is presented for these analyses. At the start of the event when the reactor is at full power, the core temperature is approximately 260°F (400°K) higher than the clad temperature. By 500 seconds after reactor trip, the difference is on the order of tens of degrees, with the core

temperature being a slight over-estimation of the clad temperature. The plots of the core temperature response are of interest *after* the initial cooldown from the reactor trip. If there is no core uncovery during the accident, no peak temperature is reported in Section A.4 or A.9 for that case.

Although a limit of 2200°F is acceptable and the calculation can be made on a best estimate basis, "success" in the MAAP4 analyses occurs at a substantially lower temperature. When there is significant clad oxidation, the heatup rate of the core is increased. Clad oxidation begins at 1490°F (1083°K), but has only a minor impact on the heatup rate until approximately 1700°F (1200°K). To demonstrate margin to core damage, baseline sequence peak core temperatures after core uncovery are shown to be less than 1350°F (1000°K). Since the low probability baseline sequence produces the highest peak temperature, this approach provides substantial margin in terms of both the peak temperature and the probability of producing elevated core temperatures.

A.1.4.3 Sensitivity Analyses

If the peak temperature of the baseline sequence is greater than 1350°F (1000°K), sensitivity analyses are performed on the baseline sequence to demonstrate that the temperature will not increase to greater than 2200°F (1477°K) for reasonable changes in plant parameters which affect the performance of the hardware credited in the sequence. Code parameters and thermal-hydraulic uncertainties for the baseline sequences are addressed as a separate issue and with a more rigorous treatment elsewhere and are not addressed in these analyses. The plant parameter sensitivity analyses are performed varying the parameters one-at-a-time. Combinations of sensitivities are of low probability and are not performed in these analyses. The plant parameters which are considered for sensitivity analyses are listed below:

- automatic depressurization system minimum flow
- core makeup tank minimum flow
- accumulator minimum flow
- passive residual heat removal minimum heat removal
- normal residual heat removal injection minimum flow
- in-containment refueling water storage tank gravity injection minimum flow.

Automatic Depressurization System (ADS). The flow requirements for the ADS system are defined in the design basis analyses and are controlled by inspection, testing and acceptance criteria (ITAAC). The MAAP4 parameters for the ADS valve areas are input as the minimum equivalent areas per the ADS requirements. Therefore, no additional sensitivities are performed on the ADS flows.

Core Makeup Tanks (CMT). The flow requirements for the CMT are defined in the design basis analyses and are controlled by inspection, testing and acceptance criteria (ITAAC). The MAAP4 parameters for the CMT are input to calculate best-estimate flow. CMT parameters are adjusted to calculate minimum flow for applicable baseline sequence sensitivity analyses.

Accumulators. The flow requirements for the accumulators are defined in the design basis analyses and are controlled by inspection, testing and acceptance criteria (ITAAC). The MAAP4 parameters for the accumulators are input to calculate best-estimate flow. Accumulator parameters are adjusted to calculate minimum flow for applicable baseline sequences.

Passive Residual Heat Removal (PRHR). The heat removal requirements for the PRHR are defined in the design basis analyses and are controlled by inspection, testing and acceptance criteria (ITAAC). The MAAP4 parameters for the PRHR are input to calculate the best-estimate heat removal. The PRHR parameters are adjusted to calculate minimum heat removal for applicable baseline sequences.

In-Containment Refueling Water Storage Tank (IRWST) Gravity Injection. The flow requirements for the IRWST gravity injection are defined in the design basis analyses and are controlled by inspection, testing and acceptance criteria (ITAAC). The MAAP4 parameters for the IRWST gravity injection are input to calculate best-estimate flow. Gravity injection parameters are adjusted to calculate minimum flow for applicable baseline sequence sensitivity analyses.

A.2 Initiating Events

The event trees, as described in Chapter 4, are structured to identify the accident sequences that may occur following each internal initiating event. For the MAAP4 analyses, the initiating events are grouped into five event categories. This process is necessary to limit the number of MAAP4 cases to consider. However, the events are grouped in a manner that does not lose any of the important detail of the event tree success paths analyzed with MAAP4.

The five initiating event categories for the MAAP4 analyses are medium loss of coolant (MLOCA), intermediate loss of coolant (NLOCA), small loss of coolant (SLOCA), steam generator tube rupture (SGTR), and transient. All of the event trees fit into these categories except LLOCA, ISLOCA, vessel rupture, and ATWS; the success criteria for these initiating events are not addressed with MAAP4 analyses.

The following sections contain information on each of the initiating event categories. This includes a list of the applicable event trees and a discussion of the success criteria and success paths that are addressed by the MAAP4 analyses. The basis for grouping the event trees is provided by identifying the similarities and differences in the success paths.

This section only includes the rationale for the grouping of the events. Results from each of the initiating events are summarized in Section A.9. Throughout the remainder of Appendix A, initiating events are referred to by the grouping established within this section. For example, the events that are initiated without a break in the reactor coolant system are referred to as "transient," without any reference to the specific event tree. Whether the initiating event was a loss of feedwater or a steamline break is not important to the analysis

conclusions, and the minor differences between these events are addressed within subsection A.2.5 and Section A.9.

A.2.1 Medium Loss-of-Coolant Accident (MLOCA)

A medium loss-of-coolant accident is a break in the primary system that is large enough to depressurize the reactor coolant system to the point that the normal residual heat removal can be actuated without the opening of the automatic depressurization system lines. In other words, without automatic depressurization system, the reactor coolant system will depressurize below the 175 psia shutoff head of the normal residual heat removal pumps due to the blowdown from the break. The applicable event trees are:

- Medium loss-of-coolant accident
- Core makeup tank line break
- Direct vessel injection (DVI) line break

The primary difference in these initiating events is the location of the break. The MLOCA event tree considers breaks on the hot leg or cold leg of the reactor coolant system that are equivalent or greater than 5 in. inner diameter (see Section A.3).

The core makeup tank line break is defined as any break in the core makeup tank balance line or core makeup tank injection line up to the check valves. The core makeup tank line break is very similar to a MLOCA on the cold leg, except the faulted core makeup tank is assumed to be unavailable for core cooling. Therefore, the core makeup tank success criteria is one-out-of-one core makeup tanks for the core makeup tank line break, while it is one-out-of-two core makeup tanks on the MLOCA event tree. Normal residual heat removal is a possible source of long-term cooling, since the check valves in the core makeup tank line prevent the normal residual heat removal injection from being lost directly out the break.

The direct vessel injection line break has different effective break areas depending on the location of the break. For all locations, the effective break area initially corresponds to the 4.0 in. flow restrictor in the direct vessel injection line connection to the RPV. After the core makeup tank actuation signal, a second break pathway is created if the isolation valve opens for the core makeup tank connected to the broken direct vessel injection line. The second pathway can be equivalent to 3.7 in. ID or 8 in. ID depending on the location (refer to Figure A-1). The second pathway allows coolant loss from the reactor coolant system via the cold leg and core makeup tank. Furthermore, if the broken direct vessel injection line is the pathway for the normal residual heat removal, the normal residual heat removal injection flow is lost out the break. No success path is credited on the event tree for normal residual heat removal.

Each of the above event trees include automatic depressurization system success criteria:

- ADM -- full depressurization, automatic actuation
- ADQ -- full depressurization, manual actuation

The full depressurization cases rely on gravity drain from the in-containment refueling water storage tank for long-term cooling. There are no "partial" depressurization cases, since long-term cooling with the normal residual heat removal is possible without the opening of automatic depressurization system lines for this initiating event definition. Since automatic depressurization system is triggered from a core makeup tank level signal, the automatic actuation cases credit one core makeup tank and no accumulators. The manual actuation cases credit one accumulator and no core makeup tanks. Event tree paths with the failure of all core makeup tanks and accumulators result in core damage.

The MAAP4 analyses that support the initiating events discussed above consider the system response based on the different break scenarios. Results from the analyses are discussed in Section A.9.

The MLOCA cases are analyzed until the in-containment refueling water storage tank injects into the reactor coolant system and turns around the core temperature. This does not encompass the final top event on the event trees, which is recirculation. The success criteria for top event RECIR are addressed in subsection 6.4.25.

A.2.2 Intermediate Loss-of-Coolant Accident (NLOCA)

An intermediate loss-of-coolant accident (NLOCA) is a break in the primary system that is too small to allow normal residual heat removal injection without automatic depressurization system, but large enough to allow fourth-stage automatic depressurization system actuation without passive residual heat removal or stage one, two, or three automatic depressurization system lines. In other words, without automatic depressurization system, the reactor coolant system depressurizes below the stage four automatic depressurization system interlock of 1000 psia but remains above 175 psia due to the blowdown from the break. The applicable event tree is the intermediate loss-of-coolant accident.

In addition, there is a transfer to the NLOCA event tree from the transient event trees if a pressurizer safety valve fails to close after opening to relieve pressure during the transient.

The automatic depressurization system success criteria included in this initiating event are:

- ADU -- partial depressurization, automatic actuation
- ADZ -- partial depressurization, manual actuation
- ADM -- full depressurization, automatic actuation
- ADQ -- full depressurization, manual actuation

The partial depressurization cases rely on normal residual heat removal injection for long-term cooling. The full depressurization cases rely on either normal residual heat removal or gravity drain from the in-containment refueling water storage tank for long-term cooling, but the analyses are performed with the more limiting in-containment refueling water storage tank gravity drain case. Since automatic depressurization system is triggered from a core makeup tank level signal, the automatic actuation cases credit one core makeup tank and no accumulators. The manual actuation cases credit one accumulator and no core makeup tanks.

Event tree paths with the failure of all core makeup tanks and accumulators result in core damage.

The MAAP4 analyses that support the initiating events discussed above consider the system response for breaks in the primary system from 2 in. to 5 in. inner diameter (refer to Section A.3). In addition, the system response to a stuck open pressurizer safety valve is addressed. Results from the analyses are discussed in Section A.9.

The NLOCA cases are analyzed until the in-containment refueling water storage tank injects into the reactor coolant system and turns around the core temperature. This does not encompass the final top event on the event trees, which is recirculation. The success criteria for top event RECIR are addressed in subsection 6.4.25.

A.2.3 Small Loss-of-Coolant Accident (SLOCA)

A small loss-of-coolant accident is a break in the primary system that is large enough that the CVS makeup flow is not sufficient to replace the lost inventory, yet the break is small enough that passive residual heat removal must operate or stage one, two, or three automatic depressurization system lines must open for the fourth-stage automatic depressurization system to be automatically actuated. In other words, without automatic depressurization system, the reactor coolant system pressure remains above 1000 psia, the stage four automatic depressurization system interlock. The applicable event trees are:

- Small loss-of-coolant accident
- RCS leak
- passive residual heat removal heat exchanger tube rupture

The reactor coolant system leak initiating event encompasses all breaks in the reactor coolant system up to 3/8 in., which is the largest size for which the CVS can compensate for the lost inventory. Although the reactor coolant system leak event addresses smaller breaks than the SLOCA event, the system response is similar if the CVS is not providing injection. Therefore, if the CVS fails, or if the operator fails to take actions that will keep the CVS injecting, the reactor coolant system leak progresses as a SLOCA. Thus, the reactor coolant system leak initiating event is included in the SLOCA group for the MAAP4 analyses.

The passive residual heat removal heat exchanger tube rupture event fits within the break size of a SLOCA. The passive residual heat removal heat exchanger tube rupture is considered as a separate event tree, since it is feasible for the operator to terminate the event by isolating the break. In addition, the operation of the CVS could reduce the effective break size of the rupture. If the break is not isolated, the passive residual heat removal heat exchanger tube rupture progresses as a SLOCA. The MAAP4 analyses consider the success paths on the SLOCA event tree without CVS and without isolation of the break.

Each of the above event trees include automatic depressurization system success criteria:

- AD1A -- partial depressurization, automatic, without passive residual heat removal
- ADV -- partial depressurization, automatic, with passive residual heat removal
- ADY -- partial depressurization, manual, without passive residual heat removal
- ADZ -- partial depressurization, manual, with passive residual heat removal
- ADA -- full depressurization, automatic, without passive residual heat removal
- ADS -- full depressurization, automatic, with passive residual heat removal
- ADC -- full depressurization, manual, without passive residual heat removal
- ADN -- full depressurization, manual, with passive residual heat removal

Separate analyses are done to support each set of automatic depressurization system success criteria. In all cases, reactor trip is assumed to be successful. In the partial depressurization cases, only the normal residual heat removal is credited for long term heat removal. In the full depressurization cases, either normal residual heat removal or in-containment refueling water storage tank gravity drain lead to success paths, but the analyses are performed with the more limiting in-containment refueling water storage tank gravity drain case. The automatic depressurization system actuation cases credit one core makeup tank and take no credit for accumulators. The manual automatic depressurization system actuation cases credit one accumulator and assume that the core makeup tanks have failed. Event tree paths with the failure of all core makeup tanks and accumulators result in core damage.

The MAAP4 analyses that support the initiating events discussed above consider the system response for breaks in the primary system up to 2 in. (refer to Section A.3). In addition, sensitivity analyses consider the effects of the passive residual heat removal tube rupture location. Results from the analyses are discussed in Section A.9.

The SLOCA cases are analyzed until either the normal residual heat removal injects or the in-containment refueling water storage tank gravity drains into the reactor coolant system and turns around the core temperature. This does not encompass the final top event on the event trees, which is recirculation. The success criteria for top event RECIR are addressed in subsection 6.4.25.

A.2.4 Steam Generator Tube Rupture

The steam generator tube rupture initiating event is a specialized small loss-of-coolant accident. It is separated into its own category because the loss of primary coolant through the steam generator can result in different system response than when the loss of coolant is to the containment. There is a transfer to the steam generator tube rupture event tree if a tube rupture occurs as a consequence of a steamline break or stuck-open steam generator safety valve.

As discussed in Section 4.9, the steam generator tube rupture event can be described in terms of three phases. The first and second phases are scenarios where non-safety systems, operator actions, and automatic isolation of the faulted steam generator are credited. These scenarios are not generally addressed with MAAP4 analyses. The third phase, when the actuation of

automatic depressurization system lines is needed to prevent core damage, is addressed with the MAAP4 cases.

The steam generator tube rupture event tree includes automatic depressurization system success criteria:

- AD1A -- partial depressurization, automatic, without passive residual heat removal
- ADV -- partial depressurization, automatic, with passive residual heat removal
- ADY -- partial depressurization, manual, without passive residual heat removal
- ADZ -- partial depressurization, manual, with passive residual heat removal
- ADA -- full depressurization, automatic, without passive residual heat removal
- ADS -- full depressurization, automatic, with passive residual heat removal
- ADC -- full depressurization, manual, without passive residual heat removal
- ADN -- full depressurization, manual, with passive residual heat removal

Separate analyses are done to support each set of automatic depressurization system success criteria. In the partial depressurization cases, only the normal residual heat removal is credited for long term heat removal. In the full depressurization cases, either normal residual heat removal or in-containment refueling water storage tank gravity drain lead to success paths, but the analyses are performed with the more limiting in-containment refueling water storage tank gravity drain case. The automatic depressurization system actuation cases credit one core makeup tank, and take no credit for accumulators. The manual automatic depressurization system actuation cases credit one accumulator, and assume that the core makeup tanks have failed. Event tree paths with the failure of all core makeup tanks and accumulators result in core damage.

For the MAAP4 analyses to support the automatic depressurization system success criteria above, there are a number of paths on the event tree to address. Generally, the analyses focus on scenarios without CVS or startup feedwater, and with the steam generators isolated. However, the effect of CVS and startup feedwater, relative to the automatic depressurization system success criteria, are discussed in Section A.9.

The steam generator tube rupture cases are analyzed until either the normal residual heat removal injects or the in-containment refueling water storage tank gravity drains into the reactor coolant system and turns around the core temperature. This does not encompass the final top event on the event trees, which is recirculation. The success criteria for top event RECIR are addressed in subsection 6.4.25.

A.2.5 Transient

Transients are initiating events in which there is no break in the reactor coolant system. The potential for core damage arises from the loss of heat removal capabilities, resulting in the loss of primary side inventory through the pressurizer safety valves. The applicable event trees are:

- Transient with main feedwater available
- Loss-of-feedwater flow to one steam generator

- Loss-of-feedwater flow to both steam generators
- Loss of condenser
- Loss of reactor coolant system flow
- Core power excursion
- Loss of component cooling/service water
- Loss of compressed air
- Loss-of-offsite power
- Main steam line break downstream of main steam isolation valves
- Main steam line break upstream of main steam isolation valves
- Main steam line safety valve stuck open

For all the transient initiating events, there are success paths on the event trees when startup feedwater or passive residual heat removal is available. The verification of these paths is not addressed by the MAAP4 analyses (refer to Chapter 6). Instead, the MAAP4 analyses start from the common point in the above event trees, which includes: no main feedwater, no startup feedwater, no passive residual heat removal, no stuck open pressurizer safety valve, and successful reactor trip. With these conditions, the automatic depressurization system must be actuated to lower the reactor coolant system pressure to the point that either normal residual heat removal or in-containment refueling water storage tank gravity drain can provide long-term cooling for the core. The automatic depressurization system success criteria in most of the transient event trees are the same. In the loss-of-offsite power event tree, however, there are separate success criteria case names that represent the same scenarios, in terms of the MAAP4 analyses. The list below identifies the automatic depressurization system success criteria for most of the transient events, with the case names for the loss-of-offsite power event in parentheses:

- AD1A -- partial depressurization, automatic (ADRA)
- AD1 -- partial depressurization, manual (ADR)
- ADA -- full depressurization, automatic (ADAL, ADAB)
- ADT -- full depressurization, manual (ADL, ADB)

Separate analyses are done to support each set of automatic depressurization system success criteria. In the partial depressurization cases, only the normal residual heat removal is credited for long-term heat removal. In the full depressurization cases, either normal residual heat removal or in-containment refueling water storage tank gravity drain lead to success paths, but the analyses are performed with the more limiting in-containment refueling water storage tank gravity drain case. The automatic depressurization system actuation cases credit one core makeup tank, and take no credit for accumulators. The manual automatic depressurization system actuation cases credit one accumulator, and assume that the core makeup tanks have failed to inject.

For the MAAP4 analyses to support the above event trees, the reactor trip could be caused by a variety of signals, due to the different initiating events. Generally, a loss of feedwater is modeled, and the decrease in the steam generator water level is the reactor trip signal credited. This is the limiting scenario, since the reactor stays at full power for approximately a minute, while the secondary heat sink starts to deplete. If there were a steamline break, the

secondary heat sink would also deplete quickly. An additional consideration is that events, such as core power excursion, will generate extra power that must be removed. For the loss-of-offsite power event, the reactor coolant pumps trip at the same time that the loss of feedwater occurs. Sensitivities on the effects of the reactor trip, the depletion of the secondary side heat sink, and the reactor power level are contained in Section A.9.

The transient cases are analyzed until either the normal residual heat removal injects or the in-containment refueling water storage tank gravity drains into the reactor coolant system and turns around the core temperature. This does not encompass the final top event on the event trees, which is recirculation. The success criteria for top event RECIR are addressed in subsection 6.4.25.

A.3 Break Size Definitions

Loss-of-coolant accidents have been sub-divided into different categories for the initiating events, since the system response is dependent on the size of the break. The definition for each loss-of-coolant accident initiating event has been given in subsection A.2 and is based on whether different coolant injection sources can be used without automatic depressurization system actuation. The ability for coolant to be injected by a particular means, whether by pumps or gravity drain, is dependent on the reactor coolant system pressure. Table A-2 lists the reactor coolant system pressure "requirements" for each of the loss-of-coolant accident categories.

A.4 Baseline Cases Supporting Automatic Depressurization System Success Criteria

The majority of the MAAP4 analyses are focused on the verification of the automatic depressurization system success criteria. Table A-4 summarizes the automatic depressurization system success criteria definitions with applicable initiating events. The success criteria are grouped based on whether the reactor coolant system depressurization is partial or full, and whether the automatic depressurization system lines are automatically or manually opened. Partial depressurization cases rely on the normal residual heat removal as the long-term inventory injection and heat removal source, while full depressurization cases rely on the in-containment refueling water storage tank gravity drain for this function. Normal residual heat removal can also be used in full depressurization cases, but the analyses focus on the in-containment refueling water storage tank gravity drain, since this is more difficult to achieve, and thus more limiting for automatic depressurization system success criteria definitions.

Table A-4 was constructed by reviewing the event trees to determine where each success criterion is used. For example, success criterion ADV is used in the SLOCA and steam generator tube rupture event trees. Success criterion ADV is used in success paths that credit any one line from any stage automatic depressurization system, along with one core makeup tank, passive residual heat removal and normal residual heat removal. Therefore, MAAP4 cases were analyzed for each of the initiating event categories with the system assumptions based on the event trees. Since the ADV success criterion includes the possibility of a line being opened from any stage, multiple cases were analyzed to cover each possibility. Stage two or stage three lines were considered to be one case, since they have the same line size; the only difference is an additional 2 minute delay from stage two to stage three. MLOCA, NLOCA success configurations do not include PRHR since the PRHR system is not credited on the event tree for these LOCA initiating events. Transient initiating events do not include PRHR since operation of the PRHR results in success without depressurization for the non-LOCA initiating events. For each success criterion, the baseline MAAP4 case and some supporting cases are listed on Table A-4, and are discussed in the sections below. Results from all the MAAP4 cases are summarized in Section A.9.

The following sections summarize the results from the MAAP4 cases identified in Table A-4. Subsection A.4.1 addresses automatic depressurization system actuation cases, with one core makeup tank, no accumulators and including normal residual heat removal. Subsection A.4.2 addresses manual automatic depressurization system actuation cases with no core makeup tanks, with one accumulator and with normal residual heat removal. Subsection A.4.3 addresses automatic depressurization system actuation cases with one core makeup tank, no accumulators and including in-containment refueling water storage tank gravity drain. Subsection A.4.4 addresses manual automatic depressurization system actuation cases with no core makeup tanks, with one accumulator and with in-containment refueling water storage tank gravity drain. In each section, cases with and without passive residual heat removal are considered as defined in the event trees. In the manual actuation cases, different operator action times are considered.

Possible interactions from other systems have been considered, and are addressed in subsection A.8.1.

A.4.1 Automatic Partial Depressurization for RNS Operation

Initiating events addressed by the MAAP4 analyses, except MLOCA (which includes CMT and SI line breaks), include pathways on the event trees that rely on "partial" depressurization by the automatic depressurization system to reduce the reactor coolant system pressure below the normal residual heat removal shutoff head. MLOCA cases do not require the automatic depressurization system for normal residual heat removal operation, since the MLOCA break size has been defined based on allowing normal residual heat removal operation without the opening of any automatic depressurization system lines. Automatic actuation of the depressurization system is based on a low core makeup tank level signal. Therefore the automatic depressurization system valves can be automatically opened only if at least one core makeup tank injects. Failure of the core makeup tank to inject, which requires operator action to open the automatic depressurization system valves, is addressed in subsection A.4.2.

This section documents the MAAP4 analyses that define the number of automatic depressurization system valves that must automatically open for success criteria AD1A, ADRA, ADU and ADV. The AD1A, ADRA and ADU success criteria represent cases without the passive residual heat removal, while the ADV success criterion represents cases with the passive residual heat removal. The goal of these analyses is to verify the minimum number of automatic depressurization system valves from any stage that will be sufficient to achieve success.

A.4.1.1 NLOCA Success Criterion ADU

ADU is the success criterion for automatic partial depressurization for the intermediate LOCA initiating event. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one normal RHR pump. The success configuration for success criterion ADU is at least:

- 2 of 2 stage 1 or 1 of 8 stage 2,3,4 ADS lines.

The assumptions for the baseline case (MAAP4 case x1b) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- limiting break size and location: 2" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADU are presented in Tables A-4.1a and A-4.1b. Baseline case x1b results in a peak core temperature of 1147°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and

to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.1a and A-4.1b which demonstrate that the 2" diameter cold leg break is the limiting case for success criterion ADU, and that the ADS success configuration of 2 stage one lines is more limiting than one stage 2,3 or one stage 4 lines.

A.4.1.2 SLOCA Success Criterion AD1A

AD1A is the success criterion for automatic partial depressurization for the small LOCA initiating event with PRHR failure. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one normal RHR pump. Since the SLOCA initiating event results in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion AD1A is at least:

- 2 of 2 stage 1 or 1 of 4 stage 2,3 ADS lines.

The assumptions for the baseline case (MAAP4 case s16k) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- limiting break size and location: 0.5" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion AD1A are presented in Tables A-4.2a and A-4.2b. Baseline case s16k results in a peak core temperature of 1284°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.2a and A-4.2b which demonstrate that the 0.5 inch diameter hot leg break is the limiting case for success criterion AD1A, and that the ADS success configuration of two stage 1 lines is more limiting than one stage 2,3 line.

A.4.1.3 SLOCA Success Criterion ADV

ADV is the success criterion for automatic partial depressurization for the small LOCA initiating event with PRHR success. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection and heat removal are supplied by at least one normal RHR pump and the PRHR. Since the PRHR reduces the RCS pressure below the stage 4 valve interlock pressure, stage 4 can open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADV is at least:

- 1 of 10 stage 1,2,3,4 ADS lines.

The assumptions for the baseline case (MAAP4 case s10) are:

- minimum ADS: 1 stage 1 line
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- successful PRHR operation
- limiting break size and location: 0.5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADV are presented in Tables A-4.3a and A-4.3b. Baseline case s10 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.3a and A-4.3b. None of the cases result in core uncovery. The single stage one valve provides the least depressurization capacity, and is considered to be the limiting case.

A.4.1.4 SGTR Success Criterion AD1A

AD1A is the success criterion for automatic partial depressurization for the SGTR initiating event with PRHR failure. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one normal RHR pump. Since the SGTR initiating event results in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion AD1A is at least:

- 2 of 2 stage 1 or 1 of 4 stage 2,3 ADS lines.

The assumptions for the baseline case (MAAP4 case g10a) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- break: SGTR

The MAAP4 results for the baseline and supporting case for success criterion AD1A are presented in Tables A-4.4a and A-4.4b. Baseline case g10a results in a peak core temperature of 1109°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.4a and A-4.4b which demonstrate that the ADS success configuration of 2 stage one lines is more limiting than one stage 2,3 line.

A.4.1.5 SGTR Success Criterion ADV

ADV is the success criterion for automatic partial depressurization for the SGTR initiating event with PRHR success. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection and heat removal are supplied by at least one normal RHR pump and the PRHR. The secondary side is not isolated, otherwise the depressurization of the PRHR reduces the pressure below the secondary relief valve setpoint and the loss of coolant is terminated and the sequence results in success. Since the PRHR reduces the RCS pressure below the stage 4 valve interlock pressure, stage 4 can open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADV is at least.

- 1 of 10 stage 1,2,3,4 ADS lines.

The assumptions for the baseline case (MAAP4 case g11) are:

- minimum ADS: 1 stage 1 line
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- successful PRHR operation
- break: unisolated SGTR

The MAAP4 results for the baseline and supporting cases for success criterion ADV are presented in Tables A-4.5a and A-4.5b. Baseline case g11 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.5a and A-4.5b. None of the cases result in core uncovery. The single stage one valve provides the least depressurization capacity, and is considered to be the limiting case.

A.4.1.6 Transient Success Criteria AD1A and ADRA

AD1A is the success criterion for automatic partial depressurization for the non-LOCA initiating events. ADRA is the equivalent of AD1A for loss of offsite power events. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one normal RHR pump. Since the transient initiating events result in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criteria AD1A and ADRA is at least:

- 2 of 2 stage 1 or 1 of 4 stage 2,3 ADS lines.

The assumptions for the baseline case (MAAP4 case t1) are:

- minimum ADS: 2 stage one lines
- minimum short term injection: 1 CMT
  minimum long term injection: 1 RNS pump
- limiting initiating event: loss of main and startup feedwater (see section A.9.5).

The MAAP4 results for the baseline and supporting cases for success criterion AD1A are presented in Tables A-4.6a and A-4.6b. Baseline case t1 results in a peak core temperature of 1305°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. An additional supporting case is presented in Tables A-4.6a and A-4.6b which demonstrate that the ADS success configuration of 2 stage one lines is more limiting than one stage 2,3 line.

A.4.2 Manual Depressurization for RNS Operation

The automatic depressurization system can only be automatically actuated based on a low core makeup tank level signal. If both core makeup tanks fail to inject water, then it is necessary for the operator to manually open the automatic depressurization system lines. This is the scenario addressed in this section, which covers success criteria AD1, ADUM, ADR and ADZ. All of the initiating events being addressed by MAAP4 analyses, except MLOCA, use one of these success criteria. By definition, the MLOCA initiating event can depressurize the reactor coolant system sufficiently without ADS to allow normal residual heat removal injection.

When manual automatic depressurization system actuation is credited, the operator action time is an uncertainty that must be considered. The operator action time needs to be defined from a signal that failed to perform its function. For transients, the focus of the operator is on heat removal. If both startup feedwater and the passive residual heat removal fail to initiate, the operator would have the necessary indications that manual action may be needed. This indication will generally occur for transient initiating events when a low steam generator water level signal fails to actuate the passive residual heat removal. For loss-of-coolant accidents, the focus of the operator is on inventory control. The indication that manual actuation may be needed is when the core makeup tanks fail to inject after a low pressurizer pressure or low pressurizer level signal. The core makeup tank actuation signal also produces a passive residual heat removal actuation signal. Therefore, operator action time for manual automatic depressurization system actuation could always be referenced from the time of the passive residual heat removal actuation signal for all the initiating events. For loss-of-coolant accidents, this is the same as if the operator action time is referenced from the core makeup tank actuation signal.

The human reliability analysis for this action does not credit delay times greater than 30 minutes. Therefore, the baseline sequences only consider the operator action delays for 30

minutes or less. Cases with longer delay times are included with all the MAAP4 supporting analyses in section 4.9. The core makeup tank actuation signal is used as a starting point to measure the operator action time, but the core makeup tank fails to inject. Only accumulator injection is modeled prior to normal residual heat removal injection.

A.4.2.1 NLOCA Success Criterion ADUM

ADUM is the success criterion for manual partial depressurization for the intermediate LOCA initiating event. The need for manual actuation of the depressurization system on the event tree path using ADUM is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The success configuration for success criterion ADUM is at least:

- 2 of 2 stage 1 or 1 of 8 stage 2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case xh2) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- operator delay time: 15 minutes after CMT signal
- limiting break size and location: 2" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADUM are presented in Tables A-4.7a and A-4.7b. Baseline case x2h results in a peak core temperature of 1127°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.7a and A-4.7b which demonstrate that the 2" diameter break is the limiting case for success criterion ADUM with little sensitivity to the break location. The ADS success configuration of 2 stage one lines is more limiting than one stage 2/3 or one stage 4 lines. The operator action delay time of 15 minutes produces a higher peak temperature than the 30 minute delay since the decay heat is higher at the earlier time and the core uncovery occurs as a result of the depressurization.

A.4.2.2 SLOCA Success Criterion AD1

AD1 is the success criterion for manual partial depressurization for the small LOCA initiating event with PRHR failure. The need for manual actuation of the depressurization system on the event tree path using AD1 is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The small LOCA initiating

event results in an elevated RCS pressure above the interlock pressure of the stage 4 ADS valves, however, the interlock can be manually overridden to open stage 4. The success configuration for success criterion AD1 is at least:

- 2 of 2 stage 1 or 1 of 8 stage 2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case s19b2) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- operator delay time: 15 minutes after CMT signal
- limiting break size and location: 0.5" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion AD1 are presented in Tables A-4.8a and A-4.8b. Baseline case s19b2 results in a peak core temperature of 1266°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.8a and A-4.8b which demonstrate that the 0.5" diameter break is the limiting case for success criterion AD1 with little sensitivity to the break location. The ADS success configuration of 2 stage one lines is more limiting than one stage 2/3 or one stage 4 lines. The operator action delay time of 15 minutes produces a higher peak temperature than the 30 minute delay since the decay heat is higher at the earlier time and the core uncovery occurs as a result of the depressurization.

A.4.2.3 SLOCA Success Criterion ADZ

ADZ is the success criterion for manual partial depressurization for the small LOCA initiating event with PRHR success. The need for manual actuation of the depressurization system on the event tree path using ADZ is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The small LOCA initiating event results in an elevated RCS pressure above the interlock pressure of the stage 4 ADS valves, however, the interlock can be manually overridden to open stage 4. The success configuration for success criterion ADZ is at least:

- 1 of 10 stage 1,2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case s13a) are:

- minimum ADS: 1 stage 1 lines

- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- successful PRHR operation
- operator delay time: 15 minutes after CMT signal
- limiting break size and location: 0.5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADZ are presented in Tables A-4.9a and A-4.9b. Baseline case s13a results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.9a and A-4.9b which demonstrate that none of the cases result in core uncovery. The ADS success configuration of 1 stage one line is assumed to be more limiting than one stage 2/3 or one stage 4 lines since it is the smallest line. The operator action delay time of 15 minutes is assumed to be the most limiting since it results in an earlier core uncovery and higher decay heat.

A.4.2.4 SGTR Success Criterion AD1

AD1 is the success criterion for manual partial depressurization for the SGTR initiating event with PRHR failure. The need for manual actuation of the depressurization system on the event tree path using AD1 is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The SGTR initiating event results in an elevated RCS pressure above the interlock pressure of the stage 4 ADS valves, however, the interlock can be manually overridden to open stage 4. The success configuration for success criterion AD1 is at least:

- 2 of 2 stage 1 or 1 of 8 stage 2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case g12d) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- operator delay time: 15 minutes after CMT signal
- break: SGTR

The MAAP4 results for the baseline and supporting cases for success criterion AD1 are presented in Tables A-4.10a and A-4.10b. Baseline case g12d results in a peak core

temperature of 1034°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.10a and A-4.10b which demonstrate that the ADS success configuration of 2 stage one lines is the most limiting. The operator action delay time of 15 minutes produces a higher peak temperature than the 30 minute delay since the decay heat is higher at the earlier time and the core uncovery occurs as a result of the depressurization.

A.4.2.5 SGTR Success Criterion ADZ

ADZ is the success criterion for manual partial depressurization for the SGTR initiating event with PRHR success. The need for manual actuation of the depressurization system on the event tree path using ADZ is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The secondary side is not isolated, otherwise the depressurization of the PRHR reduces the pressure below the secondary relief valve setpoint and the loss of coolant is terminated and the sequence results in success. The SGTR initiating event results in an elevated RCS pressure above the interlock pressure of the stage 4 ADS valves, however, the interlock can be manually overridden to open stage 4. The success configuration for success criterion ADZ is at least:

- 1 of 10 stage 1,2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case g13) are:

- minimum ADS: 1 stage 1 lines
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- operator delay time: 15 minutes after CMT signal
- break: unisolated SGTR

The MAAP4 results for the baseline and supporting cases for success criterion ADZ are presented in Tables A-4.11a and A-4.11b. Baseline case g13 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.9a and A-4.9b which demonstrate that none of the cases result in core uncovery. The ADS success configuration of 1 stage one line is assumed to be more limiting than one stage 2/3 or one stage 4 lines since it is the smallest line. The operator action delay time of 15 minutes is assumed to be the most limiting since will result in an earlier core uncovery.

A.4.2.6 **Transient Success Criteria AD1 and ADR**

AD1 is the success criterion for manual partial depressurization for the transient initiating events. ADR is the equivalent success criteria as AD1 for loss of offsite power. The need for manual actuation of the depressurization system on the event tree path using AD1 is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one normal RHR pump. The transient initiating events result in an elevated RCS pressure above the interlock pressure of the stage 4 ADS valves, however, the interlock can be manually overridden to open stage 4. The success configuration for success criterion AD1 and ADR is at least:

- 2 of 2 stage 1 or 1 of 8 stage 2,3,4 ADS lines
  maximum operator action delay of 30 minutes after the PRHR signal

The assumptions for the baseline case (MAAP4 case t3h) are:

- minimum ADS: 2 stage 1 lines
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 RNS pump
- operator delay time: 15 minutes after PRHR signal
- limiting initiating event: loss of main and startup feedwater (see section A.9.5).

The MAAP4 results for the baseline and supporting cases for success criterion AD1 are presented in Tables A-4.12a and A-4.12b. Baseline case t3h results in a peak core temperature of 1280°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.12a and A-4.12b which demonstrate that the ADS success configuration of 2 stage one lines is more limiting than one stage 2,3 or one stage 4 lines. The operator action delay time of 15 minutes produces a higher peak temperature than the 30 minute delay since the decay heat is higher at the earlier time and the core uncovery occurs as a result of the depressurization.

A.4.3 **Automatic Depressurization for IRWST Gravity Drain**

Initiating events addressed by the MAAP4 analyses include "full" depressurization pathways on the event trees that reduce the reactor coolant system pressure so that in-containment refueling water storage tank gravity drain can occur. Automatic actuation of the automatic depressurization system is based on a low core makeup tank level signal. Therefore the automatic depressurization system valves can be automatically opened only if at least one core makeup tank injects. Failure of the core makeup tank to inject, requiring manual action to open the automatic depressurization system lines, is addressed in subsection A.4.4.

This section documents the MAAP4 analyses that define the number of automatic depressurization system lines that must automatically open for success criteria ADAB, ADAL, ADA, ADS and ADM. The ADAB, ADAL, ADA and ADM success criteria represent cases without the passive residual heat removal, while case ADS includes passive residual heat removal. The goal of these analyses is to identify the minimum number of ADS lines that must open to allow gravity injection and achieve success.

A.4.3.1 MLOCA Success Criterion ADM

ADM is the success criterion for automatic full depressurization for the medium LOCA initiating event. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one line of gravity injection. The success configuration for success criterion ADM is at least:

- 2 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case m3g4) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- limiting break size and location: 5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADM are presented in Tables A-4.13a and A-4.13b. Baseline case m3g4 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases with variations in break size and location are presented in Tables A-4.13a and A-4.13b which also result in no core uncovery.

A.4.3.2 NLOCA Success Criterion ADM

ADM is the success criterion for automatic full depressurization for the intermediate LOCA initiating event. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADM is at least:

- 2 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case x3d4) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- limiting break size and location: 2" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADM are presented in Tables A-4.14a and A-4.14b. Baseline case x3d4 results in a peak core temperature of 956°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.14a and A-4.14b which demonstrate that the 2" diameter hot leg break is the limiting case for success criterion ADM.

A.4.3.3 SLOCA Success Criterion ADA

ADA is the success criterion for automatic full depressurization for the small LOCA initiating event with PRHR failure. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one gravity injection line. Since the SLOCA initiating event results in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADA is at least:

- 3 of 4 stage 2,3 ADS lines, or
  1 of 4 stage 2,3 and 1 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case s1t2) are:

- minimum ADS: 3 stage 2,3 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- limiting break size and location: 1.75" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADA are presented in Tables A-4.15a and A-4.15b. Baseline case s1t2 results in a peak core temperature of 1534°F. This case demonstrates substantial margin to the 2200°F acceptance criterion, but sensitivity cases with minimum gravity injection flow and minimum CMT flow are performed to assure that rapid cladding oxidation does not occur and drive the temperature

beyond the limit. Reasonable limits on the short-term and long-term injection flows do not result in significant peak temperature differences. Additional supporting cases are presented in Tables A-4.15a and A-4.15b which demonstrate that the 1.75 inch diameter cold leg break is the limiting case for success criterion ADA, and that the ADS success configuration of 3 stage 2,3 lines is more limiting than one stage 2,3 and one stage 4 lines.

A.4.3.4 SLOCA Success Criterion ADS

ADS is the success criterion for automatic full depressurization for the small LOCA initiating event with PRHR success. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection and heat removal are supplied by at least one gravity injection line and the PRHR. Since the PRHR reduces the RCS pressure below the stage 4 valve interlock pressure, stage 4 can open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADS is at least:

- 3 of 4 stage 2,3 ADS lines or
  1 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case s4z) are:

- minimum ADS: 3 stage 2,3 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- successful PRHR operation
- limiting break size and location: 1.75" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADS are presented in Tables A-4.16a and A-4.16b. Baseline case s4z results in a peak core temperature of 1251°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.16a and A-4.16b. The analyses show that the 1.75 inch diameter break is the limiting break size. The analyses show little sensitivity to break location. The 3 stage 2,3 ADS line configuration is more limiting than the 1 stage 4 line.

An interesting result of these analyses is that the smallest of the SLOCA break sizes with operational PRHR has lower peak temperatures with no containment isolation. This occurs because the PRHR is able to remove more heat at the lower pressures and temperatures in the containment, and the heat removal compensates for the difficulty in gravity injection at the

lower pressures. The same effect is not seen at the larger end of the break range since the PRHR is not as effective at the lower pressures in the RCS.

A.4.3.5 SGTR Success Criterion ADAG

ADAG is the success criterion for automatic full depressurization for the SGTR initiating event with PRHR failure. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one gravity injection line. Since the SGTR initiating event results in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADAG is at least:

- 1 of 4 stage 2,3 and 1 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case g14e) are:

- minimum ADS: 1 stage 3 and 1 stage 4 line
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- break: SGTR

The MAAP4 results for the baseline case for success criterion ADAG is presented in Tables A-4.17a and A-4.17b. Baseline case g14e results in a peak core temperature of 685°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur.

A.4.3.6 SGTR Success Criterion ADS

ADS is the success criterion for automatic full depressurization for the SGTR initiating event with PRHR success. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection and heat removal are supplied by at least one gravity injection line and the PRHR. The secondary side is not isolated, otherwise the depressurization of the PRHR reduces the pressure below the secondary relief valve setpoint and the loss of coolant is terminated and the sequence results in success. Since the PRHR reduces the RCS pressure below the stage 4 valve interlock pressure, stage 4 can open without the successful operation of stages 1, 2 or 3. The success configuration for success criterion ADS is at least:

- 3 of 4 stage 2,3 ADS lines or
  1 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case g15) are:

- minimum ADS: 3 stage 2,3 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- successful PRHR operation
- break: unisolated SGTR.

The MAAP4 results for the baseline and supporting cases for success criterion ADS are presented in Tables A-4.18a and A-4.18b. Baseline case s4z results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.18a and A-4.18b, and none result in core uncovery.

A.4.3.7 Transient Success Criteria ADA, ADAL, ADAB

ADA is the success criterion for automatic full depressurization for the non-LOCA initiating events. ADAL and ADAB are the equivalent success criteria for loss of offsite power and station blackout, respectively. Automatic actuation of the depressurization system requires at least one core makeup tank to generate the signal on low level, and long-term injection is supplied by at least one gravity injection line. Since the transient initiating events result in elevated RCS pressures, the stage 4 valves are interlocked out and cannot open without the successful operation of stages 1, 2 or 3. The success configuration for success criteria ADA, ADAL and ADAB is at least:

- 3 of 4 stage 2,3 ADS lines, or
  1 of 6 stage 1,2,3 and 1 of 4 stage 4 ADS lines.

The assumptions for the baseline case (MAAP4 case t5t) are:

- minimum ADS: 3 stage 2,3 lines
- containment isolation failure
- minimum short term injection: 1 CMT
  minimum long term injection: 1 gravity injection line
- limiting initiating event: loss of main and startup feedwater (see section A.9.5).

The MAAP4 results for the baseline and supporting cases for success criterion ADA are presented in Tables A-4.19a and A-4.19b. Baseline case t5t results in a peak core temperature of 1262°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to the temperatures at which substantial oxidation is expected to occur. Additional supporting cases are presented in Tables A-4.19a and A-4.19b which demonstrate that the ADS success configuration of 3 stage 2,3 lines is more limiting than one stage 1 and one stage 4 lines.

A.4.4 Manual Depressurization for IRWST Gravity Drain

The automatic depressurization system can only be automatically actuated based on a low core makeup tank level signal. If both core makeup tanks fail to inject water, then it is necessary for the operator to manually open the automatic depressurization system lines. This is the scenario addressed in this section, which covers success criteria for ADB, ADL, ADT, and ADQ. The MLOCA, NLOCA, SLOCA, SGTR and transient initiating events use these success criteria.

When manual automatic depressurization system actuation is credited, the operator action time is an uncertainty that must be considered. The operator action time needs to be defined from a signal that failed to perform its function. For transients, the focus of the operator is on heat removal. If both startup feedwater and the passive residual heat removal fail to initiate, the operator would have the necessary indications that manual action may be needed. This indication will generally occur for transient initiating events when a low steam generator water level signal fails to actuate the passive residual heat removal. For loss-of-coolant accidents, the focus of the operator is on inventory control. The indication that manual actuation may be needed is when the core makeup tanks fail to inject after a low pressurizer pressure or low pressurizer level signal. The core makeup tank actuation signal also produces a passive residual heat removal actuation signal. Therefore, operator action time for manual automatic depressurization system actuation could always be referenced from the time of the passive residual heat removal actuation signal for all the initiating events. For loss-of-coolant accidents, this is the same as if the operator action time is referenced from the core makeup tank actuation signal.

The event tree quantification does not credit delay times greater than 30 minutes. Therefore, the baseline sequences only consider the operator action delays for 30 minutes or less. Cases with longer delay times are included with all the MAAP4 supporting analyses in section 4.9. The core makeup tank actuation signal is used as a starting point to measure the operator action time, but the core makeup tank fails to inject. Only accumulator injection is modeled prior to normal residual heat removal injection.

A.4.4.1 MLOCA Success Criterion ADQ

ADQ is the success criterion for manual full depressurization for the medium LOCA initiating event. The need for manual actuation of the depressurization system on the event tree path using ADQ is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is

supplied by at least one gravity injection line. The success configuration for success criterion ADQ is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case m6e5) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 30 minutes after CMT signal
- limiting break size and location: 8.75" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADQ are presented in Tables A-4.20a and A-4.20b. Baseline case m6e5 results in a peak core temperature of 1554°F. This case demonstrates substantial margin to the 2200°F acceptance criterion, but sensitivity cases with minimum gravity injection flow and minimum accumulator flow are performed to assure that rapid cladding oxidation does not occur and drive the temperature beyond the limit. Reasonable limits on the short-term and long-term injection flows do not result in significant peak temperature differences. Additional supporting cases are presented in Tables A-4.20a and A-4.20b which demonstrate that the 8.75" diameter hot leg break is the limiting case for success criterion ADQ. The operator action delay time of 30 minutes produces a higher peak temperature than a 15 minute delay since the core is uncovered prior to depressurization and the longer uncovery time produces higher temperatures. For time delays less than 25 minutes, the core temperature is less than 1200°F.

A.4.4.2 NLOCA Success Criterion ADQ

ADQ is the success criterion for manual full depressurization for the intermediate LOCA initiating event. The need for manual actuation of the depressurization system on the event tree path using ADQ is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. Long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADQ is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case x4g) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 30 minutes after CMT signal
- limiting break size and location: 4.75" diameter hot leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADQ are presented in Tables A-4.21a and A-4.21b. Baseline case x4g results in a peak core temperature of 969°F. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. Additional supporting cases are presented in Tables A-4.21a and A-4.21b which demonstrate that the 4.75" diameter break is the limiting case for success criterion ADQ. The operator action delay time of 30 minutes produces a higher peak temperature than the 15 minute delay since the core is uncovered prior to depressurization and the longer uncovery time produces higher temperatures. Hot leg break is assumed to be the limiting break location based on the results of MAAP4 analyses for ADQ MLOCA presented in section A.4.4.1 which produces similar results.

A.4.4.3 SLOCA Success Criterion ADT (PRHR Failure)

ADT is the success criterion for manual full depressurization for the small LOCA initiating event with PRHR failure. The need for manual actuation of the depressurization system on the event tree path using ADT is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. The small LOCA event results in a RCS pressure that is higher than the ADS stage 4 interlock pressure, however the interlock can be manually overridden to open stage 4 valves without first opening stage 1,2,or 3 ADS lines. Long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADT is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case s6a4) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator

minimum long term injection: 1 gravity injection line

- operator delay time: 15 minutes after CMT signal
- limiting break size and location: 0.5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADT are presented in Tables A-4.22a and A-4.22b. Baseline case s6a4 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. Additional supporting cases are presented in Tables A-4.22a and A-4.22b which demonstrate that the 0.5" diameter break is the limiting case for success criterion ADT. The operator action delay time of 15 minutes is assumed to be more limiting than the 30 minute delay (although neither uncovers the core) since any potential core uncovery would occur after ADS, and decay heat is higher at the earlier time.

A.4.4.4 SLOCA Success Criterion ADT (PRHR Success)

ADT is the success criterion for manual full depressurization for the small LOCA initiating event with PRHR success. The need for manual actuation of the depressurization system on the event tree path using ADT is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by accumulator. Long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADT is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case s8a4) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 15 minutes after CMT signal
- limiting break size and location: 0.5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADT are presented in Tables A-4.23a and A-4.23b. Baseline case s8a4 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. Additional supporting cases are presented in Tables A-4.23a and A-4.23b which demonstrate that the 0.5"

diameter break is the limiting case for success criterion ADT. The operator action delay time of 15 minutes is assumed to be more limiting than the 30 minute delay (although neither uncovers the core) since any potential core uncovery would occur after ADS, and decay heat is higher at the earlier time.

A.4.4.5 SGTR Success Criterion ADT (PRHR Failure)

ADT is the success criterion for manual full depressurization for the SGTR initiating event with PRHR failure. The need for manual actuation of the depressurization system on the event tree path using ADT is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by an accumulator. The SGTR event results in a RCS pressure that is higher than the ADS stage 4 interlock pressure, however the interlock can be manually overridden to open stage 4 valves without first opening stage 1,2,or 3 ADS lines. Long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADT is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case g16) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 15 minutes after CMT signal
- break: SGTR.

The MAAP4 results for the baseline and supporting cases for success criterion ADT are presented in Tables A-4.24a and A-4.24b. Baseline case g16 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. An additional supporting case is presented in Tables A-4.24a and A-4.24b which presents the 30 minute operator action delay. The operator action delay time of 15 minutes is assumed to be more limiting than the 30 minute delay (although neither uncovers the core) since any potential core uncovery would occur after ADS, and decay heat is higher at the earlier time.

A.4.4.6 SGTR Success Criterion ADT (PRHR Success)

ADT is the success criterion for manual full depressurization for the SGTR initiating event with PRHR success. The need for manual actuation of the depressurization system on the event tree path using ADT is a result of the failure of both the core makeup tanks which

generate the ADS signal, so short term makeup water is supplied by accumulator. Long-term injection is supplied by at least one gravity injection line. The secondary side is not isolated, otherwise the depressurization of the PRHR reduces the pressure below the secondary relief valve setpoint and the loss of coolant is terminated and the sequence results in success. The success configuration for success criterion ADT is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the CMT signal

The assumptions for the baseline case (MAAP4 case g17) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 15 minutes after CMT signal
- break: unisolated SGTR.

The MAAP4 results for the baseline and supporting cases for success criterion ADT are presented in Tables A-4.25a and A-4.25b. Baseline case g17 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. An additional supporting case is presented in Tables A-4.25a and A-4.25b which presents the 30 minute operator delay which does not result in core uncovery. The operator action delay time of 15 minutes is assumed to be more limiting than the 30 minute delay (although neither uncovers the core) since any potential core uncovery would occur after ADS, and decay heat is higher at the earlier time.

A.4.4.7 Transient Success Criterion ADT

ADT is the success criterion for manual full depressurization for the transient initiating events. The need for manual actuation of the depressurization system on the event tree path using ADC is a result of the failure of both the core makeup tanks which generate the ADS signal, so short term makeup water is supplied by accumulator. Long-term injection is supplied by at least one gravity injection line. The success configuration for success criterion ADT is at least:

- 2 of 4 stage 4 ADS lines
  maximum operator action delay of 30 minutes after the PRHR signal

The assumptions for the baseline case (MAAP4 case t9a3) are:

- minimum ADS: 2 stage 4 lines
- containment isolation failure
- minimum short term injection: 1 accumulator
  minimum long term injection: 1 gravity injection line
- operator delay time: 15 minutes after PRHR signal
- limiting break size and location: 0.5" diameter cold leg break.

The MAAP4 results for the baseline and supporting cases for success criterion ADT are presented in Tables A-4.26a and A-4.26b. Baseline case t9a3 results in no core uncovery. This case demonstrates substantial margin to the 2200°F acceptance criterion and to temperatures at which rapid oxidation of the cladding is expected to occur. Additional supporting cases are presented in Tables A-4.26a and A-4.26b which demonstrate that the operator action delay time of 15 minutes is more limiting than the 30 minute delay since any potential core uncovery occurs after ADS, and decay heat is higher at the earlier time.

A.4.5 ADS Manual Actuation for Failure of Automatic Actuation

The focus of the automatic depressurization system success criteria with at least one functional CMT is for automatic actuation, operator action is also credited in the event trees if the automatic depressurization system valves fail to open when the low core makeup tank level setpoint is reached. MAAP4 analyses of the automatic ADS baseline cases with delayed operation, presented in Table A-4.27a and A-4.27b, show the acceptable operator action time for most sequences after the low core makeup tank level setpoint is 30 minutes. The one exception is the small LOCA full depressurization case with PRHR failure (criterion ADA). This case is quantified at the cutset level such that failure of the automatic actuation of the ADS for small LOCA full depressurization results in core damage.

A.5 Accumulator and Core Makeup Tank Success Criteria

The success criteria for the accumulator and core makeup tank systems is that one of the tanks will inject water when the system actuation requirements are met. In the structure of the event trees, either accumulators or core makeup tanks are credited (but not both) for any given success path. The MAAP4 analyses to support the automatic depressurization system success criteria have also supported the accumulator and core makeup tank success criteria by modeling only one accumulator or one core makeup tank in the baseline analyses presented in section A.4 (subsection A.8.1 includes a discussion of analyses that assumed more than one core makeup tank or accumulator.) The accumulator success criteria that are addressed by MAAP4 analyses are AC1A and AC2AB. The core makeup tank success criteria that are

addressed by MAAP4 analyses are CM1A, CM2AB, CM2L, CM2P, and CM2SL. However, success criteria AC2AB and CM2AB are not addressed by MAAP4 analyses for large loss-of-coolant accident and ATWS events, respectively.

In the core makeup tank success criteria, the core makeup tank is assumed to automatically actuate based on the core makeup tank actuation signals. (The core makeup tank actuation signals credited in MAAP4 analyses are listed in subsection A.1.2.) However, if automatic actuation fails, credit is taken if the operator is able to take action within a certain period of time. Results from the MAAP4 analyses determine what the acceptable time delay is. Table A-4.28a and A-4.28b present the MAAP4 baseline case results with successful CMT operation analyzed with the actuation of the CMT delayed by the maximum time credited in the event tree analysis.

The MLOCA event, because it causes the most immediate need for coolant inventory makeup, is the most restrictive of the analyses performed with MAAP4 regarding the acceptable delay in core makeup tank actuation. Smaller break sizes in the reactor coolant system result in slower loss of inventory, and thus longer delays in makeup inventory from the core makeup tank may be acceptable. When a MLOCA occurs, the core makeup tank actuation signal occurs within the first few seconds of the accident. The core makeup tank level is maintained for approximately 5 minutes while the core makeup tank operates in a recirculation mode. In the recirculation mode, the cold water is injected to the downcomer through the direct vessel injection line, and the warmer water recirculates from the cold leg through the balance line to the top of the core makeup tank, maintaining core makeup tank level. When the top of the balance line uncovers, the recirculation mode ends, and the core makeup tank injects quickly. Therefore, while the core makeup tank is in the recirculation mode, it is not providing substantial coolant inventory make-up to the reactor coolant system. MAAP4 analyses show successful MLOCA results when the core makeup tank actuation is delayed by up to 10 minutes.

The acceptable delay in the opening of the core makeup tank isolation valves, from the time of the actuation signal, is as follows:

- Medium loss-of-coolant accident - 10 minutes
- Intermediate loss-of-coolant accident - 10 minutes
- Small loss-of-coolant accident - 20 minutes
- Steam generator tube rupture - 30 minutes
- Transients - 30 minutes

The one exception to these times is the SGTR full automatic depressurization case with PRHR failure. This case will be quantified at the cutset level such that failure of automatic actuation of the CMT will lead to core damage.

A.6 Passive Residual Heat Removal Success Criteria

The success criteria for the passive residual heat removal system is that one-out-of-two passive residual heat removal heat exchangers will function. The MAAP4 analyses for SLOCA and steam generator tube rupture with automatic depressurization system actuation have included cases that credit passive residual heat removal. The success criteria that are addressed by MAAP4 analyses are PRL and PRS. System responses from analyses that include the operation of the passive residual heat removal heat exchanger are discussed in subsections A.4.1.3, A.4.1.5, A.4.2.3, A.4.2.5, A.4.3.4, A.4.3.6, A.4.4.4, and A.4.4.6.

In the passive residual heat removal success criteria, passive residual heat removal is assumed to automatically actuated based on the passive residual heat removal actuation signals. (The passive residual heat removal actuation signals credited in MAAP4 analyses are listed in subsection A.1.2.) However, if automatic actuation fails, credit is taken if the operator is able to take action within a certain period of time. Results from the MAAP4 analyses determine that 30 minutes is an acceptable time delay to credit in the event tree analysis. Table A-4.29a and A-4.29b present the MAAP4 results of baseline cases with the operation of the PRHR delayed by 30 minutes.

A.7 Normal Residual Heat Removal and In-Containment Refueling Water Storage Tank Success Criteria

Long-term cooling of the core is provided by either the normal residual heat removal pumps or the in-containment refueling water storage tank gravity drain. The normal residual heat removal success criteria that are addressed by MAAP4 analyses are RNP and RNR. The in-containment refueling water storage tank gravity drain success criteria that are addressed by MAAP4 analyses are IW1A and IW2AB. However, success criteria RNR and IW2AB are not addressed by MAAP4 analyses for ATWS, and IW2AB is not addressed for large loss-of-coolant accident events.

The in-containment refueling water storage tank success criteria is for gravity injection to be provided through one direct vessel injection line. Representative MAAP4 analyses that include this model are discussed in subsections A.4.3 and A.4.4.

The normal residual heat removal success criteria is for injection to be provided from one normal residual heat removal pump. Representative MAAP4 analyses that include this model are discussed in subsections A.4.1 and A.4.2.

For the normal residual heat removal success criteria, the MAAP4 analyses assume that the operator has taken the necessary actions to align the normal residual heat removal system for operation by the time that the reactor coolant system pressure is below the normal residual heat removal pump shut-off head. This occurs the quickest in the MLOCA analyses, in which the normal residual heat removal pump shut-off head may be reached within approximately five minutes after accident initiation, when only one core makeup tank or one accumulator is credited. The baseline MAAP4 analyses take credit for the start of normal residual heat

removal injection at this time. Sensitivity analyses are done to determine the impact of delaying the start of normal residual heat removal. MAAP4 analyses presented in Tables A-4.30a and A-4.30b show successful MLOCA results when the normal residual heat removal operation is delayed until 30 minutes after the reactor coolant system break occur. Breaks at the smaller end of the MLOCA range (5 inch diameter) and smaller take longer than 30 minutes from the time of the break to depressurized below the RNS pump shut-off head.

For other initiating events analyzed with MAAP4, normal residual heat removal can be credited only after automatic depressurization system lines have been actuated. In most of the analyses, a reduced number of automatic depressurization system lines is credited, and therefore the depressurization time until the normal residual heat removal shut-off head is reached may be longer than if all the automatic depressurization system lines opened. However, there are a number of events that the operator could use to indicate that actions should begin to align the normal residual heat removal. Table A-9 lists the approximate times that it takes for the RCS pressure to fall below normal residual heat removal shut-off head after different indicating events in the sequences. The event tree analysis credits a delay time of 30 minutes from the CMT injection signal for the operator to actuate RNS.

A.8 Containment Isolation

Containment isolation was questioned as a condition for long-term recirculation cooling to ensure an adequate water supply. The concern is for paths on the event tree in which passive injection works properly, but the containment is not isolated and water inventory is lost as steam through the opening. Calculations were performed to determine that there is sufficient inventory for at least 2.7 days to keep the top of the fuel covered with water, regardless of whether containment isolation is successful.

The calculation to determine the minimum time until inadequate water inventory would be a concern for long-term core cooling is based on the assumption that the entire inventory from the in-containment refueling water storage tank is emptied into the reactor and lower containment. The initial water volume from the reactor coolant system is neglected since much of it would have flashed to steam upon exiting the reactor coolant system. The inventory from the core makeup tanks and accumulators is also conservatively neglected. The water is assumed to boil off at a rate determined by the decay heat rate. With these factors, the top of the core remains covered for 2.7 days, assuming that there is no return of condensed steam from the containment shell.

A sensitivity on the above calculation is performed to determine the effect of condensate reflux from the passive containment cooling system cooling. The fraction of water that would be returned back to the containment water pool due to condensation of the containment shell is uncertain. Figure A-50 shows that as the condensation rate approaches the boiloff rate, the time to containment uncovery approaches infinity. Based on best estimate approximations, the reflux condensation from a dry passive containment cooling system shell is approximately 2 lbm/s (1 kg/s), leading to core uncovery in 3.5 days. The reflux condensation from a wet passive containment cooling system shell is estimated to be approximately 6.5 lbm/s (3 kg/s), leading to core uncovery in 8.2 days. Nevertheless, the failure of containment isolation does

not cause a water inventory concern for at least 2.7 days, conservatively assuming no reflux condensation.

Although containment isolation is not a concern for long term water inventory concerns, it can impact event sequences that rely on the in-containment refueling water storage tank gravity drain as the long term cooling source. For the in-containment refueling water storage tank to gravity drain into the reactor coolant system, the reactor coolant system pressure must decrease to within approximately 15 psi (1 bar) of the containment pressure. When the containment is not isolated, the containment pressure remains low, and the reactor coolant system pressure must decrease further than when the containment is isolated. Therefore the success criteria definitions are based on analyses that consider the limiting scenario of no containment isolation. The analyses without containment isolation are discussed in Section A.9. The isolation failure is assumed to be the largest single opening in the containment isolation system, which is the containment air filtration system line with an 18 inch diameter (area of 254 in^2).

A.9 Sensitivity Analyses

Sensitivity analyses of the success criteria baseline cases are performed to demonstrate the robustness of the success criteria in terms of interactions with other passive and active systems and uncertainties related to the thermal-hydraulics of the system and modeling in the codes (passive system performance). The sensitivity analyses are presented in this section.

A.9.1 Systems Interactions

[LATER - this section will be completed as part of the thermal-hydraulic uncertainty tasks]

A.9.2 Passive System Performance

[LATER - this section will be completed as part of the thermal-hydraulic uncertainty tasks]

A.10 MAAP4 Results

[LATER - this section will be completed as part of the thermal-hydraulic uncertainty tasks]

A.11 References

A-1 EPRI Project 3131-02, "MAAP4 - Modular Accident Analysis Program for LWR Power Plants - Computer Code Manual," Rev. 0, May 1994.

A-2 EPRI TR-100743, "MAAP PWR Application Guidelines for Westinghouse and Combustion Engineering Plants," June 1992.

A-3 "Advanced Light Water Reactor Utility Requirements Document," Volume III, Chapter 1, Appendix A, Revisions 5 & 6, December 1993.

Table A-1

ACTUATION AND TRIP SIGNALS USED IN AP600 MAAP4 ANALYSES

System Trip or Actuation	Signals
Reactor Trip	• Low pressurizer pressure • Low pressurizer level • Low SG narrow range level • CMT actuation signal
Reactor Coolant Pump Trip	• CMT actuation signal
ADS Actuation (Stage 1, 2, 3)	• Low-1 CMT level
ADS Actuation (Stage 4)	• Low-2 CMT level; RCS pressure must be less than 1000 psia for automatic actuation
CMT Actuation	• Low-2 pressurizer level • Low SG wide range level with high hot leg temperature • Low-1 pressurizer pressure • High-1 containment pressure • Low steamline pressure • Low-3 cold leg temperature
PRHR Actuation	• Low SG narrow range level with low SFW flow • Low SG wide range level • CMT actuation signal
Accumulator Injection	• RCS pressure less than 700 psia
NRHR Injection	• RCS pressure less than 175 psia
IRWST Gravity Drain	• Pressure difference between RCS and containment is approximately 15 psia

Table A-2

RCS PRESSURE REQUIREMENTS FOR LOCA CATEGORIES

LOCA Category	Functional Definition	Required RCS Pressure
Large	IRWST gravity drain	~ 50 psia (RCS to containment ΔP of ~15 psia)
Medium	NRHR shutoff head	$\leq$ 175 psia
Intermediate	Fourth-stage ADS line can open without PRHR or earlier stage ADS	$\leq$ 1000 psia
Small	Fourth-stage ADS line cannot open without PRHR or earlier stage ADS	> 1000 psia

<u>Note</u>:
To define the break size that corresponds to each LOCA category, MAAP4 analyses were done to determine the RCS pressure response prior to core uncovery. The results from these cases are summarized in Table A-3.

Table A-3

BREAK SIZE DEFINITION, NO ADS

Pipe ID (in)	RCS Pressure at Core Uncovery (Bars)	RCS Pressure at Core Uncovery (psia)	Initiating Event
1	132.8	1926	SLOCA
1.75	72.56	1052	
2	66.91	970	NLOCA
3	32.29	470	
4	18.11	263	
4.75	12.61	183	
5	11.40	165	MLOCA
6	7.85	114	
7	5.69	83	
8	4.33	63	
8.75	3.73	54	
9	3.58[1]	52[1]	LLOCA

Note:
1. IRWST injects before core uncovers; given pressure is at time of IRWST injection.

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			
	AD1A ADRA	Automatic Actuation: 2/2 stage 1 OR 1/4 stage 2,3	CMT	NRHR			s16k	g10a	t1
	ADV	Automatic Actuation: 1/10 stage 1,2,3,4	CMT	PRHR NRHR			s10	g11	
	ADUM AD1 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)			s6a4	g16	t9a3
	ADT	Manual Actuation: 2/4 Stage 4	Accum	PRHR IRWST(1)			s8a4	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 A-4.1a
MAAP4 Analyses Supporting ILOCA Success Criterion ADU

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap Run	Type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
x1b	baseline	2	-	-	-	1	-	-	1 pump	-	2" cold leg	1147
x1c	support	-	1	-	-	1	-	-	1 pump	-	2" cold leg	no uncov
x1d	support	-	-	1	-	1	-	-	1 pump	-	2" cold leg	no uncov
x1a	support	1	-	-	-	1	-	-	1 pump	-	4.75" cold leg	no uncov
x1b3	support	2	-	-	-	1	-	-	1 pump	-	stuck SV	810
x1b4	support	2	-	-	-	1	-	-	1 pump	-	2" hot leg	1075
x1d2	support	-	-	1	-	1	-	-	1 pump	-	2" hot leg	581

Table A-4.1b
SEQUENCE OF EVENTS FOR ILOCA SUCCESS CRITERION ADU MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x1b	-	-	51	3367	2256	-	-	-	4788	-	4274	52% @ 4778	1147
x1c	-	-	51	3377	-	-	2492	-	3096	-	-	-	-
x1d	-	-	51	3499	-	-	-	3629	3866	-	-	-	-
x1a	-	-	7	1937	803	-	-	-	2367	-	-	-	-
x1b3	-	-	3057	5825	4694	-	-	-	7174	-	6934	74% @ 7235	810
x1b4	-	-	75	3371	2285	-	-	-	4392	-	3991	56% @ 4396	1075
x1d2	-	-	75	3390	-	-	-	3670	2829	-	3794	86% @ 3891	810

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.2a
MAAP4 Analyses Supporting SLOCA Success Criterion AD1A

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
s16k	baseline	2	-	-	-	1	-	-	1 pump	-	0.5" hot leg	1284
s17	support	-	1	-	-	1	-	-	1 pump	-	0.5" cold leg	861
s16	suuport	2	-	-	-	1	-	-	1 pump	-	0.5" cold leg	1261
s16c	support	2	-	-	-	1	-	-	1 pump	-	1.75" cold leg	1176
s16c2	support	-	1	-	-	1	-	-	1 pump	-	1.75" cold leg	no uncov

Table A-4.2b
SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION AD1A MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s16k	-	-	1290	14520	13678	-	-	-	15234	-	14110	32% @ 15220	1284
s17	-	-	830	14380	-	-	13823	-	14424	-	13980	66% @ 14480	861
s16	-	-	830	14480	13584	-	-	-	15148	-	14080	33% @ 15190	1261
s16c	-	-	57	3896	2769	-	-	-	5325	-	4805	49% @ 5308	1176
s16c2	-	-	57	3895	-	2888	-	-	3583	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.3a
MAAP4 Analyses Supporting SLOCA Success Criterion ADV

Case		Equipment Assumptions										Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	
s10	baseline	1	-	-	-	1	-	Yes	1 pump	-	0.5" cold leg	no uncov
s11	support	-	1	-	-	1	-	Yes	1 pump	-	0.5" cold leg	no uncov
s12	support	-	-	1	-	1	-	Yes	1 pump	-	0.5" cold leg	no uncov
s10a	support	1	-	-	-	1	-	Yes	1 pump	-	1.75" cold leg	no uncov

Table A-4.3b
SEQUENCE OF EVENTS FOR SLCOA SUCCESS CRITERION ADV MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Wat[illegible] (%) at T[illegible]	Peak Temp (°F)
s10	-	-	830	-	38219	-	-	-	38684	-	-	[illegible]	-
s11	-	-	830	39430	-	-	38458	-	38830	-	-	[illegible]	-
s12	-	-	830	45750	-	-	-	45145	45241	-	-	-	-
s10a	-	-	57	-	3308	-	-	-	3131	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.4a
MAAP4 Analyses Supporting SGTR Success Criterion AD1A

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
g10a	baseline	2	-	-	-	1	-	-	1 pump	-	SGTR	1109
g10c	support	-	1	-	-	1	-	-	1 pump	-	SGTR	no uncov

Table A-4.4b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION AD1A MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g10a	-	-	115	13650	12650	-	-	-	16434	-	15660	49% @ 16470	1109
g10c	-	-	115	13750	-	-	12882	-	14217	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.5a
MAAP4 Analvses Supporting SGTR Success Criterion ADV

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
g11	baseline	1	-	-	-	1	-	Yes	1 pump	-	SGTR no sec isol	no uncov
g11a	support	-	1	-	-	1	-	Yes	1 pump	-	SGTR no sec isol	no uncov
g11b	support	-	-	1	-	1	-	Yes	1 pump	-	SGTR no sec isol	no uncov

Table A-4.5b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADV MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g111	-	-	100	-	-	-	-	-	2758	-	-	-	-
g11a	-	-	100	-	-	-	-	-	2758	-	-	-	
g11b	-	-	100	-	-	-	-	-	2758	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.6a
MAAP4 Analyses Supporting Transient Success Criterion AD1A

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
t1	baseline	2	-	-	-	1	-	-	1 pump	-	Transient	1305
t2	support	-	1	-	-	1	-	-	1 pump	-	Transient	832

Table A-4.6b
SEQUENCE OF EVENTS FOR TRANSIENT SUCCESS CRITERION AD1A MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
t1	-	-	4698	10080	9096	-	-	-	10842	-	10080	35% @ 10890	1305
t2	-	-	4698	9970	-	-	9336	-	9994	-	9569	73% @ 9769	832

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.7a
MAAP4 Analyses Supporting NLOCA Success Criterion ADUM

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
x2h	baseline	2	-	-	M	-	1	-	1 pump	-	2" hot leg ADS @ 15 min	1127
x2f	support	-	1	-	M	-	1	-	1 pump	-	2" cold leg ADS @ 15 min	no uncov
x2g	support	-	-	1	M	-	1	-	1 pump	-	2" cold leg ADS @ 15 min	no uncov
x2e	support	2	-	-	M	-	1	-	1 pump	-	2" cold leg ADS @ 15 min	1100
x2e2	support	2	-	-	M	-	1	-	1 pump	-	2" cold leg ADS @ 30 min	857
x2h2	support	2	-	-	M	-	1	-	1 pump	-	4.75" hot leg ADS @15 min	no uncov
x2h3	support	2	-	-	M	-	1	-	1 pump	-	4.75" hot leg ADS @ 30 min	980
x2h4	support	-	1	-	M	-	1	-	1 pump	-	4.75" hot leg ADS @ 30 min	964
x2h5	support	-	-	1	M	-	1	-	1 pump	-	4.75" hot leg ADS @ 30	964

Table A-4.7b
SEQUENCE OF EVENTS FOR NLOCA SUCCESS CRITERION ADUM MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x2h	1318	4807	-	-	974	-	-	-	3249	-	1519	77% @ 3244	1127
x2f	1145	2752	-	-	-	-	951	-	1560	-	-	-	-
x2g	1045	1341	-	-	-	-	-	951	1204	-	-	-	-
x2e	1347	4745	-	-	951	-	-	-	3338	-	1751	78% @ 3265	1100
x2e2	2080	4890	-	-	1851	-	-	-	4140	-	3304	85% @ 4112	857
x2h2	512	1545	-	-	912	-	-	-	1203	-	-	-	-
x2h3	512	2053	-	-	1812	-	-	-	1835	-	923	83% @ 1742	980
x2h4	512	1994	-	-	-	-	1812	-	1821	-	923	82% @ 1742	964
x2h5	512	1965	-	-	-	-	-	1812	1816	-	923	82% @ 1742	964

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.8a
MAAP4 Analyses Supporting SLOCA Success Criterion AD1

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
maap run	type	ADS 1	ADS 2/3	ADS 4	ADS M	CMT	ACC	PRHR	NRHR	IRWST		
s19b2	baseline	2	-	-	M	-	1	-	1 pump	-	0.5" hot leg ADS @ 15 min	1266
s20	support	-	1	-	M	-	1	-	1 pump	-	0.5" cold leg ADS @ 30 min	no uncov
s21	support	-	-	1	M	-	1	-	1 pump	-	0.5" cold leg ADS @ 30 min	no uncov
s19b	support	2	-	-	M	-	1	-	1 pump	-	0.5" cold leg ADS @ 15 min	1263
s19	support	2	-	-	M	-	1	-	1 pump	-	0.5" cold leg ADS @ 30 min	1144
s19h	support	2	-	-	M	-	1	-	1 pump	-	1.75" cold leg ADS @30 min	1017
s19i	support	2	-	-	M	-	1	-	1 pump	-	1.75" hot leg ADS @ 30 min	1029
s19k	support	2	-	-	M	-	1	-	1 pump	-	1.75" hot leg ADS @ 15 min	1170

Table A-4.8b
SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION AD1 MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min. Water Level (%) at Time (sec)	Peak Temp (°F)
s19b2	2861	9701	-	-	2190	-	-	-	5289	-	2963	68% @ 5289	1266
s20	2864	4761	-	-	-	-	2630	-	3370	-		-	-
s21	2764	3072	-	-	-	-	-	2630	2918	-	-	-	-
s19b	2449	9256	-	-	1730	-	-	-	4828	-	2549	70% @ 4627	1263
s19	3273	9367	-	-	2630	-	-	-	5744	-	3676	74% @ 5698	1144
s19h	2178	5561	-	-	1861	-	-	-	4281	-	2990	81% @ 4202	1017
s19i	2175	5541	-	-	1901	-	-	-	4205	-	2478	80% @ 4202	1029
s19k	1434	5442	-	-	1001	-	-	-	3439	-	1535	76% @ 3258	1170

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.9a

MAAP4 Analyses Supporting SLOCA Success Criterion ADZ

Case		Equipment Assumptions										Sensitivity Definition	Max Core Temp (°F)
maap Run	type	ADS 1	ADS 2/3	ADS 4	ADS M	CMT	ACC	PRHR	NRHR	IRWST			
s13a	baseline	1	-	-	M	-	1	Yes	1 pump	-		0.5" cold leg ADS @ 15 min	no uncov
s14	support	-	1	-	M	-	1	Yes	1 pump	-		0.5" cold leg ADS @ 30 min	no uncov
s14a	support	-	-	1	M	-	1	Yes	1 pump	-		0.5" cold leg ADS @ 30 min	no uncov
s13	support	1	-	-	M	-	1	Yes	1 pump	-		0.5" cold leg ADS @ 30 min	no uncov
s13g	support	1	-	-	M	-	1	Yes	1 pump	-		1.75" cold leg ADS @ 30	no uncov

Table A-4.9b

SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION ADZ MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s13a	2149	6307	-	-	1730	-	-	-	3326	-	-	-	-
s14	2475	3430	-	-	-	-	2630	-	3148	-	-	-	-
s14a	2475	3031	-	-	-	-	-	2630	2870	-	-	-	-
s13	2475	-	-	-	2630	-	-	-	4588	-	-	-	-
s13g	929	-	-	-	1857	-	-	-	3264	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.10a
MAAP4 Analyses Supporting SGTR Success Criterion AD1

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
g12d	baseline	2	-	-	M	-	1	-	1 pump	-	SGTR ADS @ 15 min	1034
g12b	support	-	-	1	M	-	1	-	1 pump	-	SGTR ADS @ 15 min	no uncov
g12e	support	2	-	-	M	-	1	-	1 pump	-	SGTR ADS @ 30 min	977
g12c	support	-	-	1	M	-	1	-	1 pump	-	SGTR ADS @ 30 min	no uncov

Table A-4.10b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION AD1 MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g12d	1618	10582	-	-	1015	-	-	-	7800	-	6362	77% @ 7879	1034
g12b	1116	1522	-	-	-	-	-	1015	1311	-	-	-	-
g12e	2438	10893	-	-	1915	-	-	-	8530	-	7373	80% @ 8681	977
g12c	2034	2341	-	-	-	-	-	1915	2171	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.11a
MAAP4 Analyses Supporting SGTR Success Criterion ADZ

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
g13	baseline	1	-	-	M	-	1	Yes	1 pump	-	SGTR ADS @ 15 min, no sec isol	no uncov
g13a	support	1	-	-	M	-	1	Yes	1 pump	-	SGTR ADS @ 30 min, no sec isol	no uncov

Table A-4.11b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADZ MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g13	515	2841	-	-	1000	-	-	-	2424	-	-	-	-
g13a	515	2967	-	-	1900	-	-	-	2534	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.12a
MAAP4 Analyses Supporting Transient Success Criterion AD1

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
t3h	baseline	2	-	-	M	-	1	-	1 pump	-	Trans ADS @ 15 min	1280
t4a	support	-	1	-	M	-	1	-	1 pump	-	Trans ADS @ 15 min	no uncov
t4c	support	-	-	1	M	-	1	-	1 pump	-	Trans ADS @ 15 min	no uncov
t3i	support	2	-	-	M	-	1	-	1 pump	-	Trans ADS @ 30 min	1152
t4b	support	-	1	-	M	-	1	-	1 pump	-	Trans ADS @ 30 min	no uncov
t4d	support	-	-	1	M	-	1	-	1 pump	-	Trans ADS @ 30 min	no uncov

Table A-12b
SEQUENCE OF EVENTS FOR SUCCESS CRITERION AD1 MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
t3h	1735	9039	-	-	960	-	-	-	4147	-	1836	69% @ 4269	1280
t4a	1332	3784	-	-	-	-	960	-	1829	-	-	-	-
t4c	1129	1431	-	-	-	-	-	960	1273	-	-	-	-
t3i	2559	9177	-	-	1860	-	-	-	5095	-	2963	73% @ 5085	1152
t4b	2153	5031	-	-	-	-	1860	-	2684	-	-	-	-
t4d	2052	2319	-	-	-	-	-	1860	2159	-	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.13a
MAAP4 Analyses Supporting MLOCA Success Criterion ADM

Case		Equipment Assumptions										Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	
m3g4	baseline	-	-	2	-	1	-	-	-	1 line	5" cold leg, no CI	no uncov
m3n3	support	-	-	2	-	1	-	-	-	1 line	5" hot leg, no CI	no uncov
m3r3	support	-	-	1	-	1	-	-	-	1 line	8.75" hot leg, no CI	no uncov
m4a3	support	-	-	2	-	1	-	-	-	1 line	DVI line, no CI	no uncov

Table A-4.13b
SEQUENCE OF EVENTS FOR MLOCA SUCCESS CRITERION ADM MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
m3g4	-	-	7	1940	-	-	-	1398	-	2151	-	-	-
m3n3	-	-	11	1846	-	-	-	1386	-	1872	-	-	-
m3r3	-	-	3	1615	-	-	-	1148	-	1647	-	-	-
m4a3	-	-	11	2162	-	-	-	1537	-	2342	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.14a
MAAP4 Analyses Supporting NLOCA Success Criterion ADM

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
x3d4	baseline	-	-	2	-	1	-	-	-	1 line	2" hot leg, no CI	959
x3b	support	-	-	1	-	1	-	-	-	1 line	2" hot leg	1230
x3a	support	-	-	1	-	1	-	-	-	1 line	2" cold leg	545
x3j5	support	-	-	2	-	1	-	-	-	1 line	4.75" cold leg, no CI	no uncov

Table A-4.14b
SEQUENCE OF EVENTS FOR NLOCA SUCCESS CRITERION ADM MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x3d4	-	-	73	3391	-	-	-	3771	-	4024	3792	45% @ 3992	959
x3b4	-	-	75	3390	-	-	-	3670	-	4095	3791	39% @ 4092	1230
x3a	-	-	51	2499	-	-	-	3670	-	4755	4633	85% @ 4734	545
x3j5	-	-	7	1958	-	-	-	1428	-	2247	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.15a
MAAP4 Analyses Supporting SLOCA Success Criterion ADA

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
s1t2	baseline	-	3	-	-	1	-	-	-	1 line	1.75" cold leg, no CI	1534
s3b7	support	-	1	1	-	1	-	-	-	1 line	1.75" cold leg, no CI	1285
s1t4	support	-	3	-	-	1	-	-	-	1 line	1.75" hot leg, no CI	1493
s3b2	support	-	1	1	-	1	-	-	-	1 line	0.5 cold leg, no CI	1176
s1u2	support	-	3	-	-	1	-	-	-	1 line	0.5 hot leg, no CI	1220
s1t6	sens	-	3	-	-	1	-	-	-	1 line	1.75" cold leg, no CI, min grav inj	1588
s1t7	sens	-	3	-	-	1	-	-	-	1 line	1.75" cold leg, no CI, min CMT flow	1514

Table A-4.15b
SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION ADA MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s1t2	-	-	57	3814	-	2910	3031	-	-	5108	4617	59% @ 5119	1534
s3b7	-	-	57	3918	-	-	3031	3428	-	4868	4522	69% @ 4925	1285
s1t4	-	-	100	3813	-	2931	3051	-	-	4848	4415	61% @ 4917	1493
s3b2	-	-	830	14340	-	-	13741	13939	-	14475	13940	42% @ 14440	1176
s1u2	-	-	1249	14460	-	13895	14015	-	-	14650	14060	49% @ 14660	1220
s1t6	-	-	59	3793	-	2917	3037	-	-	5101	4595	57% @ 5097	1588
s1t7	-	-	57	3991	-	2921	3040	-	-	5295	4794	59% @ 5295	1514

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.16a

MAAP4 Analyses Supporting SLOCA Success Criterion ADS

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
s4z	baseline	-	3	-	-	1	-	Yes	-	1 line	1.75" hot leg, no CI	1273
s4b2	support	-	-	1	-	1	-	Yes	-	1 line	1.75" cold leg, no CI	no uncov
s4b	support	-	3	-	-	1	-	Yes	-	1 line	1.75" cold leg	1058
s4z1	support	-	3	-	-	1	-	Yes	-	1 line	1.75" hot leg	1080
s4g1	support	-	3	-	-	1	-	Yes	-	1 line	0.5" hot leg, no CI	656
s4g	support	-	3	-	-	1	-	Yes	-	1 line	0.5" hot leg	1091
s4z2	support	-	-	1	-	1	-	Yes	-	1 line	0.5" cold leg, no CI	no uncov

Table A-4.16b

SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION ADS MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s4z	-	-	100	5001	-	4104	4224		-	6570	6203	73% @ 6603	1274
s4b2	-	-	57	5210	-	-	-	4689	-	6176	-	-	-
s4b	-	-	57	4892	-	3951	4071	-	-	6598	6395	82% @ 6695	1058
s4z1	-	-	101	4998	-	4092	4212	-	-	6447	6200	80% @ 6501	1080
s4g1	-	-	1249	43350	-	42644	42754	-	-	45495	45350	88% @ 45550	656
s4g	-	-	1290	39480	-	38568	38688	-	-	42431	41580	64% @ 42690	1091
s4z2	-	-	830	43000	-	-	-	42590	-	43926	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.17a
MAAP4 Analyses Supporting SGTR Success Criterion ADAG

Case		Equipment Assumptions										Sensitivity Definition	Max Core Temp (°F)
		ADS											
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST			
g14e	baseline	-	1	1	-	1	-	-	-	1 line		SGTR, no CI	685

Table A-4.17b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADAG MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g14e	-	-	116	13770	-	-	12926	13366	-	16317	16080	81% @ 16380	685

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.18a
MAAP4 Analyses Supporting SGTR Success Criterion ADS

Case		Equipment Assumptions										Sensitivity Definition	Max Core Temp (°F)
		ADS											
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST			
g15	baseline	-	3	-	-	1	-	Yes	-	1 line		SGTR, no sec isol, no CI	no uncov
g15a	support	-	-	1	-	1	-	Yes	-	1 line		SGTR, no sec isol, no CI	no uncov
g15b	support	-	3	-	-	1	-	Yes	-	1 line		SGTR, no sec isol	no uncov
g15c	support	-	3	-	-	1	-	Yes	-	1 line		SGTR, no sec isol	no uncov

Table A-4.18b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADS MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g15	-	-	100	10090	-	9006	9126	-	-	10701	-	-	-
g15a	-	-	100	11330	-	-	-	10757	-	11738	-	-	-
g15b	-	-	100	10180	-	9049	9169	-	-	10722	-	-	-
g15c	-	-	100	11330	-	-	-	10770	-	11527	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.19a

MAAP4 Analyses Supporting Transient Success Criterion ADA

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
t5t	baseline	-	3	-	-	1	-	-	-	1 line	Trans, no CI	1262
t7a1	support	-	1	1	-	1	-	-	-	1 line	Trans, no CI	1194
t7a2	support	1	-	1	-	1	-	-	-	1 line	Trans, No CI	1252

Table A-4.19b

SEQUENCE OF EVENTS FOR TRANSIENT SUCCESS CRITERION ADA MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
t5t	-	-	4847	9774	-	9057	9177	-	-	10033	9272	50% @ 10080	1262
t7a1	-	-	4847	9773	-	-	9177	9387	-	10028	9272	52% @ 10080	1194
t7a2	-	-	4847	9981	8937	-	-	9773	-	10720	10180	50% @ 10690	1251

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.20a
MAAP4 Analyses Supporting MLOCA Success Criterion ADQ

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
m6e5	baseline	-	-	2	M	-	1	-	1	1 line	8.75" hot leg, ADS @ 30 min, no CI	1554
m6e6	support	-	-	2	M	-	1	-	1	1 line	8.75" hot leg, ADS @ 15 min, no CI	no uncov
m6e	support	-	-	2	M	-	1	-	1	1 line	5" hot leg, ADS @ 30 min, no CI	740
m6e2	support	-	-	2	M	-	1	-	1	1 line	5" cold leg, ADS @ 30 min, no CI	no uncov
m6e4	support	-	-	2	M	-	1	-	1	1 line	5" hot leg, ADS @ 15 min, no CI	no uncov
m6e8	support	-	-	2	M	-	1	-	1	1 line	8.75" hot leg, ADS @ 25 min, no CI	1199
m6e5a	sens	-	-	2	M	-	1	-	1	1 line	8.75" hot leg, ADS @ 30, no CI, min accm flow	1540
m6e5b	sens	-	-	2	M	-	1	-	1	1 line	8.75 hot leg, ADS @ 30, no CI, min grav inj	1556

Table A-4.20b
SEQUENCE OF EVENTS FOR MLOCA SUCCESS CRITERION ADQ MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
m6e5	100	682	-	-	-	-	-	1802	-	1803	1122	40% @ 1738	1554
m6e6	100	682	-	-	-	-	-	902	-	969	-	-	-
m6e	412	1930	-	-	-	-	-	1811	-	2053	1134	86% @ 1740	740
m6e2	407	1937	-	-	-	-	-	1806	-	2111	-	-	-
m6e4	412	1074	-	-	-	-	-	911	-	1266	-	-	-
m6e8	100	682	-	-	-	-	-	1502	-	1510	1122	56% @ 1527	1199
m6e5a	100	691	-	-	-	-	-	1802	-	1803	1119	41% @ 1735	1540
m6e5b	100	682	-	-	-	-	-	1802	-	1803	1122	40% @ 1738	1556

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A4.21a
MAAP4 Analyses Supporting NLOCA Success Criterion ADQ

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
x4g	baseline	-	-	2	M	-	1	-	-	1 line	4.75" hot leg, ADS @ 30 min, no CI	969
x4g2	support	-	-	2	M	-	1	-	-	1 line	4.75" hot leg, ADS @ 15 min, no CI	no uncov
x4e4	support	-	-	2	M	-	1	-	-	1 line	2" hot leg, ADS @ 15 min, no CI	no uncov
x4f2	support	-	-	2	M	-	1	-	-	1 line	2" hot leg, ADS @ 30 min	no uncov
x4d	support	-	-	1	M	-	1	-	-	1 line	2" hot leg, ADS @ 30 min	714
x4d2	support	-	-	1	M	-	1	-	-	1 line	2" hot leg, ADS @ 15 min	1058

Table A-4.21b
SEQUENCE OF EVENTS FOR NLOCA SUCCESS CRITERION ADQ MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x4g	516	1946	-	-	-	-	-	1812	-	2082	925	82% @ 1539	969
x4g2	516	1085	-	-	-	-	-	912	-	1293	-	-	-
x4e4	1028	1182	-	-	-	-	-	973	-	2359	-	-	-
x4f2	1943	2066	-	-	-	-	-	1875	-	3920	-	-	-
x4d	1943	2163	-	-	-	-	-	1875	-	3920	3803	82% @ 3905	715
x4d2	1117	1343	-	-	-	-	-	975	-	2990	2775	70% @ 2982	1058

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.22a
MAAP4 Analyses Supporting SLOCA Success Criterion ADT

Case		Equipment Assumptions										Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	
s6a4	baseline	-	-	2	M	-	1	-	-	1 line	0.5" cold leg, ADS @ 15 min, no CI	no uncov
s6a3	support	-	-	2	M	-	1	-	-	1 line	0.5" cold leg, ADS @ 30 min, no CI	no uncov
s6a1	support	-	-	1	M	-	1	-	-	1 line	0.5" cold leg, ADS @ 30 min, no CI	1867
s6a2	support	-	-	1	M	-	1	-	-	1 line	1.75" cold leg, ADS @ 30 min, no CI	1700

Table A-4.22b
SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION ADT MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s6a4	1828	1966	-	-	-	-	-	1730	-	3409	-	-	-
s6a3	2767	2858	-	-	-	-	-	2630	-	3769	-	-	-
s6a1	2767	3043	-	-	-	-	-	2630	-	6401	5769	47% @ 6377	1867
s6a2	1967	2187	-	-	-	-	-	-1857	-	5256	4588	52% @ 5202	1700

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.23a
MAAP4 Analyses Supporting SLOCA Success Criterion ADT

Case		Equipment Assumptions										Sensitivity Definition	Max Core Temp (°F)
		ADS											
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST			
s8a4	baseline	-	-	2	M	-	1	Yes	-	1 line		0.5 cold leg, ADS @ 15, no CI	no uncov
s8a3	support	-	-	2	M	-	1	Yes	-	1 line		0.5 cold leg, ADS @ 30, no CI	no uncov
s8a1	support	-	-	1	M	-	1	Yes	-	1 line		0.5 cold leg, ADS @ 30, no CI	1839
s8a2	support	-	-	1	M	-	1	Yes	-	1 line		1.75 cold leg, ADS @ 30, no CI	1362

Table A-4.23b
SEQUENCE OF EVENTS FOR SLOCA SUCCESS CRITERION ADT MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s8a4	1837	1969	-	-	-	-	-	1730	-	3460	-	-	-
s8a3	2463	2869	-	-	-	-	-	2630	-	3867	-	-	-
s8a1	2463	3024	-	-	-	-	-	2630	-	6428	5795	48% @ 6408	1839
s8a2	205	1201	-	-	-	-	-	1805	-	3438	3157	65% @ 3464	1326

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.24a
MAAP4 Analyses Supporting SGTR Success Criterion ADT

Case		Equipment Assumptions										
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	Max Core Temp (°F)
g16	baseline	-	-	2	M	-	1	-	-	1 line	SGTR, ADS @ 15 min, no CI	no uncov
g16a	support	-	-	2	M	-	1	-	-	1 line	SGTR, ADS @ 30 min, no CI	no uncov

Table A-4.24b
SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADT MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g16	1123	1254	-	-	-	-	-	1015	-	1351	-	-	-
g16a	2042	2125	-	-	-	-	-	1915	-	2356	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.25a

MAAP4 Analyses Supporting SGTR Success Criterion ADT

Case		Equipment Assumptions										Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	
g17	baseline	-	-	2	M	-	1	Yes	-	1 line	SGTR, ADS @ 15, no sec isol, no CI	no uncov
g17a	support	-	-	2	M	-	1	Yes	-	1 line	SGTR, ADS @ 30, no sec isol, no CI	no uncov

Table A-4.25b

SEQUENCE OF EVENTS FOR SGTR SUCCESS CRITERION ADT MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
g17	511	1232	-	-	-	-	-	1000	-	2611	-	-	-
g17a	515	2093	-	-	-	-	-	1899	-	2581	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.26a
MAAP4 Analyses Supporting Transient Success Criterion ADT

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	type	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
t9a3	baseline	-	-	2	M	-	1	-	-	1 line	Trans, ADS @ 15, no CI	no uncov
t9a1	support	-	-	1	M	-	1	-	-	1 line	Trans, ADS @ 15, no CI	> 2200
t9a2	support	-	-	1	M	-	1	-	-	1 line	Trans, ADS @ 30, no CI	1872

Table A-4.26b
SEQUENCE OF EVENTS FOR TRANSIENT SUCCESS CRITERION ADT MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
t9a3	1028	1195	-	-	-	-	-	960	-	2520	-	-	-
t9a1	1128	1425	-	-	-	-	-	960	-	4592	3913	44% @ 4625	>2200
t9a2	2053	2293	-	-	-	-	-	1860	-	5681	5016	50 % @ 5628	1872

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A4.27a

MAAP4 Analyses Supporting ADS Manual Action Delay Time from Low-1 CMT Level (Auto Failed)

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	Succ. Crit	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
x1bop1	ADU	2	-	-	M	1	-	-	1	-	2" cold leg, ADS @ 30	1147
s16kop1	AD1A	2	-	-	M	1	-	-	1	-	0.5" hot leg, ADS @ 30	1565
s10op1	ADV	1	-	-	M	1	-	Yes	1	-	0.5" cold leg, ADS @ 30	no uncov
g10aop1	AD1A	2	-	-	M	1	-	-	1	-	SGTR, ADS @ 30	1542
g11op1	ADV	1	-	-	M	1	-	Yes	1	-	SGTR, no sec isol, ADS @ 30	no uncov
t1op1	AD1A	2	-	-	M	1	-	-	1	-	Trans, ADS@ 30	1109
m3g4op1	ADM	-	-	2	M	1	-	-	-	1	5" cold leg, no CI, ADS @ 30	no uncov
x3d4op1	ADM	-	-	2	M	1	-	-	-	1	2" hot leg, no CI, ADS @ 30	no uncov
s1t2op1	ADA	-	3	-	M	1	-	-	-	1	1.75" cold leg, no CI, ADS @ 30	>2200
s4zop1	ADS	-	3	-	M	1	-	Yes	-	1	1.75 cold leg, no CI, ADS @ 30	1520
g14eop1	ADAG	-	1	1	M	1	-	-	-	1	SGTR, no CI, ADS @ 30	1594
g15op1	ADS	-	3	-	M	1	-	Yes	-	1	SGTR, no CI, ADS @ 30	663
t5top1	ADA	-	3	-	M	1	-	-	-	1	Trans, no CI, ADS @ 30	1047

Table A-4-27b

SEQUENCE OF EVENTS FOR ADS DELAY MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x1bop1	-	-	51	3262	1851	-	-	-	4796	-	4266	53% @ 4772	1147
si6kop1	-	-	1290	4976	3090	-	-	-	6693	-	5883	37% @ 6689	1565
s10op1	-	-	830	6526	2630	-	-	-	4022	-	-	-	-
g10aop1	-	-	116	3682	1916	-	-	-	7574	-	6699	36% @ 7603	1542
g11op1	-	-	100	5705	1400	-	-	-	2611	-	-	-	-
t1op1	-	-	4698	8250	6498	-	-	-	9934	-	9286	52% @ 9997	1109
m3g4op1	-	-	7	1843	-	-	-	1806	-	2441	-	-	-
x3d4op1	-	-	73	3361	-	-	-	1873	-	3131	-	-	-
slt2op1	-	-	57	2851	-	1857	1857	-	-	4902	3752	14% @ 8160	>2200
s4zop1	-	-	100	3475	-	1900	1900	-	-	5045	4476	60% @ 5077	1520
g14eop1	-	-	116	3472	-	-	1916	1916	-	[illegible]	3572	18% @ 3572	1594
g15op1	-	-	100	3534	-	1900	1900	-	-	5301	5137	85% @ 5337	663
t5top1	-	-	4847	7936	-	6647	6647	-	-	9204	9204	76% @ 9245	1047

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.28a MAAP4 Analyses Supporting CMT Manual Action Delay Time from CMT Signal (Auto Failed)												
Case		Equipment Assumptions										Max Core Temp (°F)
maap run	Succ. Crit	ADS 1	ADS 2/3	ADS 4	ADS M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	
x1bop2	ADU	2	-	-	-	1	-	-	1	-	2" cold leg, CMT @ 10	1128
s16kop2	AD1A	2	-	-	-	1	-	-	1	-	0.5" hot leg, CMT @ 20	1269
s10op2	ADV	1	-	-	-	1	-	Yes	1	-	0.5" cold leg, CMT @ 20	no uncov
g10aop2	AD1A	2	-	-	-	1	-	-	1	-	SGTR, CMT @ 30	1098
g11op2	ADV	1	-	-	-	1	-	Yes	1	-	SGTR, no sec isol, CMT @ 30	no uncov
t1op2	AD1A	2	-	-	-	1	-	-	1	-	Trans, CMT@ 30	1026
m3g4op2	ADM	-	-	2	-	1	-	-	-	1	5" cold leg, no CI, CMT @ 10	no uncov
x3d4op2	ADM	-	-	2	-	1	-	-	-	1	2" hot leg, no CI, CMT @ 10	846
s1t2op2	ADA	-	3	-	-	1	-	-	-	1	1.75" cold leg, no CI, CMT @ 20	1622
s4zop2	ADS	-	3	-	-	1	-	Yes	-	1	1.75 cold leg, no CI, CMT @ 20	1334
g14eop2	ADAG	-	1	1	-	1	-	-	-	1	SGTR, no CI, CMT @ 30	>2200
g15op2	ADS	-	3	-	-	1	-	Yes	-	1	SGTR, no CI, CMT @ 30	no uncov
t5top2	ADA	-	3	-	-	1	-	-	-	1	Trans, no CI, CMT @ 30	1241

DRAFT

Table A-4.28b
SEQUENCE OF EVENTS FOR CMT DELAY MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
x1bop2	-	-	651	3274	2203	-	-	-	4796	-	4282	53% @ 4788	1128
s16kop2	-	-	2490	14610	13711	-	-	-	15276	-	14200	32% @ 15310	1269
s10op2	-	-	2029	-	43798	-	-	-	44496	-	-	-	-
g10aop2	-	-	1915	14000	12927	-	-	-	16698	-	16020	50% @ 16720	1098
g11op2	-	-	1899	-	-	-	-	-	2737	-	-	-	-
t1op2	-	-	6498	8063	6960	-	-	-	9992	-	5828	33% @ 6437	1026
m3g4op2	-	-	607	2260	-	-	-	1681	-	2473	-	-	-
x3d4op2	-	-	673	3412	-	-	-	3499	-	3796	3613	53% @ 3814	[illegible]
s1t2op2	-	-	1257	3784	-	2829	2949	-	-	5359	4787	55% @ 5388	1623
s4zop2	-	-	1300	5107	-	4025	4146	-	-	6737	6208	66% @ 6809	1334
g14eop2	-	-	1315	13820	-	-	13040	13329	-	18376	16130	0% @ 22240	>2200
g15op2	-	-	1300	10060	-	8922	9042	-	-	10769	-	-	-
t5top2	-	-	6647	8156	-	7229	7349	-	-	9897	5727	22% @ 6647	1241

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-4.29a
MAAP4 Analyses Supporting PRHR Manual Action Delay Time from PRHR Signal (Auto Failed)

Case		Equipment Assumptions									Sensitivity Definition	Max Core Temp (°F)
		ADS										
maap run	Succ. Crit	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST		
s10op3	ADU	1	-	-	-	1	-	Yes	1	-	0.5" cold leg, PRHR @ 30	no uncov
g11op3	AD1A	1	-	-	-	1	-	Yes	1	-	SGTR, no sec isol, PRGR @ 30	no uncov
s4zop3	ADV	-	3	-	-	1	-	Yes	-	1	1.75" cold leg, no CI, PRHR @ 30	1043
g15op3	AD1A	-	3	-	-	1	-	Yes	-	1	SGTR,no sec isol, no CI, PRHR @ 30	no uncov

Table A-4.29b
SEQUENCE OF EVENTS FOR PRHR DELAY MAAP4 ANALYSES

Case	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
s10op3	-	-	830	38010	35889	-	-	-	37451	-	-	-	-
g11op3	-	-	100	-	-	-	-	-	3274	-	-	-	-
s4zop	-	-	100	4183	-	3285	3405	-	-	5625	5385	79% @ 5686	1040
g15op	-	-	100	7900	-	6883	7003	-	-	8435	-	-	-

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

DRAFT

Table A-4.30a

MAAP4 Analyses Supporting RNS Manual Action Delay Time from Break Initiation (Auto Failed)

Case		Equipment Assumptions										
		ADS										Max Core Temp
maap run	Succ. Crit	1	2/3	4	M	CMT	ACC	PRHR	NRHR	IRWST	Sensitivity Definition	(°F)
m2c2	ADU	-	-	-	-	-	1	-	1	-	8.75" hot leg, NRHR @ 30	1353
m2c3	AD1A	-	-	-	-	-	1	-	1	-	8.75" hot leg, NRHR @ 20	558
m2c	ADV	-	-	-	-	-	1	-	1	-	8.75" cold leg	no uncov
m2b	AD1A	-	-	-	-	-	1	-	1	-	5" hot leg (note 1)	880
m2	ADV	-	-	-	-	-	1	-	1	-	5" cold leg (note 1)	671
m1	AD1A	-	-	-	-	1	-	-	1	-	5" cold leg (note 1)	no uncov
m1a	ADM	-	-	-	-	1	-	-	1	-	5" hot leg (note 1)	688

Note: 1 - NRHR cannot inject until after 30 minutes.

Table A-4.30b

SEQUENCE OF EVENTS FOR RNS DELAY MAAP4 ANALYSES

	Accum. Inj (sec)		CMT Injection (sec)		Opening of ADS Valves (sec)				Start of Injection (sec) *		Core Uncovery *		
Case	Start	Empty	Start	Empty	1	2	3	4	NRHR	IRWST	Start (sec)	Min Water Level (%) at Time (sec)	Peak Temp (°F)
m2c2	101	686	-	-	-	-	-	-	1800	-	1120	67% @ 1425	1353
m2c3	101	686	-	-	-	-	-	-	1200	-	1120	91% @ 1120	558
m2c	101	749	-	-	-	-	-	-	359	-	-	-	-
m2b	410	2468	-	-	-	-	-	-	1993	-	1130	85% @ 1947	880
m2	406	2953	-	-	-	-	-	-	2631	-	2259	90% @ 2560	671
m1	-	-	7	1858	-	-	-	-	3860	-	-	-	-
m1a	-	-	11	2048	-	-	-	-	4045	-	3393	48% @ 4012	1264

* Times for the start of NRHR, IRWST core uncovery and minimum water level are from MAAP4 output that does not capture output at every timestep. Therefore, the times listed in these sections are not exact and typically may differ from the actual analytical prediction by ±100 seconds

Table A-5

SLOCA CASES FOR ADS MANUAL ACTUATION (NRHR OPERATION)

Case	Operator Action Time	CMT Actuation Signal	ADS Lines Manually Opened
S19b	15 minutes	830 seconds	1730 seconds
S19d	120 minutes	830 seconds	8030 seconds
S19g	210 minutes	830 seconds	13430 seconds

Table A-6

AUTOMATIC ADS SUCCESS CRITERIA FOR IRWST GRAVITY DRAIN, NO PRHR

Success Criteria Case	Success Criteria Definition	MAAP4 Case	MAAP4 Peak Core Temperature (°F)
ADM	2/4 stage 4	MLOCA, m3n	No Core Uncovery
		NLOCA, x3b3	779
ADAB, ADAL, ADA	3/4 stage 2,3 OR 1/6 stage 1,2,3 and 1/4 stage 4	SLOCA, s1	1108
		SGTR, g4	1335
		Transient, t5	1158

Table A-7

TRANSIENT CASES FOR ADS MANUAL ACTUATION (IRWST GRAVITY DRAIN)

Case	Operator Action Time	PRHR Actuation Signal	ADS Lines Manually Opened
T9a	30 minutes	60 seconds	1860 seconds
T9b	90 minutes	60 seconds	5460 seconds
T9d	150 minutes	60 seconds	9060 seconds

Table A-8

NLOCA CASES FOR ADS MANUAL ACTUATION (IRWST GRAVITY DRAIN)

Case	Operator Action Time	CMT Actuation Signal	ADS Lines Manually Opened
X4d2	15 minutes	75 seconds	975 seconds
X4d4	60 minutes	75 seconds	3675 seconds

Table A-9

APPROXIMATE TIMES THAT NRHR IS CREDITED IN MAAP4 ANALYSES

Initiating Event	Time of NRHR Operation, After ...			
	Event Initiation	PRHR Actuation Signal	CMT Actuation Signal	ADS Actuation
NLOCA	40 minutes	40 minutes	40 minutes	20 minutes
SLOCA	85 minutes	85 minutes	85 minutes	25 minutes
SGTR	2 hours	2 hours	2 hours	30 minutes
Transient	3 hours	3 hours	90 minutes	25 minutes

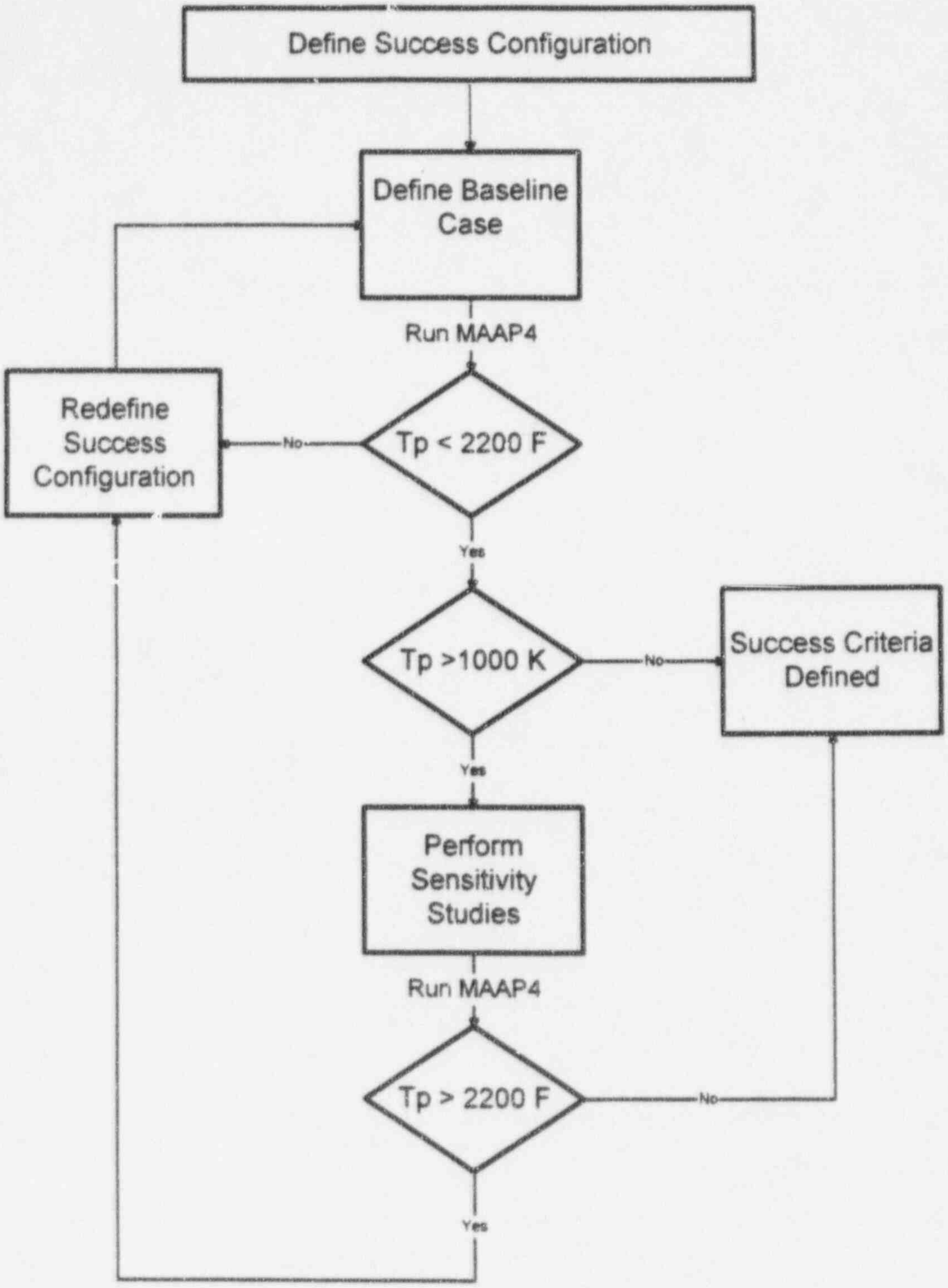

Figure A-1
Process for Justification of Success Criteria
Defined With MAAP4 Analyses

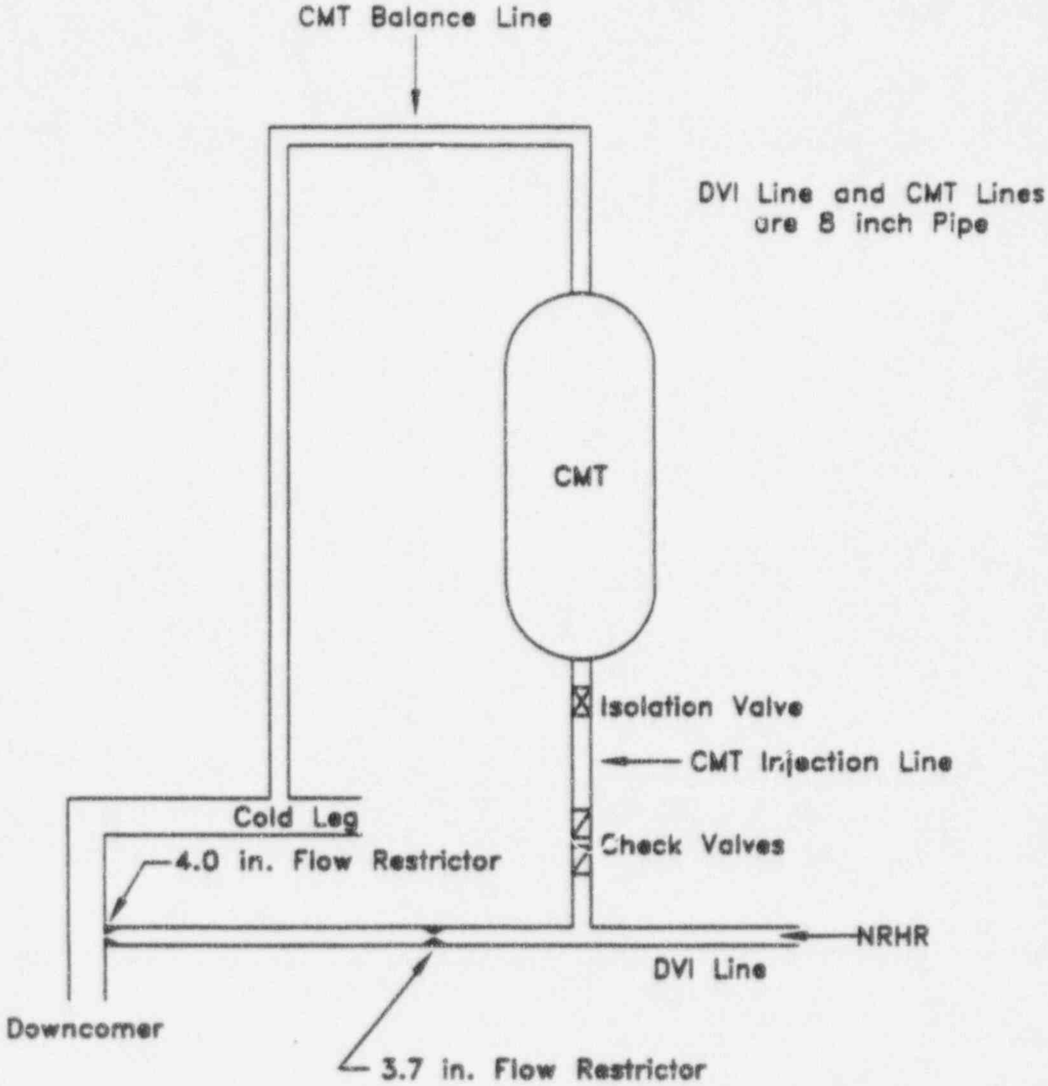

Figure A-2
Diagram of CMT and DVI Lines