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AREVA NP Environmental Report
Standard Design Certification

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AREVA NP Inc.

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
001	Section 3.0 Section 4.0	Sections 3.0 and 4.0 were updated as a result of responses to RAI 6, Question 19-121, RAI 45, Question 19-190, RAI 133, Question 19-230, Question 19-237, Question 19-238, and RAI 236, Question 19-313 Editorial changes were made throughout the document.

Contents

List of Tables

Nomenclature

Acronym	Definition
AAC	Alternate Alternating Current
AC	Alternating Current
AMSAC	ATWS Mitigation System Actuation Circuitry
AOC	Averted Off-site Property Damage Costs
AOE	Averted Occupational Exposures
AOSC	Averted On-site Costs
APE	Averted Public Exposure
ATWS	Anticipated Transient Without Scram
AVS	Annulus Ventilation System
BWR	Boiling Water Reactor
CCWS	Component Cooling Water System
CRDM	Control Rod Drive Mechanism
CDF	Core Damage Frequency
CGCS	Combustible Gas Control System
COE	Cost of Enhancement
CVCS	Chemical Volume and Control System
DC	Direct Current
DCER	Design Certification Environmental Report
DWS	Demineralized Water System
EBS	Extra Borating System
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generators
EFW	Emergency Feedwater
EFWS	Emergency Feedwater System
EOP	Emergency Operating Procedures
ESWS	Emergency Service Water System
FSAR	Final Safety Analysis Report
HMDS	Hydrogen Mixing Distribution System

Acronym	Definition
HVAC	Heating, Ventilation, and Air Conditioning
IRWST	In-containment Refueling Water Storage Tank
ISLOCA	Interfacing System Loss of Coolant Accident
LDS	Leak Detection System
LHSI	Low Head Safety Injection
LOCA	Loss of Coolant Accident
LOOP	Loss Of Off-site Power
LRF	Large Release Frequency
MFW	Main Feedwater
MHSI	Medium Head Safety Injection
MSIV	Main Steam Isolation Valve
MSLB	Main Steam Line Break
MSRIV	Main Steam Relief Isolation Valve
MSRT	Main Steam Relief Train
MSRV	Main Steam Relief Valves
MSS	Main Steam System
MSSV	Main Steam Safety Valves
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
PAR	Passive Autocatalytic Recombiner
PDS	Primary Depressurization System
PRA	Probabilistic Risk Assessment
PSRV	Pressurizer Safety Relief Valve
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RCP	Reactor Coolant Pump
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RHR	Residual Heat Removal

Acronym	Definition
SAHRS	Severe Accident Heat Removal System
SAMDA	Severe Accident Mitigation Design Alternatives
SBO	Station Blackout
SLC	Standby Liquid Control
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
SCWS	Safety Chilled Water System
SIS	Safety Injection System
SRV	Safety Relief Valve
SSS	Start-up Shutdown System
SW	Service Water
UPS	Uninterruptible Power Supply

Executive Summary

The objective of this Design Certification Environmental Report (DCER) is to satisfy the NRC's regulatory requirements in 10 CFR 52.47(b)(2), specifying that an application for design certification must include an environmental report, and in 10 CFR 51.55(a), which states that the DCER "must address the costs and benefits of severe accident mitigation design alternatives, and the bases for not incorporating severe accident mitigation design alternatives in the design to be certified."

This report details the SAMDA assessment performed in support of the U.S. EPR design certification. The principal element of the SAMDA assessment is a maximum benefit analysis. The maximum benefit equates to the cost obtained by the elimination of all severe accident risk. It serves to aid the SAMDA candidate screening and the cost-benefit analysis for SAMDA candidates selected for further consideration.

A total of 167 SAMDA candidates developed from industry and U.S. EPR documents were evaluated in this analysis. The low probability of core damage events in the U.S. EPR design coupled with reliable severe accident mitigation features provide significant protection to the public and the environment. A detailed analysis of specific severe accident mitigation design alternatives from previous industry studies, and from U.S. EPR probabilistic risk assessment (PRA) insights, was performed against broad acceptance criteria. None of the SAMDA candidates met the criteria; therefore, the overall conclusion is that no additional plant modifications are cost beneficial to implement due to the robust design of the U.S. EPR with respect to prevention and mitigation of severe accidents.

1.0 INTRODUCTION

The U.S. EPR design is an evolutionary pressurized water reactor (PWR) that incorporates proven technology within an optimized configuration to enhance safety. The U.S. EPR plant has been designed for the prevention and mitigation of design basis accidents as well as beyond design basis (i.e., severe) accidents. The ultimate design objective is to restrict the radiological consequences to the immediate vicinity of the plant and reduce the likelihood of stringent countermeasures such as evacuation or relocation of the neighboring population. The U.S. EPR design takes full advantage of the insights gained from operating experience (e.g., individual plant examinations), PRA, severe accident research, and accident analysis by incorporating features to reduce the likelihood of severe accidents, and in the unlikely occurrence of a severe accident, to minimize and mitigate the consequences of such an accident.

The objective of this DCER is to satisfy the NRC's regulatory requirements in 10 CFR 52.47(b)(2), specifying that an application for design certification must include an environmental report, and in 10 CFR 51.55(a), which states that the DCER "must address the costs and benefits of severe accident mitigation design alternatives, and the bases for not incorporating severe accident mitigation design alternatives in the design to be certified."

This report provides details of the SAMDA assessment performed in support of the U.S. EPR design certification. The principal element of the SAMDA assessment is a maximum benefit analysis. The maximum benefit equates to the cost obtained by the elimination of all severe accident risk. It serves to aid the SAMDA candidate screening and the cost-benefit analysis for SAMDA candidates selected for further consideration.

This DCER, is expected to form the basis of the NRC's environmental assessment, as addressed in 10 CFR 51.30(d), to comply with the requirements of Section 102(2)(c) of the National Environmental Policy Act of 1969 (NEPA)[1].

[1] The U.S. Court of Appeals decision, in *Limerick Ecology Action v. NRC*, 869 F.2d 719 (3rd Cir. 1989), has been interpreted to require the NRC to include consideration of SAMDAs in the environmental impact review performed under the referenced section of NEPA.

2.0 METHODOLOGY

The methodology used to develop a comprehensive list of U.S. EPR SAMDA candidates, calculate the maximum benefit, and define the screening criteria used to categorize the SAMDA candidates is addressed in this section.

For the purpose of this evaluation, SAMDA candidates are defined as enhancements to the U.S. EPR plant design that have the potential to prevent core damage and significant releases from the containment. The SAMDA candidates can be characterized as both hardware (i.e., physical modification of plant structures, systems and components) and non-hardware (i.e., operation and maintenance programs) changes. The SAMDA candidates encompassing non-hardware changes are beyond the scope of the U.S. EPR Design Certification application. The comprehensive list of SAMDA candidates were developed for the U.S. EPR design by reviewing industry documents and considering plant-specific enhancements. The U.S. EPR design is an evolutionary PWR; therefore, particular interest was paid to existing SAMDA candidates for PWRs. The primary industry document supporting the development of U.S. EPR SAMDA candidates is NEI 05-01, Severe Accident Mitigation Alternatives (SAMA) Analysis, Guidance Document (Reference 1). The candidate selection method presented in NEI 05-01 for completing a SAMDA analysis relies on guidance from NUREG/BR-0184 (Reference 2), experience gained through past SAMDA analyses, and insights gained from a review of previous NRC evaluations of SAMDA analyses and associated requests for additional information.

The results of the U.S. EPR Level 1 PRA were used in the development of plant-specific SAMDA candidates. The Level 1 PRA estimates the core damage frequency (CDF) considering a spectrum of initiating events (e.g., transients, loss of coolant accidents (LOCA), loss of Alternating Current (AC)/Direct Current (DC) bus) and the subsequent failure (or success) of various plant mitigation systems and their associated support systems. The details of the selection of initiating events and success criteria for the mitigation system for the U.S. EPR design are addressed in Section 19.1 of the Final

Safety Analysis Report (FSAR). For each initiating event, an event tree is developed to provide a graphical representation of the potential core-damage sequences. The top functional events (i.e., headers) in these event trees reflect the success or failure (as defined in the mission success criteria) of the systems and operator actions required to mitigate the initiating events. For each mitigation and support system considered in the event trees, a fault tree is constructed to quantitatively estimate the unavailability of the system to perform the required accident mitigation function(s). The fault trees and event trees are solved in an integrated fashion using a PRA computer code to estimate CDF and to support the quantification of large release frequency (LRF). Fault tree quantification software provides qualitative results in the form of cutsets. The quantification results are reviewed and significant contributors to the CDF are identified (e.g., using importance measures). The cutsets provide the sequence of events (leading to core damage) and identify the contribution the sequence of events has to the CDF. These cutsets are used to develop the plant-specific SAMDA candidates.

The maximum benefit evaluation uses the guidance provided in NEI 05-01 (Reference 1) and NUREG/BR-0184 (Reference 2) to determine the severe accident impact. The severe accident impact is determined by summing the occupational exposure cost, on-site cost, public exposure cost, and off-site property damage cost. Occupational exposure and on-site costs consider the monetary impact of both the immediate and long-term on-site effects including the cost related to staff exposure, cleanup, decontamination, and replacement costs. The public exposure and off-site damage costs consider the Level 3 PRA performed for the U.S. EPR design.

The U.S. EPR Level 3 PRA was developed to provide an overall risk perspective of the U.S. EPR design. For the Level 3 PRA model development and execution, the MELCOR accident consequence code system (MACCS2) computer code was used. MACCS2 is an atmospheric dispersion and deposition code that is used to estimate the radiological doses, health effects, and economic consequences that could result from postulated accidental releases of radioactive materials (e.g., damaged fuel, fission products) into the atmosphere. MACCS2 is traditionally used for the quantification of Level 3 PRA.

The SAMDA candidates developed for the U.S. EPR design were qualitatively screened using seven categories. The intent of the screening is to identify the candidates for further risk-benefit calculation. For each SAMDA candidate, a screening criterion and basis for screening are identified to justify the implementation or exclusion of the SAMDA candidate in the U.S. EPR design. The seven categories used in the screening include:

- Not applicable.
- Already implemented.
- Combined.
- Excessive implementation cost.
- Very low benefit.
- Not required for design certification.
- Considered for further evaluation.

The screening categories were chosen based on guidance from NEI 05-01. (Reference 1).

3.0 SAMDA CANDIDATE DEVELOPMENT

The comprehensive list of SAMDA candidates were developed for the U.S. EPR design by reviewing industry documents for generic PWR enhancements and considering plant-specific enhancements. The primary industry document supporting the development of U.S. EPR generic PWR SAMDA candidates is NEI 05-01 (Reference 1).

The cutsets from the U.S. EPR Level 1 and Level 2 PRA were evaluated to identify plant-specific modifications for inclusion in the comprehensive list of SAMDA candidates.

The top 100 Level 1 cutsets include the cutsets contributing more than one percent to the total CDF. For the U.S. EPR design, this equates to approximately fifty percent of the total CDF. The percentage of the individual contribution to the total CDF for the 101^{st} cutset was 0.10 percent. The cutset contribution to the U.S. EPR CDF is evenly distributed and shows no outliers. The individual contribution of any one of the top 100 cutsets is small (the top cutset contributes approximately six percent to the total CDF). If a cutset was removed through added plant redundancy of diversity, it would have a small impact on the total U.S. EPR CDF.

The U.S. EPR top 100 LRF cutsets were evaluated to identify modifications that would reduce the likelihood of the occurrence of significant containment challenges. This population of cutsets specifically excluded the contribution to LRF of the core damage sequences due to main steam line break (MSLB) inside containment with main feedwater (MFW) unisolated. This exclusion verifies that the overly conservative treatment of an event does not artificially reduce the importance of other containment failure mechanisms, as shown in the Response to Request for Additional Information (RAI) 22, Supplement 3, Question 19-160. The top 100 LRF cutsets include the cutsets contributing greater than one percent to the total LRF. For the U.S. EPR design, this equates to approximately fifty percent of the total LRF and includes low importance cutsets that contribute only 0.10 percent each to the total LRF.

Risk-significant design alternatives for the U.S. EPR design have been addressed by a detailed evaluation of the top 100 CDF and LRF cutsets to identify plant-specific modification for inclusion in the comprehensive list of U.S. EPR SAMDA candidates. Through the evaluation of the top 100 CDF cutsets, numerous U.S. EPR specific operator actions and hardware-based SAMDA candidates were developed. When evaluating the top 100 LRF cutsets, no additional SAMDA candidates were identified. Generic SAMDA candidates from NEI 05-01 (Reference 1) were determined to be applicable to U.S. EPR specific SAMDA candidates through the evaluation of the top 100 CDF and LRF cutsets. These SAMDA candidates were not duplicated in the analysis.

The comprehensive list of SAMDA candidates considered for implementation in the U.S. EPR design are provided in Table 3-1. Each SAMDA candidate is categorized and identified according to a global modification identifier.

Table 3-1 List of SAMDA Candidates

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
Enhancements Related to AC and DC Power		
AC/DC-01	Provide additional DC battery capacity.	This SAMDA would ensure longer battery life during a station blackout (SBO) and consequently reduce the plant exposure to long term SBO sequences.
AC/DC-02	Replace lead-acid batteries with fuel cells.	The intent of this SAMDA is to extend DC power availability during a SBO event by replacing station batteries with fuel cells that would extend DC power availability to 24 hours.
AC/DC-03	Add additional battery charger or portable, diesel-driven battery charger to existing DC system	This SAMDA would improve the availability of the DC power system.
AC/DC-04	Improve DC bus load shedding.	This SAMDA would extend DC power availability during an SBO event.
AC/DC-05	Provide DC bus cross-ties.	This SAMDA would improve the availability of the DC power system.
AC/DC-06	Provide additional DC power to the 120/240V vital AC system.	The intent of this SAMDA is to increase the availability of the 120V AC buses.
AC/DC-07	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.	The intent of this SAMDA is to increase the availability of the 120V AC buses.
AC/DC-08	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.	This SAMDA would improve the chances of a successful response to the loss of two 120V AC buses.
AC/DC-09	Provide an additional diesel generator.	This SAMDA would add a fifth diesel generator which would increase on-site emergency AC power reliability and availability (i.e., decrease the probability of SBO scenario).
AC/DC-10	Revise procedure to allow bypass of diesel generator trips.	The intent of this SAMDA is to extend diesel generator operation.
AC/DC-11	Improve 4.16 kV bus cross-tie ability.	This SAMDA would improve AC power availability.
AC/DC-12	Create AC power cross-tie capability with other unit (multi-unit site).	This SAMDA would increase the availability of on-site AC power.
AC/DC-13	Install an additional, buried off-site power source.	This SAMDA would reduce the probability of loss of off-site power (LOOP) event.
AC/DC-14	Install a gas turbine generator.	This SAMDA involves installing a combustion turbine generator for the purpose of improving on-site AC power reliability (i.e., decrease the frequency of a SBO scenario).
AC/DC-15	Install tornado protection on gas turbine generator.	This SAMDA would provide tornado protection for a gas turbine generator and associated support systems to prevent a loss of the system due to tornado and high-wind events. This would increase the reliability of on-site AC power.
AC/DC-16	Improve uninterruptible power supplies.	The intent of this SAMDA is to increase the availability of power supplies supporting front-line equipment.
AC/DC-17	Create a cross-tie for diesel fuel oil (multi-unit site).	For multi-unit sites, this SAMDA would add diesel fuel oil redundancy (i.e., increase diesel generator availability).

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
AC/DC-18	Develop procedures for replenishing diesel fuel oil.	This SAMDA would allow long-term diesel operation.
AC/DC-19	Use fire water system as a backup source for diesel cooling.	This SAMDA would provide redundancy for the diesel cooling support systems. This would increase the diesel generator availability.
AC/DC-20	Add a new backup source of diesel cooling.	This SAMDA would provide a redundant source of diesel cooling.
AC/DC-21	Develop procedures to repair or replace failed 4 kV breakers.	This SAMDA would offer a recovery path from a failure of breakers the perform transfer of 4.16 kV non-emergency buses from unit station service transformers.
AC/DC-22	In training, emphasize steps in recovery of off-site power after an SBO.	The intent of this SAMDA is to reduce human error associated with recovery of SBO events through the combined means of enhanced training and procedural guidance.
AC/DC-23	Develop a severe weather conditions procedure.	This SAMDA would improve off-site power recovery following external weather related events.
AC/DC-24	Bury off-site power lines.	This SAMDA would reduce the probability of LOOP event, particularly during severe weather.
Enhancements Related to Anticipated Transient Without Scram (ATWS)		
AT-01	Add an independent boron injection system.	This SAMDA would improve the availability of boron injection during an ATWS.
AT-02	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	This SAMDA would improve equipment availability after an ATWS.
AT-03	Provide an additional control system for rod insertion (e.g., AMSAC).	This SAMDA would provide redundancy and reduce the frequency of an ATWS.
AT-04	Install an ATWS sized filtered containment vent to remove decay heat.	This SAMDA would increase the ability to remove reactor heat from ATWS vents.
AT-05	Revise procedure to bypass main steam isolation valve (MSIV) isolation in turbine trip ATWS scenarios.	Discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., Standby Liquid Control (SLC) injection, lower water level, depressurize reactor pressure vessel) than if the main condenser was unavailable, resulting in lower human error probabilities.
AT-06	Revise procedure to allow override of low pressure core injection during an ATWS event.	On failure of high pressure core injection and condensate, some plants direct reactor depressurization followed by five minutes of automatic lower pressure core injection. This SAMDA would allow immediate control of low pressure core injection.
AT-07	Install motor generator set trip breakers in control room.	This SAMDA would reduce the frequency of core damage due to an ATWS.
AT-08	Provide capability to remove power from the bus powering the control rods.	This SAMDA would decrease the time required to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has a rapid pressure excursion).
Enhancements Related to Containment Bypass		
CB-01	Install additional pressure or leak monitoring instruments for detection of interfacing system loss of coolant accidents (ISLOCA).	This SAMDA would reduce the frequency of an ISLOCA.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CB-02	Add redundant and diverse limit switches to each containment isolation valve.	This SAMDA would provide enhanced isolation valve position indication, which would reduce frequency of containment isolation failure and ISLOCAs.
CB-03	Increase leak testing of valves in ISLOCA paths.	This SAMDA would reduce the frequency of an ISLOCA.
CB-04	Install self-actuating containment isolation valves.	This SAMDA would reduce the frequency of isolation failures.
CB-05	Locate residual heat removal (RHR) inside containment.	This SAMDA would reduce the frequency of ISLOCA outside of containment.
CB-06	Ensure that ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	This SAMDA would scrub ISLOCA releases.
CB-07	Revise Emergency Operating Procedures (EOP) to improve ISLOCA identification.	A plant had a scenario in which a RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment. Procedural enhancements would establish that LOCA outside of containment would be observed.
CB-08	Improve operator training on ISLOCA coping.	This SAMDA would involve the implementation of additional training to address ISLOCA identification and decrease the effects of such an event.
CB-09	Institute a maintenance practice to perform a 100% inspection of steam generator (SG) tubes during each refueling outage.	This SAMDA would reduce the frequency of a steam generator tube rupture (SGTR) event.
CB-10	Replace SGs with a new design.	This SAMDA would reduce the frequency of an SGTR event.
CB-11	Increase the pressure capacity of the secondary side so that an SGTR would not cause the relief valves to lift.	This SAMDA would prevent a direct release pathway to the environment in the event of an SGTR sequence.
CB-12	Install a redundant spray system to depressurize the primary system during an SGTR.	This SAMDA would enhance depressurization capabilities during SGTR.
CB-13	Proceduralize use of pressurizer vent valves during SGTR sequences.	This SAMDA would be a backup method to using pressurizer sprays to reduce primary system pressure following an SGTR.
CB-14	Provide improved instrumentation to detect SGTRs, such as Nitrogen-16 monitors.	This SAMDA would improve mitigation of SGTRs.
CB-15	Route the discharge from the main steam safety valves (MSSV) through a structure where a water spray would condense the steam and remove most of the fission products.	The intent of this SAMDA is to reduce the consequences of an SGTR.
CB-16	Install a highly reliable (closed loop) SG shell-side heat removal system that relies on natural circulation and stored water sources.	The intent of this SAMDA is to reduce the consequences of an SGTR.
CB-17	Revise EOP to direct isolation of a faulted SG.	This SAMDA would reduce consequences of an SGTR.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CB-18	Direct SG flooding after an SGTR, prior to core damage.	This SAMDA would provide improved scrubbing of SGTR releases by maintaining adequate water coverage of a ruptured SG tube.
CB-19	Vent MSSVs in containment.	This SAMDA would route the MSSVs steam releases back into containment to minimize releases to the environment due to an SGTR event.
CB-20	Install relief valves in the component cooling water system (CCWS).	This SAMDA would relieve pressure buildup from a reactor coolant pump (RCP) thermal barrier tube rupture and aid in preventing the onset of an ISLOCA.
Enhancements Related to Core Cooling Systems		
CC-01	Install an independent active or passive high pressure injection system.	This SAMDA would improve prevention of core melt sequences and provide system redundancy.
CC-02	Provide an additional high pressure injection pump with independent diesel.	This SAMDA would reduce the frequency of core melt from small break LOCA and SBO sequences.
CC-03	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	The intent of this SAMDA is to extended high pressure coolant injection and reactor core isolation cooling.
CC-04	Add a diverse low pressure injection system.	This SAMDA would improve the injection capability.
CC-05	Provide capability for alternate injection via diesel-driven fire pump.	This SAMDA would improve the injection capability.
CC-06	Improve Emergency Core Cooling System (ECCS) suction strainers.	This SAMDA would enhance the reliability of the ECCS suction.
CC-07	Add the ability to manually align ECCS recirculation.	This SAMDA would provide a backup should automatic or remote operation fail to align ECCS recirculation.
CC-08	Add the ability to automatically align ECCS to recirculation mode upon refueling water storage tank depletion.	This SAMDA would enhance the reliability of the ECCS suction.
CC-09	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	This SAMDA would extend the reactor water storage capacity in the event of an SGTR. The time available for recovery depends mostly on the refueling water storage tank inventory; therefore, a consideration for refilling the tank once it reaches a specified low level could prolong the cooling of the core for an indefinite period, if the SG tube leak rate could be decreased (i.e., through primary system depressurization) to less than the available refueling water storage tank makeup capacity.
CC-10	Provide an in-containment reactor water storage tank (IRWST).	An IRWST provides a continuous source of water to the safety injection pumps during a LOCA event, since water released from a breach of the primary system collects in the IRWST, and thereby eliminates the need to realign the safety injection pumps for long-term post-LOCA recirculation.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CC-11	Throttle low pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	This SAMDA would extend the reactor water storage tank capacity.
CC-12	Emphasize timely recirculation alignment in operator training.	This SAMDA would reduce the human error probability associated with recirculation failure.
CC-13	Upgrade the chemical and volume control system (CVCS) to mitigate small break LOCAs.	For a plant like the Westinghouse AP600, where the CVCS can not mitigate a small break LOCA, an upgrade would decrease the frequency of core damage.
CC-14	Change the IRWST suction from four check valves to two check and two air-operated valves.	This SAMDA would remove common mode failure of all four injection paths.
CC-15	Replace two of the four electric safety injection pumps with diesel-powered pumps.	This SAMDA would reduce the probability of common cause failure of the safety injection system (SIS). This SAMDA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMDA is to provide diversity within the high- and low-pressure SISs.
CC-16	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in an SBO.	This SAMDA would improve the chance of successful operation during an SBO event in which high are temperatures may be encountered (no ventilation to main steam areas).
CC-17	Create a reactor coolant depressurization system.	The intent of this SAMDA is to allow the low pressure ECCS injection in the event of a small LOCA and high-pressure safety injection failure.
CC-18	Make procedure changes for reactor coolant system (RCS) depressurization.	This SAMDA would allow the low pressure ECCS injection in the event of a small LOCA and high-pressure safety injection failure.
CC-19	Provide an additional flow path from the refueling water tank to the high-pressure SIS through a diversified suction flow path check valve.	This SAMDA would reduce the potential of a common cause failure of refueling water tank flow path check valves failing to open or any other failure obstructing the flow path.
CC-20	Provide actuator diversity for the motor-operated valves in the high-pressure SIS.	This SAMDA would reduce the potential for common cause failure of high-pressure safety injection motor-operated valves by replacing redundant train valves with diversified valve actuators, such as air-operated actuators.
CC-21	Modify the containment sump strainers to prevent plugging.	This SAMDA would decrease the probability of the strainers in the containment sump from plugging.
Enhancements Related to Containment Phenomena		
CP-01	Create a reactor cavity flooding system.	This SAMDA would enhance debris coolability, reduce core-concrete interaction, and provide fission product scrubbing.
CP-02	Install a passive containment spray system.	This SAMDA would improve containment spray capability.
CP-03	Use the fire water system as a backup source for the containment spray system.	This SAMDA would improve containment spray capability.
CP-04	Install an unfiltered, hardened containment vent.	This SAMDA would increase decay heat removal capability for non-ATWS events, without scrubbing released fission products.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CP-05	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter, Option 2: Multiple Venturi Scrubber	Assuming injection is available (non-ATWS sequences), this SAMDA would provide alternate decay heat removal with the released fission products being scrubbed.
CP-06	Enhance fire protection system and standby gas treatment system hardware and procedures.	This SAMDA would improve fission product scrubbing in severe accidents.
CP-07	Provide post-accident containment inerting capability.	This SAMDA would reduce the likelihood of hydrogen and carbon monoxide gas combustion.
CP-08	Create a large concrete crucible with heat removal potential to contain molten core debris.	Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat. This will increase the cooling and containment of the molten core debris.
CP-09	Create a core melt source reduction system.	Refractory material would be placed underneath the reactor vessel such that a molten core falling on the material would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur. This SAMDA would increase cooling and containment of molten core debris.
CP-10	Strengthen primary and secondary containment (e.g., add ribbing to containment shell).	This SAMDA would reduce the probability of containment overpressurization.
CP-11	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	This SAMDA would reduce the probability of base mat melt through.
CP-12	Provide a reactor vessel exterior cooling system.	This SAMDA would increase the potential to cool a molten core before it causes vessel failure, by submerging the lower head in water.
CP-13	Construct a building to be connected to primary and secondary containment and maintained at a vacuum.	This SAMDA would provide a separate building/structure that would be normally maintained at vacuum and would be connected to the primary containment boundary following an accident, thereby depressurizing the primary containment and further reducing emissions from severe accidents.
CP-14	Institute simulator training for severe accident scenarios.	This SAMDA would improve arrest of core melt progress and prevention of containment failure.
CP-15	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. The improved leak detection would reduce the LOCA frequency.
CP-16	Delay containment spray actuation after a large LOCA.	This SAMDA would lengthen time of reactor water storage tank availability.
CP-17	Install automatic containment spray pump header throttle valves.	This SAMDA would extend the time over which water remains in the reactor water storage tank, when full containment spray flow is not needed.
CP-18	Install a redundant containment spray system.	This SAMDA would increase containment heat removal ability.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CP-19	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	This SAMDA would reduce hydrogen detonation.
CP-20	Install a passive hydrogen control system.	This SAMDA would reduce hydrogen detonation potential without requiring electric power.
CP-21	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	This SAMDA would reduce the probability of containment failure.
CP-22	Install a secondary containment filtered ventilation.	For plants with a secondary containment, this SAMDA would filter fission products released from the primary containment.
CP-23	Provide actuator diversity for motor-operated valves in the containment spray system.	This SAMDA would reduce the potential for a common cause failure of containment spray system motor-operated valves by replacing redundant train motor-operated valves with diverse valve actuators, such as air-operated actuators.
Enhancements Related to Cooling Water		
CW-01	Add redundant DC control power for service water (SW) pumps.	The intent of this SAMDA is to increase the availability of the SW.
CW-02	Replace ECCS pump motors with air-cooled motors.	This SAMDA would eliminate ECCS dependency on SW.
CW-03	Enhance procedural guidance for use of crosstied component cooling or SW pumps.	This SAMDA would reduce the frequency of the loss of either of these cooling water systems.
CW-04	Add a SW pump.	This SAMDA would increase the availability of cooling water.
CW-05	Enhance the screen wash system.	This SAMDA would reduce the potential for loss of SW due to clogging of the screens.
CW-06	Cap downstream piping of normally closed component cooling water drain and vent valves.	This SAMDA would reduce the frequency of loss of component cooling water initiating events, some of which can be attributed to catastrophic failure of one of the many single isolation valves.
CW-07	Enhance loss of component cooling water (or loss of SW) procedures to facilitate stopping the RCPs.	This SAMDA reduces the potential for RCP seal damage due to pump bearing failure.
CW-08	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the RCS prior to seal LOCA.	This SAMDA would reduce the probability of RCP seal failure.
CW-09	Additional training on loss of component cooling water.	This SAMDA would potentially improve the success of operator actions after a loss of component cooling water.
CW-10	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	This SAMDA would reduce the effect of a loss of component cooling water by providing a means to maintain the charging pump seal injection following a loss of normal cooling water.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
CW-11	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heatup time.	This SAMDA would increase the time before the loss of component cooling water and RCP seal failure during a loss of essential raw cooling water sequences.
CW-12	Increase charging pump lube oil capacity.	This SAMDA would lengthen the time before charging pump failure due to lube oil overheating in loss of cooling water sequences.
CW-13	Install an independent RCP seal injection system, with dedicated diesel.	This SAMDA would add redundancy to RCP seal cooling alternatives, reducing the frequency of core damage from loss of component cooling water, SW, or SBO.
CW-14	Install an independent RCP seal injection system, without dedicated diesel.	This SAMDA would add redundancy to RCP seal cooling alternatives, reducing the frequency of core damage from loss of component cooling water, SW, but not an SBO.
CW-15	Use existing hydro test pump for RCP seal injection.	This SAMDA would add redundancy to RCP seal cooling alternatives, reducing the frequency of core damage from loss of component cooling water, SW, but not an SBO.
CW-16	Install improved RCP seals.	Improved RCP seals would reduce the likelihood of RCP seal LOCA.
CW-17	Install an additional component cooling water pump.	This SAMDA would reduce the likelihood of a loss of component cooling water leading to a RCP seal LOCA.
CW-18	Prevent makeup pump flow diversion through the relief valves.	If spurious high pressure injection relief valve opening creates a flow diversion large enough to prevent RCP seal injection, then this SAMDA would reduce the frequency of loss of RCP seal cooling.
CW-19	Change procedures to isolate RCP seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	This SAMDA would reduce the frequency of core damage due to a loss of seal cooling.
CW-20	Implement procedures to stagger high pressure safety injection pump use after a loss of SW.	This SAMDA would allow high pressure injection to be extended prior to overheating following a loss of SW.
CW-21	Use fire prevention system pumps as a backup seal injection and high pressure makeup source.	This SAMDA would reduce the frequency of a RCP seal LOCA.
CW-22	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the CCWS, or install a component cooling water header cross-tie.	This SAMDA would improve the ability to cool RHR heat exchangers.
U.S. EPR Specific Enhancements		
EPR-01	Provide an additional safety chilled water system (SCWS) train.	Increase availability of Heating, Ventilation, and Air Conditioning (HVAC) air handling units and process systems cooling.
EPR-02	Training for operator actions during small break LOCA scenarios.	This SAMDA would potentially improve the success of operator actions after a small break LOCA event.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
EPR-03	Operator training to initiate RHR system.	This SAMDA would potentially decrease the probability of a severe accident due to operator actions of the RHR system.
EPR-04	Training for operator actions during SGTR scenarios.	This SAMDA would potentially improve the success of operator actions after an SGTR.
EPR-05	Add redundant pressure sensors to the pressurizer and SG.	This SAMDA would increase the availability of pressure indication for the RCS.
EPR-06	Provide operator training on manually actuating the EBS.	This SAMDA would minimize the impact of steam line breaks and ATWS events.
EPR-07	Provide operator training to cross-tie Division 1 to Division 2 or Division 4 to Division 3 during both an SBO and non-SBO event.	This SAMDA would increase the availability of electrical equipment in the Safeguard Buildings.
Enhancements Related to Internal Flooding		
FL-01	Improve inspection of rubber expansion joints on main condenser.	For a plant where internal flooding due to failure of circulating water expansion joint is a concern, this SAMDA can help reduce the frequency of such an event.
FL-02	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	For a plant where internal flooding from the turbine building to safeguards areas is a concern, this modification can prevent flood propagation.
Enhancements to Reduce Fire Risk		
FR-01	Replace mercury switches in fire protection system.	The intent of this SAMDA is to decrease the probability of spurious fire suppression system actuation.
FR-02	Upgrade fire compartment barriers.	This SAMDA would decrease the consequences of a fire.
FR-03	Install additional transfer and isolation switches.	This SAMDA reduces the number of spurious actuation during a fire.
FR-04	Enhance fire brigade awareness.	This SAMDA would decrease the consequences of a fire.
FR-05	Enhance control of combustibles and ignition.	This intent of this SAMDA is to decrease the fire frequency and the consequences.
Enhancements Related to Feedwater and Condensate		
FW-01	Install a digital feed water upgrade.	This SAMDA would reduce the likelihood of a loss of MFW following a plant trip.
FW-02	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	This SAMDA would create a backup water supply for the feedwater/condensate systems.
FW-03	Install an independent diesel for the condensate storage tank makeup pumps.	This SAMDA would allow continued inventory makeup to the condensate storage tank during an SBO event.
FW-04	Add a motor-driven feedwater pump.	This SAMDA would increase the availability of feedwater.
FW-05	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	This SAMDA would reduce dual turbine-driven pump maintenance unavailability.
FW-06	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	This SAMDA would provide control air accumulators for the turbine-driven auxiliary feedwater pump flow control valves. This would eliminate the need for local manual action to align nitrogen bottles for control air following a loss of off-site power.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
FW-07	Install a new condensate storage tank (auxiliary feedwater storage tank).	This SAMDA would increase the reliability of the auxiliary feedwater system.
FW-08	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	This SAMDA would improve the success probability during an SBO.
FW-09	Proceduralize local manual operation of auxiliary feedwater system when control power path is lost.	This SAMDA would lengthen auxiliary feedwater availability during an SBO. Also provides a success path should auxiliary feedwater control power be lost in non-SBO sequences.
FW-10	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	The intent of this SAMDA is to extend the availability of the auxiliary feedwater.
FW-11	Use fire water system as a backup for SG inventory.	This SAMDA would create a backup to main and auxiliary feedwater for SG water supply.
FW-12	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	This SAMDA would allow greater inventory for the auxiliary feedwater pumps by preventing condensate storage tank flow diversion to the condenser if the condenser makeup valve fails open on loss of air or power.
FW-13	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.	This SAMDA would reduce the potential for core damage due to a loss of feedwater event.
FW-14	Modify the startup feedwater pump so that it can be used as a backup to the emergency feedwater system (EFWS), including during an SBO scenario.	This SAMDA would increase the reliability of decay heat removal.
FW-15	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	This SAMDA would increase the probability of a successful feed and bleed.
FW-16	Perform surveillances on manual valves used for backup auxiliary feedwater pump suction.	This SAMDA would improve the success probability for providing alternate water supply to the auxiliary feedwater pumps.
Enhancements Related to Heating, Ventilation, and Air Conditioning (HVAC)		
HV-01	Provide a redundant train or means of ventilation.	This SAMDA would increase the availability of components dependent on room cooling.
HV-02	Add a diesel building high temperature alarm or redundant louver and thermostat.	This SAMDA would improve diagnosis of a loss of diesel building HVAC.
HV-03	Stage backup fans in switchgear rooms.	This SAMDA would increase availability of ventilation in the event of a loss of switchgear ventilation.
HV-04	Add a switchgear room high temperature alarm.	This SAMDA would improve diagnosis of a loss of switchgear HVAC.
HV-05	Create ability to switch emergency feedwater (EFW) room fan power supply to station batteries in an SBO.	This SAMDA would allow continued fan operation in an SBO.
Enhancements Related to Instrument Air and Nitrogen Supply		
IA-01	Provide cross-unit connection of uninterruptible compressed air supply.	This SAMDA would increase the ability to vent containment using the hardened vent.
IA-02	Modify procedure to provide ability to align diesel power to more air compressors.	For plants that do not have diesel power to all normal and backup air compressors, this change allows increase reliability of instrument air following a loss of off-site power.

SAMDA ID	Potential Enhancement	Result of Potential Enhancement
IA-03	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	This SAMDA would eliminate instrument air system dependence on SW cooling.
IA-04	Install nitrogen bottles as backup gas supply for safety relief valves (SRV).	This SAMDA would extend operation of safety-relief valves during an SBO and loss of air events.
IA-05	Improve SRV and MSIV pneumatic components.	This SAMDA would improve the availability of SRVs and MSIVs.
Enhancements to Reduce Seismic Risk		
SR-01	Increase seismic ruggedness of plant components.	This SAMDA would increase the availability of necessary plant equipment during and after a seismic event.
SR-02	Provide additional restraints for CO_2 tanks.	This SAMDA would increase the availability of fire protection given a seismic event.
Other Enhancements		
OT-01	Install digital large break LOCA protection system.	Use plant instrumentation and logic to improve the capability to identify symptoms/precursors of a large break LOCA (a leak before break) through the installation of digital large break LOCA early detection.
OT-02	Enhance procedures to mitigate large break LOCA.	This SAMDA would reduce the consequences of a large break LOCA.
OT-03	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	The intent of this SAMDA is to improve the prevention of core melt sequences by making operator actions more reliable.
OT-04	Improve maintenance procedures.	The intent of this SAMDA is to improve the prevention of core melt sequences by increasing the reliability of important equipment.
OT-05	Increase training and operating experience feedback to improve operator response.	This SAMDA would improve the likelihood of success of operator actions taken in response to abnormal conditions.
OT-06	Develop procedures for transportation and nearby facility accidents.	The intent of this SAMDA is to reduce consequences of transportation and nearby facility accidents.
OT-07	Install secondary side guard pipes up to the MSIVs.	This SAMDA would prevent secondary said depressurization should a steam line break occur upstream of the MSIVs. This SAMDA would also guard against or prevent consequential multiple SGTRs following a main steam line break event.

4.0 MAXIMUM BENEFIT EVALUATION

The net value of each SAMDA is the difference between the benefit of the averted on-site and off-site risk (in U.S. Dollars) from the implementation of a particular SAMDA candidate and the cost of the enhancement (in U.S. Dollars). The methodologies provided in NUREG/BR-0184 (Reference 2) and NEI 05-01 (Reference 1) were used as guidance. The net value for each potential SAMDA candidate was determined according to the following equation:

$$\text{Net Value} = \left(APE + AOC + AOE + AOSC\right) - COE \tag{4.1}$$

where,

APE = present value of the averted public exposure ($)
AOC = present value of the averted off-site property damage costs ($)
AOE = present value of the averted occupational exposure ($)
AOSC = present value of the averted on-site costs ($)
COE = cost of the enhancement ($).

The purpose of this section is to quantitatively determine the maximum benefit for the U.S. EPR design. If the estimated cost of implementation of a specific SAMDA candidate is greater than the maximum benefit, then the design alternative would not be considered economically viable and would be eliminated from further consideration during the screening phase.

The maximum benefit calculation uses the exact numerical values instead of rounded numerical values. The cost for a given parameter may vary when performing a hand calculation using rounded numerical values.

4.1 *Risk Metrics*

The SAMDA cost-benefit evaluation uses the results of the U.S. EPR PRA. The CDF serves as the primary risk metric to characterize the frequency of occurrence of a severe accident. The actual radiological risk, as calculated in the U.S. EPR Level 3 PRA, is used to quantify off-site consequences.

The point estimate value of the CDF, as calculated by the PRA software Risk Spectrum® and as reported in U.S. EPR FSAR Tier 2, Chapter 19, is used to obtain the base case cost-benefit results. The point estimate CDF is generally different from the mean CDF because of correlated uncertainty distributions. Cost-benefit evaluation based on the mean CDF (as calculated in U.S. EPR FSAR Tier 2, Chapter 19 uncertainty evaluation) is also presented in this analysis. These results are conservative because the mean value is higher than the point estimate value. However, the use of the mean value requires caution. The numerical value of the mean CDF is not unequivocally defined like the point estimate value because it varies between different Monte Carlo runs with a limited number of simulations.

The mean value of the CDF is used in the sensitivity evaluations presented in Section 4.7, which study the impact on the results by choosing a conservative number for a selection of parameters. Using the mean instead of the point estimate maximizes the conservatism of these analyses.

4.2 *Cost-Benefit Input Parameters*

The following specific values were used for various terms in the cost-benefit evaluation:

4.2.1 *Present Value Factor*

The present value factor (*C*) was determined using Equation 4.2, which was provided in NUREG/BR-0184 (Reference 2).

$$C = \frac{e^{-rt_i} - e^{-rt_f}}{r} \tag{4.2}$$

where,

r is the discount rate (%/yr)

t_f is the facility life (yrs)

t_i is the time before facility begins operating (yrs)

For this evaluation, it is assumed that the plant is in the first year of operation. Therefore, t_i (time before facility begins operation) is equal to 0. This simplifies Equation 4.2 to:

$$C = \frac{1 - e^{-rt_f}}{r} \qquad (4.3)$$

The present value factor (C) is calculated using Equation 4.4.

$$C = \frac{1 - e^{-\left(\frac{0.07}{yr}\right)(60\,yrs)}}{\left(\frac{0.07}{yr}\right)} = 14.07\,yr \qquad (4.4)$$

where,

r = 7%/yr (NRC recommended best estimate value from Reference 1)

t_f = 60 yrs

4.2.2 *Monetary Valuation of Accident-Related Health Effects*

The conversion factor used to establish the monetary value of a unit of radiation exposure was $2,000 per person·rem averted in accordance with NUREG/BR-0184 (Reference 2). This monetary value was used for the year in which the exposure occurs and then discounted to the present value for purposes of evaluating values and impacts. This methodology is consistent with the guidelines presented in NUREG/BR-0184 (Reference 2).

4.2.3 *On-site Cleanup Period*

In this evaluation, the accident related on-site exposures were calculated assuming a ten-year cleanup period as suggested in NUREG/BR-0184 (Reference 2).

4.3 *Averted Occupational Exposures*

The NRC methodology used to estimate the accident-related occupational exposure (i.e., averted occupational exposures (AOE)) consists of two components: (1) the calculation of immediate doses (short-term) and (2) long-term doses in accordance with NUREG/BR-0184 (Reference 2). The development of the two contributions is addressed in Sections 4.3.1 and 4.3.2.

4.3.1 *Immediate Dose*

The immediate doses are those doses received at the time of the accident and during the immediate management of the accident. The immediate dose was determined using Equation 4.5, which was provided in NUREG/BR-0184 (Reference 2).

$$W_{IO} = (R)(F)(D_{IO})(C) \tag{4.5}$$

where,

- W_{IO} = monetary value of accident risk avoided from immediate doses, after discounting ($)
- R = monetary equivalent of unit dose ($/person·rem)
- F = CDF (events/yr)
- D_{IO} = immediate occupational dose, (person·rem/event)
- C = present value factor (yr)

The values for the point estimate CDF case are:

- R = 2,000 $/person·rem
- F = $5.3 \cdot 10^{-7}$ events/yr
- D_{IO} = 3,300 person·rem/event (Reference 2)
- C = 14.07 yr

$$W_{IO} = \left(2{,}000\frac{\$}{person \cdot rem}\right)\left(5.3 \cdot 10^{-7}\frac{events}{yr}\right)\left(3{,}300\frac{person \cdot rem}{event}\right)(14.07\,yr) = \$49.22 \cong \$49 \tag{4.6}$$

The values for the mean value case are:

R = 2,000 \$/person·rem

F = $7.4 \cdot 10^{-7}$ events/yr

D_{IO} = 3,300 person·rem/event (Reference 2)

C = 14.07 yr

$$W_{IO} = \left(2{,}000 \frac{\$}{person \cdot rem}\right)\left(7.4 \cdot 10^{-7} \frac{events}{yr}\right)\left(3{,}300 \frac{person \cdot rem}{event}\right)(14.07\, yr) = \$68.72 \cong \$69 \qquad (4.7)$$

4.3.2 *Long-Term Dose*

The long-term doses are received during the cleanup process and refurbishment or decontamination. The long-term dose was determined using Equation 4.8, which was provided in NUREG/BR-0184 (Reference 2).

$$W_{LTO} = (R)(F)(D_{LTO})(C)\left(\frac{1 - e^{-rm}}{rm}\right) \qquad (4.8)$$

where,

W_{LTO} = monetary value of accident risk avoided long term doses, after discounting (\$)

R = monetary equivalent of unit dose (\$/person·rem)

F = CDF (events/yr)

D_{LTO} = long-term occupational dose (person·rem/event)

C = present value factor (yr)

r = discount rate (%/yr)

m = on-site cleanup period (years)

The values for the point estimate CDF case are:

R = 2,000 \$/person·rem

F = $5.3 \cdot 10^{-7}$ events/yr

D_{LTO} = 20,000 person·rem/event (Reference 2)

C = 14.07 yr

r = 0.07 /yr (Reference 1)

m = 10 yrs

$$W_{LTO} = \left(2{,}000 \frac{\$}{person \cdot rem}\right)\left(5.3 \cdot 10^{-7} \frac{events}{yr},\right)\left(20{,}000 \frac{person \cdot rem}{event}\right)(14.07\,yr)\left(\frac{1 - e^{-\left(\frac{0.07}{yr}\right)(10\,yrs)}}{\left(\frac{0.07}{yr}\right)(10\,yrs)}\right) \quad (4.9)$$

$$W_{LTO} \cong \$214.52 \cong 215$$

The values for the mean value CDF case are:

R = 2,000 \$/person·rem

F = $7.4 \cdot 10^{-7}$ events/yr

D_{LTO} = 20,000 person·rem/event (Reference 2)

C = 14.07 yr

r = 0.07 /yr (Reference 1)

m = 10 yrs

$$W_{LTO} = \left(2{,}000 \frac{\$}{person \cdot rem}\right)\left(7.4 \cdot 10^{-7} \frac{events}{yr},\right)\left(20{,}000 \frac{person \cdot rem}{event}\right)(14.07\,yr)\left(\frac{1 - e^{-\left(\frac{0.07}{yr}\right)(10\,yrs)}}{\left(\frac{0.07}{yr}\right)(10\,yrs)}\right) \quad (4.10)$$

$$W_{LTO} = \$299.51 \cong \$300$$

4.3.3 *Total Accident-Related Occupational Exposures*

The total accident-related occupational exposure is determined by combining the immediate dose (W_{IO}) and long term dose (W_{LTO}) equations, and using the numerical values calculated in Sections 4.3.1 and 4.3.2.

The point estimate CDF case accident-related occupational exposure is:

$$AOE = W_{IO} + W_{LTO} = \$49 + \$215 = \$264 \quad (4.11)$$

The mean value CDF case accident-related occupational exposure is:

$$AOE = W_{IO} + W_{LTO} = \$69 + \$300 = \$369 \tag{4.12}$$

4.4 *Averted On-site Costs*

The calculation used to estimate the total accident-related on-site property damage (i.e., averted on-site costs (AOSC)) consists of three components: (1) the estimation of cleanup and decontamination costs, (2) repair and refurbishment, and (3) the replacement power costs over the remaining life of the facility. The repair and refurbishment costs are considered for a recoverable accident and not for a severe accident and do not need to be evaluated for this analysis. The development of the remaining two contributions is addressed in Sections 4.4.1 and 4.4.2.

4.4.1 *Cleanup and Decontamination*

The present value of the cost of cleanup and decontamination over the remaining life of the facility (U_{CD}) was determined using Equation 4.13.

$$U_{CD} = (PV_{CD})(C) \tag{4.13}$$

where,

PV_{CD} = present value of the cost of cleanup/decontamination ($)

C = present value factor (yr)

The values for the point estimate and mean value CDF cases are:

PV_{CD} = $1.1·10^9 (Reference 2)

C = 14.07 yr

$$U_{CD} = (\$1.1 \cdot 10^9)(14.07\,yr) = 1.55 \cdot 10^{10}\$ \cdot years \tag{4.14}$$

4.4.2 *Replacement Power Costs*

Replacement power costs are calculated in accordance with Reference 2. The replacement power is needed for the time following a severe accident and for the remainder of the expected generating plant life. Long-term power replacement equations were used to calculate replacement power costs in accordance with Reference 2. The present value of replacement power is calculated using Equation 4.15. (Note: Equation 4.15 was developed for discount rates between five percent and ten percent.)

$$PV_{RP} = \frac{B}{r}\left(1 - e^{-rt_f}\right)^2 \tag{4.15}$$

where,

- PV_{RP} = present value of the cost of replacement power for a single event ($)
- t_f = years remaining until end of facility life (yr)
- r = discount rate (%/yr)

and *B* is a constant representing a string of replacement power costs that occur over the lifetime of a reactor after an event (for a 910MWe "generic" reactor, NUREG/BR-0184 (Reference 2) uses a value of $\$1.2 \cdot 10^8$ \$/yr). The following equation from NEI 05-01 (Reference 1) scales the constant to the U.S. EPR power of 1600 MWe.

$$B = \$1.2 \cdot 10^8 / yr\left(\frac{1600MWe}{910MWe}\right) = \$2.11 \cdot 10^8 / yr \tag{4.16}$$

In order to determine the 2008 replacement power costs, the variable string of replacement power cost (B) was modified for inflation. The inflation rate was determined by assessing the electricity costs in 1993 and in 2008. After evaluating the retail electricity costs, the electricity cost in 1993 was approximately 7 cents/kW-h and in 2008 the cost is approximately 12 cents/kW-h. The inflation rate was calculated using the method described in this section. The 2008 value for the string of replacement power costs was calculated based on the calculated inflation rate.

$$
\begin{aligned}
&z = \frac{2008\cos t}{1993\cos t} = \frac{12cents/kW-h}{7cents/kW-h} = 1.71 \\
&(1+x)^{(\Delta y)} = z \\
&(1+x)^{(2008-1993)} = 1.71 \\
&x = 0.0366 \Rightarrow 3.66\% \\
&\mathrm{y} = \mathrm{year} \\
&\mathrm{x} = \mathrm{inflation\ rate}
\end{aligned}
$$

The inflation of the replacement power (B) scaled for the U.S. EPR design was calculated using Equation 4.17:

$$
\begin{aligned}
B_{2008} &= B_n(1+0.0366)^{(2008-n)} \\
B_{2008} &= (\$2.11E+08)(1+0.0366)^{(2008-1993)} \\
B_{2008} &= \$3.62E+08
\end{aligned}
\tag{4.17}
$$

The values for the point estimate and mean value CDF cases are:

t_f = 60 years

r = 0.07 /yr

B = \$3.62·10^8/yr

$$
PV_{RP} = \frac{\$3.62{\cdot}10^8\ /\ yr}{\left(\frac{0.07}{yr}\right)}\left(1-e^{-\left(\frac{0.07}{yr}\right)(60\,yrs)}\right)^2 = \$5.0210^9 \tag{4.18}
$$

To account for the entire lifetime of the facility, U_{RP} was then calculated from PV_{RP} as follows:

$$
U_{RP} = \frac{PV_{RP}}{r}\left(1-e^{-rt_f}\right)^2 \tag{4.19}
$$

where,

U_{RP} = present value of the cost of replacement power over the remaining life (\$·yrs)

t_f = years remaining until end of facility life (yr)

r = discount rate (%/yr)

Based on the values assumed for the point estimate and mean value CDF cases:

$$U_{RP} = \frac{\$5.02 \cdot 10^9}{\left(\frac{0.07}{yr}\right)}\left(1 - e^{-\left(\frac{0.07}{yr}\right)(60\,yrs)}\right)^2 = 6.96 \cdot 10^{10}\$\cdot yrs \tag{4.20}$$

4.4.3 *Total Averted On-site Costs*

The total AOSC is determined by combining the cleanup and decontamination (U_{CD}) and replacement power costs (U_{RP}) equations, and using the numerical values calculated in Sections 4.4.1 and 4.4.2.

The point estimate CDF case total averted on-site cost is:

$$AOSC = (U_{CD} + U_{RP})(F) = \left(1.55 \cdot 10^{10}\$\cdot years + 6.96 \cdot 10^{10}\$\cdot years\right)\left(5.3 \cdot 10^{-7}\,\frac{events}{yr}\right) = \$45{,}102 \tag{4.22}$$

The mean value CDF case total averted on-site cost is:

$$AOSC = (U_{CD} + U_{RP})(F) = \left(1.55 \cdot 10^{10}\$\cdot years + 6.96 \cdot 10^{10}\$\cdot years\right)\left(7.4 \cdot 10^{-7}\,\frac{events}{yr}\right) = \$62{,}974 \tag{4.23}$$

4.5 *Averted Public Exposure*

The off-site dose within a 50 mile radius of the site was determined using the MACCS2 model developed for the U.S. EPR PRA Level 3 analysis. The base case result of the PRA Level 3 analysis provides the off-site dose for each release category. The total off-site dose (D_t) was determined to be 0.181 person·rem per year. The averted public exposure (APE) cost was determined using Equation 4.24, which was provided in NUREG/BR-0184 (Reference 2).

$$APE = W_{pha} = (C)(Z_{pha}) \tag{4.24}$$

where,

W_{pha} = monetary value of public health risk after discounting (APE) ($)

C = present value factor (yr)

Z_{pha} = monetary value of public health risk per year before discounting ($/yr)

The values for the point estimate and mean value CDF cases are:

C = 14.07 yr

$$Z_{pha} = (R)(D_t) = \left(2{,}000 \frac{\$}{person{\cdot}rem}\right)\left(1.81{\cdot}10^{-1} \frac{person{\cdot}rem}{yr}\right) = \$362 / yr$$

$$APE = (14.07\, yr)\left(\frac{\$362}{yr}\right) = \$5094 \tag{4.25}$$

4.6 *Averted Off-site Property Damage Costs*

The economic impact for a 50 mile radius of the site was determined using the MACCS2 model developed for the U.S. EPR PRA Level 3 analysis. The base case result of the PRA Level 3 analysis provides the economic impact for each release category. The total economic impact (I_t) was determined to be 185 $/year. The averted off-site property damage cost (AOC) was determined using Equation 4.26, which was provided in NUREG/BR-0184 (Reference 2).

$$AOC = (C)(I_t) \tag{4.26}$$

where,

AOC = averted off-site property damage costs associated with a severe accident ($)

C = present value factor (yr)

Z_t = monetary value of economic impact per year before discounting ($/yr)

The values for the point estimate and mean value CDF cases are:

C = 14.07 yr

Z_t = $1.85 \cdot 10^2$ \$/yr

$$AOC = (14.07\,yr)\left(1.85 \cdot 10^{2}\,\frac{\$}{year}\right) = \$2603 \tag{4.27}$$

4.7 *Maximum Benefit*

The severe accident impact is determined by summing the occupational exposure cost, on-site cost, public exposure, and off-site property damage NEI 05-01 (Reference 1). The point estimate and mean value CDF with 2008 replacement power costs severe accident impact for the U.S. EPR design is shown in Table 4-1.

The total cost impact of a severe accident (maximum benefit) must account for the risk contribution from the internal initiating events, internal flooding, fire, and seismic. The total CDF at power for the U.S. EPR design includes the contribution from internal initiating events (55 percent), internal flooding (12 percent), and fire (33 percent). A seismic margins assessment instead of a seismic PRA was completed for the U.S. EPR design. The seismic margin analysis yields information regarding the ruggedness of the seismic design with respect to a potential severe accident. However, it does not result in the estimation of the seismic CDF which is used to determine the cost impact of a severe accident in the SAMDA analysis. To account for the seismic contribution, it was assumed that the seismic risk is equivalent to the fire risk because the fire risk in the U.S. EPR PRA analysis was evaluated to be the highest external event risk at 33 percent of the total CDF.

Increasing the severe accident impact by 33 percent includes the contribution from seismic risk and is the maximum benefit for the U.S. EPR design. The maximum benefit for the U.S. EPR design based on point estimate CDF with 2008 replacement power costs is \$70,574.

The percentage contributions of each hazard group are different for the mean value CDF. Seismic risk based on mean value CDF is assumed to be 28 percent of the total mean value CDF. The resulting maximum benefit based on the mean value CDF would be $90,931.

Table 4-1 Severe Accident Impact

	Point Estimate CDF (7% Discount Rate and 2008 Replacement Power Costs)	**Mean Value CDF** (7% Discount Rate and 2008 Replacement Power Costs)
Averted Occupational Exposure (AOE)	$264	$368
Averted On-site Cost (AOSC)	$45,102	$62,974
Averted Public Exposure (APE)	$5,094	$5,094
Averted Off-site Property Damage Cost (AOC)	$2,603	$2,603
Severe Accident Impact Internal Events, Internal Flooding, Internal Fire	$53,063	$71,040
Maximum Benefit Internal Events, Internal Flooding, Internal Fire, Seismic	**$70,574**	**$90,931**

4.8 *Sensitivity Studies*

Sensitivity cases were performed to investigate the sensitivity of certain parameters in the U.S. EPR SAMDA analysis. A total of five sensitivity benefit calculations were conducted for both the point estimate and mean value CDF with 2008 replacement power costs. This section describes the sensitivity cases.

- The first case investigated the sensitivity of the base case to the discount rate by assuming a lower discount rate of three percent. Based on guidance from Reference 2, when using a three percent discount rate, the present value of the replacement power for a single event (PV_{RP}) is $1.4E+09. This value corresponds to an average reactor life of 24 years with a power of 910 MWe. The value of PV_{RP} provided in Reference 2 needs to be adjusted to be applicable to the U.S. EPR design. The PV_{RP} value was adjusted for average reactor years remaining by using Equation 4.23, for power by using equation 4.28, and for inflation in 1993 to 2008 dollars. The same method discussed in Section 4.4.2 is applied.

$$PV_{RP} = \$1.4 \cdot 10^{9}\left(\frac{60\,years}{24\,years}\right) = \$3.50 \cdot 10^{9} \qquad (4.28)$$

$$PV_{RP} = \$3.50 \cdot 10^9 \left(\frac{1600 MWe}{910 MWe} \right) = \$6.15 \cdot 10^9 \qquad (4.29)$$

$$PV_{RP} = \$6.15 \cdot 10^9 \left(1 + 0.0366\right)^{(2008-1993)} = \$1.05 \cdot 10^{10} \qquad (4.30)$$

- The second case investigated the sensitivity of the base case to the discount rate by assuming a lower discount rate of five percent.
- The third case investigated the sensitivity of the base case to the onsite dose estimates. For the base case analysis, an immediate and long-term onsite dose to plant personnel following a severe accident is 3,300 rem and 20,000 rem, respectively. This sensitivity case uses the recommended high estimate dose values of 14,000 rem and 30,000 rem for immediate and long-term dose onsite, respectively, as suggested in NUREG/BR-0184.
- The fourth case investigated the sensitivity of the base case to the total onsite cleanup cost. For the base case analysis, the total onsite cleanup cost following a severe accident is $1,500,000. This analysis assumed a high estimated onsite cleanup cost of $2,000,000 as suggested in NUREG/BR-0184.
- The fifth case investigated the sensitivity of the increase in the replacement power cost for the U.S. EPR design. This sensitivity case projected that the cost of replacement power would double between 2008 and 2015, resulting in an electricity cost of 24 cents/kw-h in 2015 based on the assumption that the cost of electricity in 2008 is 12 cents/kw-h. The inflation rate for this sensitivity case was calculated using the method outlined in Section 4.4.2.

Table 4-2 and Table 4-3 provide the calculated benefit for the point estimate and mean value CDF with 2008 replacement power cost sensitivity cases discussed in this section.

Table 4-2 Maximum Benefit for Sensitivity Cases (Point Estimate CDF with 2008 Replacement Power Costs)

Case	**Sensitivity Case 1: Discount Rate 3%**	**Sensitivity Case 2: Discount Rate - 5%**	**Sensitivity Case 3: High Estimated Dose (On-Site)**	**Sensitivity Case 4: High On-site Cleanup Costs**	**Sensitivity Case 5: Increase Replacement Power Cost Inflation of 10.41%**
Immediate Dose Savings (On-site)	$97	$66	$209	$49	$49
Long Term Dose Savings (On-site)	$510	$317	$322	$215	$215
Total Accident Related Occupational Exposure **(AOE)**	$607	$384	$531	$264	$264
Cleanup/Decontamination Savings (On-site)	$19,110	$13,053	$8,045	$10,727	$8,045
Replacement Power Savings (On-site)	$129,243	$62,524	$36,835	$36,835	$73,675
Averted Costs of On-site Property Damage **(AOSC)**	$148,353	$75,577	$44,880	$47,562	$81,720
Total On-site Benefit	**$148,960**	**$75,960**	**$45,411**	**$47,826**	**$81,984**
Averted Public Exposure **(APE)**	$10,072	$6,880	$5,094	$5,094	$5,094
Averted Offsite Damage Savings **(AOC)**	$5,147	$3,516	$2,603	$2,603	$2,603
Total Offsite Benefit	**$15,219**	**$10,395**	**$7,697**	**$7,697**	**$7,697**
Total Benefit (On-site + Offsite)	**$164,179**	**$86,356**	**$53,108**	**$55,523**	**$89,681**
Total Benefit (On-site + Offsite + External Events)	**$218,358**	**$114,853**	**$70,633**	**$73,845**	**$119,276**

Table 4-3 Maximum Benefit for Sensitivity Cases (Mean Value CDF with 2008 Replacement Power Costs)

Case	**Sensitivity Case 1:** **Discount Rate 3%**	**Sensitivity Case 2:** **Discount Rate - 5%**	**Sensitivity Case 3:** **High Estimated Dose (On-Site)**	**Sensitivity Case 4:** **High On-site Cleanup Costs**	**Sensitivity Case 5:** **Increase Replacement Power Cost Inflation of 10.41%**
Immediate Dose Savings (On-site)	$136	$93	$292	$69	$69
Long Term Dose Savings (On-site)	$712	$443	$449	$300	$300
Total Accident Related Occupational Exposure **(AOE)**	$847	$535	$741	$368	$368
Cleanup/Decontamination Savings (On-site)	$26,682	$18,225	$11,233	$14,977	$11,233
Replacement Power Savings (On-site)	$180,452	$87,298	$51,430	$51,430	$102,867
Averted Costs of On-site Property Damage **(AOSC)**	$207,134	$105,522	$62,663	$66,407	$114,100
Total On-site Benefit	**$207,981**	**$106,058**	**$63,404**	**$66,775**	**$114,468**
Averted Public Exposure **(APE)**	$10,072	$6,880	$5,094	$5,094	$5,094
Averted Offsite Damage Savings **(AOC)**	$5,147	$3,516	$2,603	$2,603	$2,603
Total Offsite Benefit	**$15,219**	**$10,395**	**$7,697**	**$7,697**	**$7,697**
Total Benefit (On-site + Offsite)	**$223,201**	**$116,453**	**$71,101**	**$74,473**	**$122,165**
Total Benefit (On-site + Offsite + External Events)	**$285,697**	**$149,060**	**$91,009**	**$95,325**	**$156,371**

4.9 *Summary*

For a SAMDA to be cost beneficial for the U.S. EPR design, its cost must be less than the maximum benefit. For this analysis a value of $70,600 was used for the maximum benefit as addressed in Section 4.7. If mean values were used for the CDF, the maximum benefit would be $90,550.

For the U.S. EPR design, the SAMDA candidates were not categorized as *Considered for Further Evaluation*, which would remain applicable if the mean value CDF was used. This occurs because the U.S. EPR plant is designed to prevent and mitigate severe accidents, which results in a low CDF and low maximum benefit.

5.0 SCREENING SAMDA CANDIDATES

The SAMDA candidates developed, as described in Section 3.0, were qualitatively screened using select categories. The intent of the screening is to identify the candidates that warrant a detailed cost-benefit evaluation. The seven categories used in the screening include not applicable, already implemented, combined, excessive implementation cost, very low benefit, not required for design certification, and considered for further evaluation. The seven screening categories were suggested by NEI 05-01 (Reference 1). Each screening category is described in detail in the following sections.

5.1 *Not Applicable*

The SAMDA candidates were identified to determine which are definitely not applicable to the U.S. EPR design. Potential enhancements that are not considered applicable to the U.S. EPR design are those developed for systems specifically associated with boiling water reactors (BWR) or with specific PWR equipment that is not in the U.S. EPR design. For example, the candidate SAMDAs that address pneumatic main steam relief valves (MSRV) are not applicable due to the fact that the U.S. EPR MSRVs are motor driven.

Although, a modification was intended for a BWR, ice condenser containment, or other system that is not applicable to the U.S. EPR design each SAMDA was thoroughly reviewed to ensure that every potential modification similar in intent, and applicable to the U.S. EPR design, could be identified.

5.2 *Already Implemented*

The candidate SAMDAs were reviewed to ensure that the U.S. EPR design does not already include features recommended by a particular SAMDA. Also, the intent of a particular SAMDA may have been fulfilled by another design feature or modification. In these cases the candidate SAMDAs are already implemented in the U.S. EPR plant design. If a SAMDA candidate has already been implemented at the plant, it is not retained. For example, the U.S. EPR design has 47 passive autocatalytic recombiners (PAR) installed throughout containment, which passively actuate when a threshold hydrogen concentration is reached. This satisfies the SAMDA that calls for the addition of a passive hydrogen control system.

5.3 *Combined*

If one SAMDA candidate is similar to another SAMDA candidate, and can be combined with that candidate to develop a more comprehensive or plant-specific SAMDA candidate, only the combined SAMDA candidate is retained for screening. For example, installation of an independent active or passive high pressure injection system and provide an additional high pressure injection pump with independent diesel provide similar risk-reduction benefits. Therefore, these SAMDAs are evaluated in conjunction with each other.

5.4 *Excessive Implementation Cost*

Based on the maximum benefit calculated in Section 4.0 a maximum benefit of $70,600 was chosen for this analysis. If a SAMDA requires extensive changes that will obviously exceed the maximum benefit of $70,600, even without an implementation cost estimate and therefore incurs an excessive implementation cost, it is not retained.

For example, the cost of installing an additional, buried off-site power source would exceed the maximum benefit addressed above and would not require further analysis. Consideration should be given to lower cost alternatives, such as temporary connections using commercial grade equipment (i.e., portable generators and temporary cross-ties), procedure enhancements, and training enhancements that could offer a potential risk reduction at a fraction of the cost of safety-related modifications.

5.5 *Very Low Benefit*

If a SAMDA is related to a non-risk significant system for which change in reliability is known to have negligible impact on the risk profile, it is deemed to have a very low benefit and is not retained. There are two ways to determine the risk impact for the U.S. EPR design:

- The PRA Level 1 importance list is used to determine if a given system is risk significant for the U.S. EPR design. If a SAMDA candidate is associated with a system that is not included on the importance list, it can be concluded that the design alternative would have a negligible impact on the risk profile, and is not retained.
- The U.S. EPR point estimate and mean CDF for internal events, internal flooding, and internal fires are $5.3 \cdot 10^{-7}$ and $7.4 \cdot 10^{-7}$ per reactor-year, respectively. The seismic risk CDF is assumed to be equal to the internal fire CDF. The combined CDF is $7.1 \cdot 10^{-7}$ /yr ($9.5 \cdot 10^{-7}$ /yr mean value). The combined CDF for the U.S EPR is low, resulting in a low value for the maximum benefit derived in this section. The benefit from any modifications to the plant is bounded by that maximum benefit.

5.6 *Not Required for Design Certification*

Evaluation of any potential procedural or surveillance action SAMDA enhancements are not appropriate until the plant design is finalized and the plant procedures are being developed. Also, any component SAMDA enhancements for design elements which are to be finalized later in the design process will not be evaluated in this document. Therefore, if a SAMDA candidate is related to any of these enhancements, it is not retained for this analysis. These SAMDA candidates are not required for design certification.

5.7 *Considered for Further Evaluation*

Following the screening process, if a particular SAMDA was not categorized by any of the preceding categories, then the SAMDA is considered for further evaluation and subject to a cost-benefit analysis.

Table 5-1 Screening of Candidate SAMDAs

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
Enhancements Related to AC and DC Power			
AC/DC-01	Provide additional DC battery capacity.	Already Implemented	The U.S. EPR design has four battery divisions and two severe accident battery divisions. The redundancy and capacity of the battery divisions of the U.S. EPR design meets the intent of this SAMDA.
AC/DC-02	Replace lead-acid batteries with fuel cells.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $1,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
AC/DC-03	Add additional battery charger or portable, diesel-driven battery charger to existing DC system.	Already Implemented	The U.S. EPR Class 1E uninterruptible power supply system and 12 hour uninterruptible power supply system have 2 battery chargers. Normally, one battery charger is operating and the other battery charger is in standby. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
AC/DC-04	Improve DC bus load shedding.	Already Implemented	The U.S. EPR EUPS DC bus does not use load shedding. However, the 12 hour uninterruptible power supply system (UPS) DC bus sheds non-class 1E UPS loads after a 2 hour time period while continuing to supply the severe accident loads for 12 hours. The battery capacity for the U.S. EPR design is conservative when compared to the plants for which this SAMDA was originally intended; therefore, the intent of this SAMDA is considered to have been met.
AC/DC-05	Provide DC bus cross-ties.	Already Implemented	The U.S. EPR design has four battery divisions and two severe accident battery divisions. The redundancy and capacity of the battery divisions of the U.S. EPR design meets the intent of this SAMDA.
AC/DC-06	Provide additional DC power to the 120/240V vital AC system.	Already Implemented	The U.S. EPR EUPS system is sized to supply class 1E 120/240V vital AC systems. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
AC/DC-07	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.	Already Implemented	The class 1E 120V vital AC systems are supplied from a bus that is automatically supplied by the class 1E 2 hour batteries, the emergency diesel generators (EDG), and the SBO diesel generators. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
AC/DC-08	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-09	Provide an additional diesel generator.	Already Implemented	The U.S. EPR design has four independent EDGs, which are located in four separate safety class buildings. The plant also has two SBO diesel generators. Therefore, it is concluded that this configuration fulfills the intent of this SAMDA.
AC/DC-10	Revise procedure to allow bypass of diesel generator trips.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-11	Improve 4.16kV bus cross-tie ability.	Already Implemented	The U.S. EPR design has alternate feed (aka cross-tie) capability between the four divisions. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
AC/DC-12	Create AC power cross-tie capability with other unit (multi-unit site).	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-13	Install an additional, buried off-site power source.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $25,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
AC/DC-14	Install a gas turbine generator.	Already Implemented	The U.S. EPR standard electrical design incorporates 4 EDGs with only 2 EDGs required for safe shutdown. In addition to the 4 EDGs, there are two AC sources (diesel generators for standard design) for mitigating SBO events. There is significant redundancy in standby sources and the SBO diesel generators will be from a different manufacturer, etc., to maximize diversity with the EDGs. Therefore, the intent of this SAMDA is considered already implemented for the U.S. EPR design.
AC/DC-15	Install tornado protection on gas turbine generator.	Not Applicable	See response to AC/DC-14.
AC/DC-16	Improve uninterruptible power supplies.	Already Implemented	The EUPS includes battery chargers, a battery, a DC bus, and an inverter which supplies the vital loads. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
AC/DC-17	Create a cross-tie for diesel fuel oil (multi-unit site).	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
AC/DC-18	Develop procedures for replenishing diesel fuel oil.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-19	Use fire water system as a backup source for diesel cooling.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Nine Mile Point Unit 2 was estimated by Nine Mile Point Nuclear Station, LLC to require more than $500,000 in 2006. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
AC/DC-20	Add a new backup source of diesel cooling.	Combined with AC/DC-19	See response to AC/DC-19.
AC/DC-21	Develop procedures to repair or replace failed 4kV breakers.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-22	In training, emphasize steps in recovery of off-site power after an SBO.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-23	Develop a severe weather conditions procedure.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AC/DC-24	Bury off-site power lines.	Already Implemented	The 6.9kV cables from the off-site transformers to the Class 1E safety-related buses are run underground. The rest of the off-site power cables are deemed not feasible to run underground. Therefore, the intent of this SAMDA is considered already implemented for the U.S. EPR design.
Enhancements Related to Anticipated Transient Without Scram (ATWS)			
AT-01	Add an independent boron injection system.	Already Implemented	The U.S. EPR design has the extra borating system (EBS), which is an independent safety-related system. The EBS provides high pressure boron injection if the non-safety-related CVCS is not available. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
AT-02	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Already Implemented	The U.S. EPR design has pressurizer safety relief valves (PSRVs) and a primary depressurization system (PDS) that are used for overpressure protection of the RCS. There are three overpressure protection discharge trains which use three PSRVs assemblies arranged on the top of the pressurizer for overpressure protection of the RCS. The PDS consists of two parallel trains of four dedicated valves, which are independent of the PSRVs. The main steam relief trains (MSRT) are part of the SG secondary side overpressure protection. MSRT setpoint and capacity is such that with consideration of reactor trip, the MSRTs alone will prevent overpressurization of the secondary side. With the primary and secondary side of the plant having several ways to prevent overpressurization the intent of this SAMDA is considered to have already implemented for the U.S. EPR design.
AT-03	Provide an additional control system for rod insertion (e.g., ATWS mitigation system actuation circuitry (AMSAC)).	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $3,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
AT-04	Install an ATWS sized filtered containment vent to remove decay heat.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $2,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
AT-05	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AT-06	Revise procedure to allow override of low pressure core injection during an ATWS event.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
AT-07	Install motor generator set trip breakers in control room.	Already Implemented	The U.S. EPR design has the capability for a manual reactor trip performed by an operator. There are four dedicated reactor trip buttons in the main control room, one for each division. Each division consists of trip breakers, trip contactors, and transistors which control power to operating coils of the control rod drive mechanisms (CRDM). Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
AT-08	Provide capability to remove power from the bus powering the control rods.	Already Implemented	The U.S. EPR design has the capability to remove power from the bus powering the control rods by tripping the reactor trip breaks which can be performed via signal from the protection system, or from the main control room or remote shutdown station via a shunt trip coil. Therefore, the intent of this is SAMDA is considered to have already been implemented for the U.S. EPR design.
Enhancements Related to Containment Bypass			
CB-01	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Already implemented	The U.S. EPR design has a leakage detection system (LDS) that detects, quantifies, and determines the location of leakage from the reactor coolant pressure boundary (RCPB) and select portions of the main steam system (MSS) and MFW. The system continuously monitors for the slightest amount of leakage and provides operators with early warning of conditions. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CB-02	Add redundant and diverse limit switches to each containment isolation valve.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $1,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CB-03	Increase leak testing of valves in ISLOCA paths.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-04	Install self-actuating containment isolation valves.	Already Implemented	The U.S. EPR containment isolation valves automatically isolate on high containment pressure via signal from the reactor protection system. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CB-05	Locate RHR inside containment.	Excessive Implementation Cost	The RHR system is currently located in the Safeguards Building. The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $500,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CB-06	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $2,500,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CB-07	Revise EOP to improve ISLOCA identification.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-08	Improve operator training on ISLOCA coping.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-09	Institute a maintenance practice to perform a 100% inspection of SG tubes during each refueling outage.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-10	Replace SGs with a new design.	Already Implemented	The U.S. EPR design includes SGs that use Alloy 690 tubing which has shown less propensity to stress corrosion cracking than generators with Alloy 600 tubing. Since this SAMDA was designed to decrease the frequency of tube rupture events by using the industry's best practices, it is concluded that this SAMDA is already implemented.
CB-11	Increase the pressure capacity of the secondary side so that an SGTR would not cause the relief valves to lift.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $1,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CB-12	Install a redundant spray system to depressurize the primary system during an SGTR.	Already Implemented	The U.S. EPR design has a normal pressurizer spray and an auxiliary spray. The auxiliary spray is part of the CVCS and is operational during loss of off-site power. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CB-13	Proceduralize use of pressurizer vent valves during SGTR sequences.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-14	Provide improved instrumentation to detect SGTRs, such as Nitrogen-16 monitors.	Already Implemented	The U.S. EPR design incorporates instrumentation to detect SGTR. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CB-15	Route the discharge from the MSSVs through a structure where a water spray would condense the steam and remove most of the fission products.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $9,500,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CB-16	Install a highly reliable (closed loop) SG shell-side heat removal system that relies on natural circulation and stored water sources.	Already Implemented	The SGs of the U.S. EPR design are vertical shell, natural circulation, U-tube heat exchangers. The secondary side is cooled with feedwater supplied from the Deaerator/Feedwater Storage Tank. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CB-17	Revise EOP to direct isolation of a faulted SG.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-18	Direct SG flooding after an SGTR, prior to core damage.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-19	Vent MSSVs in containment.	Excessive Implementation Cost	The cost to implement an average design change requires a minimum of three months of engineering support. Engineering support involves two engineers working full-time at a rate of $100/hour on the design change. Venting the MSSVs into containment is a significant design change and requires more than three months of engineering support with places the cost over $100,000. The overall implementation cost, including equipment costs, is higher. The attainable benefit for all SAMDAs is $70,600. The attainable benefit is less than the overall implementation cost of the design change of venting MSSVs to containment, and venting the MSSVs into containment is not cost beneficial for the U.S. EPR design.
CB-20	Install relief valves in the CCWS	Already implemented	The U.S. EPR CCWS has safety valves installed between the component cooling water and RCP barrier in order to limit the component cooling water pressure in the event of an ISLOCA. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
Enhancements Related to Core Cooling Systems			
CC-01	Install an independent active or passive high pressure injection system.	Already Implemented	The U.S. EPR SIS includes 4 independent trains, each with the capability of medium head safety injection (MHSI). These trains are capable of preventing core melt sequences. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-02	Provide an additional high pressure injection pump with independent diesel.	Combined with CC-01	SAMDA CC-01 intent encompasses this SAMDA, and therefore this SAMDA is already implemented
CC-03	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CC-04	Add a diverse low pressure injection system.	Already Implemented	The U.S. EPR SIS includes 4 independent trains, each with the capability of low head safety injection (LHSI). Although not diverse the 4 independent trains of LHSI meet the intent of this SAMDA. Therefore, this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-05	Provide capability for alternate injection via diesel-driven fire pump.	Already Implemented	The U.S. EPR diesel-driven fire pump does not provide injection into the ECCSs. However, the U.S. EPR design has 4 separate independent trains of safety injection with each train capable of performing 100% of the required injection. Therefore, the intent to improve injection capability is considered to have been already implemented for the U.S. EPR design.
CC-06	Improve ECCS suction strainers.	Already Implemented	The SIS takes suction from the IRWST which is capable of backflushing, thus removing debris and preventing plugging of strainers. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-07	Add the ability to manually align ECCS recirculation.	Already Implemented	The U.S. EPR SIS already has the ability to be manually aligned to recirculation. Since the IRWST is located in the containment building and all effluent injected by the SIS and lost through a break is collected in the IRWST. This allows for recirculation. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-08	Add the ability to automatically align ECCS to recirculation mode upon refueling water storage tank depletion.	Not Applicable	The design of the IRWST and the SIS is such that it does not allow depletion of the IRWST. Since the IRWST is located in the containment building and all effluent injected by the SIS and lost through a break is eventually collected in the IRWST. Therefore, this SAMDA is not applicable to the U.S. EPR design.
CC-09	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	Already Implemented / Not Required for Design Certification	Refill or makeup water sources for the IRWST include the reactor boron water makeup system, fuel pool purification system and the demineralized water distribution system. The procedures for water makeup are beyond the scope of the U.S. EPR Design Certification application.
CC-10	Provide an in-containment reactor water storage tank.	Already Implemented	The U.S. EPR design includes an IRWST. Therefore, this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-11	Throttle low pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	Not Applicable	The U.S. EPR plant is designed such that the capacity of the IRWST is significantly large and all break effluent eventually drains back to the IRWST. Therefore, throttling of the pumps would not extend the capacity of the IRWST. Therefore, this SAMDA is not applicable to the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CC-12	Emphasize timely recirculation alignment in operator training.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CC-13	Upgrade CVCS to mitigate small LOCAs.	Not Applicable	This modification is applicable only to designs where active SISs are not designed to mitigate a small LOCA without primary system depressurization. The potential for such a scenario is not considered applicable for the U.S. EPR design.
CC-14	Change the IRWST suction from four check valves to two check and two air-operated valves.	Not Applicable	The U.S. EPR design uses motor operated valves for the IRWST suction. Therefore, this SAMDA is not applicable to the U.S. EPR design.
CC-15	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Already Implemented	The U.S. EPR design includes four independent trains each with an electric-powered pump that is backed-up by a separate diesel generator providing redundancy. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-16	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in an SBO.	Not Applicable	Spring operated valves that open at a specified setpoint are used in the U.S. EPR design but are not credited in SBO analysis. Therefore, this SAMDA is not applicable to the U.S. EPR design.
CC-17	Create a reactor coolant depressurization system.	Already Implemented	The U.S. EPR design has a reactor coolant depressurization system. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CC-18	Make procedure changes for RCS depressurization.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CC-19	Provide an additional flow path from the refueling water tank to the high-pressure SIS through a diversified suction flow path check valve.	Not Applicable	The U.S. EPR design does not have a high-pressure injection system; therefore, this SAMDA is not applicable.
CC-20	Provide actuator diversity for the motor-operated valves in the high-pressure SIS.	Not Applicable	The U.S. EPR design does not have a high-pressure injection system; therefore, this SAMDA is not applicable.
CC-21	Modify the containment sump strainers to prevent plugging.	Already Implemented	The severe accident heat removal system (SAHRS) sump is capable of backflushing, thus removing debris and preventing plugging. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
Enhancements Related to Containment Phenomena			

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CP-01	Create a reactor cavity flooding system.	Already Implemented	The recirculation function of the SAHRS has the ability to submerge the reactor cavity and the vessel up to the level of the RCS piping. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-02	Install a passive containment spray system.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $1,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CP-03	Use the fire water system as a backup source for the containment spray system.	Already Implemented	The U.S. EPR design already contains defense-in-depth for containment pressure control. Design basis post-accident pressure control is achieved through the large free volume of the containment coupled with containment heat removal via the IRWST and RHR cooling chain. In addition, for beyond design basis accident pressure control, the U.S. EPR design contains a SAHRS with a containment spray system. Because the intent of this SAMDA has already been addressed in the U.S. EPR design, this design change was not considered further in this evaluation.
CP-04	Install an unfiltered, hardened containment vent.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $3,100,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CP-05	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter, Option 2: Multiple Venturi Scrubber	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require $3,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CP-06	Enhance fire protection system and standby gas treatment system hardware and procedures.	Combined with CP-03	This SAMDA was combined with SAMDA CP-03 since this enhancement would involve hardware changes similar to those considered in CP-03. Although the modification to the standby gas treatment system are not applicable to the U.S. EPR design. Therefore, this specific SAMDA is no longer considered for further evaluation.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CP-07	Provide post-accident containment inerting capability.	Already Implemented	The hydrogen mixing and distribution system (HMDS) (a subsystem of the combustible gas control system (CGCS)) ensures that adequate communication exists throughout the containment to facilitate atmospheric mixing by using mixing dampers and rupture and convection foils above the SGs.
CP-08	Create a large concrete crucible with heat removal potential to contain molten core debris.	Already Implemented	The U.S. EPR design has a spreading area, which is a concrete structure with cast iron cooling channels and has the ability to passively cool the molten core debris. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-09	Create a core melt source reduction system.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require more than $1,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CP-10	Strengthen primary and secondary containment (e.g., add ribbing to containment shell).	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Vermont Yankee was estimated by Entergy Nuclear to require $12,000,000 in 2007. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CP-11	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Already Implemented	The U.S. EPR design has a spreading area. The spreading area consists of a 10cm layer of sacrificial concrete and cast iron cooling channels. Through several analyses performed the thickness of the sacrificial concrete would ensure that melt-through of the cast iron cooling structure would not occur. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-12	Provide a reactor vessel exterior cooling system.	Not Applicable	The severe accident progression strategy for the U.S. EPR design requires the lower head to remain dry in order for vessel failure and melt stabilization. Therefore, this SAMDA is not applicable.
CP-13	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Already Implemented	The annulus area between the double containment shells is maintained at a vacuum by the annulus ventilation system (AVS). This system is used to filter any leakage through the primary containment, in the event of design basis and severe accidents, prior to releasing it from the plant stack. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-14	Institute simulator training for severe accident scenarios.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CP-15	Improve leak detection procedures.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CP-16	Delay containment spray actuation after a large LOCA.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CP-17	Install automatic containment spray pump header throttle valves.	Already Implemented	The U.S. EPR design has an orifice plate and no throttle valves. The orifice plate would function similar to a throttle valve. Therefore, this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-18	Install a redundant containment spray system.	Excessive Implementation Cost	The U.S. EPR SAHRS has one train of containment spray. The implementation cost of a second train would be an excessive cost to the plant design.
CP-19	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Not Applicable	This SAMDA is not applicable to the U.S. EPR design because the hydrogen reduction system (a subsystem of the CGCS) uses 47 PARs, which do not require a power supply to operate as intended.
CP-20	Install a passive hydrogen control system.	Already Implemented	The U.S. EPR design has 47 PARs installed in various part of the containment. The PARs will passively actuate when a threshold hydrogen concentration is reached. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-21	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Already Implemented	The U.S. EPR design has a double shell containment and a torturous pathway from the reactor cavity to the upper containment, which enhance the protection of the containment wall from a high pressure melt ejection scenario. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CP-22	Install a secondary containment filtered ventilation.	Already Implemented	The U.S. EPR AVS is a filtered system. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CP-23	Provide actuator diversity for motor-operated valves in the containment spray system.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $425,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
Enhancements Related to Cooling Water			
CW-01	Add redundant DC control power for SW pumps.	Already Implemented	The emergency service water system (ESWS) consists of 4 safety-related trains and 1 dedicated non-safety train, which increase the availability of the SW. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-02	Replace ECCS pump motors with air-cooled motors.	Already Implemented	The U.S. EPR ECCS pump motors are cooled by component cooling water with the exception of the LHSI pump Trains 1 and 4, which are cooled by the SCWS. The CCWS and SCWS are both closed loop systems which consist of four separate and independent trains. Due to the redundancy and separation of the U.S. EPR design the intent of this SAMDA is considered to have already been implemented.
CW-03	Enhance procedural guidance for use of cross-tied component cooling or SW pumps.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-04	Add an SW pump.	Already Implemented	The ESWS consists of 4 safety related trains and 1 dedicated non-safety train, which increase the availability of the SW. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-05	Enhance the screen wash system.	Already Implemented	The ESWS filters are designed to be backwash type, therefore the reverse flow through the filters removes the debris. The intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-06	Cap downstream piping of normally closed component cooling water drain and vent valves.	Already Implemented	The U.S. EPR design uses screw plugs to cap downstream piping of normally closed component cooling water drain and vent valves.
CW-07	Enhance loss of component cooling water (or loss of SW) procedures to facilitate stopping the RCPs.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CW-08	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the RCS prior to seal LOCA.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-09	Additional training on loss of component cooling water.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-10	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	Already Implemented	The CWCS consists of 4 safety trains and 2 non-safety trains. The redundancy of the design allows for cooling of the charging pumps even after loss of 2 trains of CCWS. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-11	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heatup time.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-12	Increase charging pump lube oil capacity.	Not Applicable	The fleet of operating PWR plants use their charging pumps for high pressure safety injection. In the U.S. EPR design charging pumps are not used for accident mitigation instead four separate independent trains are used for MHSI and LHSI. Each train is capable of performing 100% of the required injection. Therefore, this SAMDA is considered not applicable for the U.S. EPR design.
CW-13	Install an independent RCP seal injection system, with dedicated diesel.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $1,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
CW-14	Install an independent RCP seal injection system, without dedicated diesel.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $1,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CW-15	Use existing hydro test pump for RCP seal injection.	Already Implemented	The U.S. EPR design does not use a hydro test pump instead it uses the EBS pumps to perform RCS hydrostatic pressure testing. The U.S. EPR design uses the CVCS pumps for RCP seal injection. Since the U.S. EPR design has a pump in place for RCP seal injection the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-16	Install improved RCP seals.	Already Implemented	In addition to the three RCP seals the U.S. EPR design is equipped with a stand still seal. The stand still seal is used in a loss of cooling event to the RCPs. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-17	Install an additional component cooling water pump.	Already Implemented	The CCWS consists of 4 safety trains and 2 non-safety trains, which provides redundancy for the system. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
CW-18	Prevent makeup pump flow diversion through the relief valves.	Combined with CW-13	This SAMDA is already in capsulated in CW-13, since this enhancement would involve changes similar to those considered in CW-13.
CW-19	Change procedures to isolate RCP seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-20	Implement procedures to stagger high pressure safety injection pump use after a loss of SW.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CW-21	Use fire prevention system pumps as a backup seal injection and high pressure makeup source.	Not Applicable	The use of fire water as a backup seal injection and reactor vessel makeup source is applicable to BWRs. The fire protection system is supplied from a non-borated water source. Injection of non-borated water into the primary system of a PWR would cause reactivity excursions. Therefore, the intent of this SAMDA is not considered applicable to the U.S. EPR design.
CW-22	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the CCWS, or install a component cooling water header cross-tie.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Browns Ferry Nuclear Plant, Units 1, 2, and 3 was estimated by Tennessee Valley Authority to require more than $150,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600). Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
U.S. EPR Specific Enhancements			

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
EPR-01	Provide an additional SCWS train.	Already Implemented	The U.S. EPR SCWS consists of four separate and independent divisions. Each division is located in one of the four Safeguard Buildings. Therefore, it is concluded that this configuration fulfills the intent of this SAMDA.
EPR-02	Training for operator actions during small LOCA scenarios.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
EPR-03	Operator training to initiate RHR system.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
EPR-04	Training for operator actions during SGTR scenarios.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
EPR-05	Add redundant pressure sensors to the pressurizer and SG.	Already Implemented	The U.S. EPR pressurizer has four redundant pressure sensors and SG 4 has three redundant pressure sensors. Therefore, it is concluded that this configuration fulfills the intent of this SAMDA.
EPR-06	Provide operator training on manually actuating the EBS.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
EPR-07	Provide operator training to cross tie Division 1 to Division 2 or Division 4 to Division 3 during both an SBO and non-SBO event.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
Enhancements Related to Internal Flooding			
FL-01	Improve inspection of rubber expansion joints on main condenser.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
FL-02	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	Not Applicable	The U.S. EPR Safeguards Building has no unsealed exterior wall or floor penetrations below plant flood level, water stops in all below grade exterior construction joints, and floor drainage. Therefore, modifying the swing direction of the doors would not prevent flood propagation and this SAMDA is not applicable to the U.S. EPR design.
Enhancements to Reduce Fire Risk			

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
FR-01	Replace mercury switches in fire protection system.	Not Required for Design Certification	The U.S. EPR design is expected to have three mercury switches, which will be located in the Fire Pump House. At this stage of the design the mercury switches are planned to be an integral part of the controller. The final design of the mercury switches will be developed during the detail design phase of the U.S. EPR design. Therefore, this SAMDA will be addressed during the COL process (or detailed design).
FR-02	Upgrade fire compartment barriers.	Excessive Implementation Cost	The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600). Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
FR-03	Install additional transfer and isolation switches.	Already Implemented	Control functions for isolation (enable/disable) will be performed via software logics. Transfer functions for clean agent suppression systems for transferring between main/reserve agent supplies would be performed locally via a switch. There would be two of them. Due to the redundancy of this system, the intent of this SAMDA is considered to be already implemented for the U.S. EPR design.
FR-04	Enhance fire brigade awareness.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
FR-05	Enhance control of combustibles and ignition.	Already Implemented	The CGCS is designed to reduce the amount of combustible gases in containment, therefore decreasing the possibility of a ignition. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
Enhancements Related to Feedwater and Condensate			
FW-01	Install a digital feed water upgrade.	Already Implemented	The U.S. EPR design uses digital feedwater instrumentation. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
FW-02	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	Already Implemented	The U.S. EPR design has a connection to the demineralized water system (DWS) is available at both the condenser hotwells and the deaerator/feedwater storage tank. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
FW-03	Install an independent diesel for the condensate storage tank makeup pumps.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $314,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.
FW-04	Add a motor-driven feedwater pump.	Already Implemented	The U.S. EPR design has four electric motor-driven feedwater pumps. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
FW-05	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	Not Applicable	The U.S. EPR design uses four motor-driven EFW pumps. Therefore, this SAMDA is considered not applicable for the U.S. EPR design.
FW-06	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	Not Applicable	The U.S. EPR design uses four motor-driven EFW pumps. Therefore, this SAMDA is considered not applicable for the U.S. EPR design.
FW-07	Install a new condensate storage tank (auxiliary feedwater storage tank).	Already Implemented	Since the U.S. EPR design is a new plant, inherently, a new condensate storage tank has been installed. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
FW-08	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	Not Applicable	The U.S. EPR design uses four motor-driven EFW pumps. Therefore, this SAMDA is considered not applicable for the U.S. EPR design.
FW-09	Proceduralize local manual operation of auxiliary feedwater system when control power path is lost.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
FW-10	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	Not Applicable	The U.S. EPR design uses four motor-driven EFW pumps. Therefore, this SAMDA is considered not applicable for the U.S. EPR design.
FW-11	Use fire water system as a backup for SG inventory.	Already Implemented	The U.S. EPR design has start-up shutdown system (SSS) and EFW, which supply water to the SGs to maintain water level and remove decay heat following a loss of normal feedwater supply. Although the fire system water is not planned to supply backup water to the SG, the backup for MFW is EFW and the backup for EFW is SSS. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
FW-12	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	Not Applicable	This design change prevents draining of the condensate storage tank to the condenser, instead leaving the volume available for auxiliary feedwater. This is beneficial in existing plants, where auxiliary feedwater uses the condensate storage tank as its normal supply. The U.S. EPR design has dedicated emergency feedwater storage tanks with a combined volume of approximately 400,000 gallons. The volume of these tanks is not used to provide condenser makeup and is not altered by a change to the condenser makeup valve position. Changing the failure position of the condenser makeup valve does not benefit the U.S. EPR design and is not applicable.
FW-13	Provide a passive, secondary- side heat-rejection loop consisting of a condenser and heat sink.	Not Required for Design Certification	The U.S. EPR design has a condenser and mechanical draft cooling tower. The mechanical draft cooling tower is powered by the Class 1E emergency power supply system and will be loaded on the EDGs in the event of a LOOP for design basis accident mitigation. Additionally, these mechanical draft cooling towers can be powered from the SBO diesel generators in the event of a LOOP for severe accident mitigation. However, the specific methods and equipment used to reject heat to the environment could vary with site location. Therefore, this SAMDA is beyond the scope of the U.S. EPR Design Certification application.
FW-14	Modify the startup feedwater pump so that it can be used as a backup to the EFWS, including during an SBO scenario.	Very Low Benefit	The U.S. EPR SSS feedwater pumps can be used to back-up the EFW system. In a LOOP event it results in a loss of the SSS feedwater pump. However, two trains of the EFW system (Divisions 1 and 4) are backed-up by the SBO diesels. The common cause failure for EFW pumps in divisions 1 and 4 is $6.7{\cdot}10^{-5}$. The common cause failure for the SBO diesel generators is $1.6{\cdot}10^{-3}$, which is 24 times higher than the common cause failure for the EFW pumps. Therefore, this SAMDA is considered to be very low benefit.
FW-15	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Already Implemented	The U.S. EPR design uses motor-operated valves for feed and bleed operation. Only one valve is required for a successful feed and bleed. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
FW-16	Perform surveillances on manual valves used for backup auxiliary feedwater pump suction.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
Enhancements Related to Heating, Ventilation, and Air Conditioning			
HV-01	Provide a redundant train or means of ventilation to the switchgear rooms.	Already Implemented	The U.S. EPR design has a means of ventilation to the switchgear rooms. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
HV-02	Add a diesel building high temperature alarm or redundant louver and thermostat.	Already Implemented	The diesel building will have multiple redundant high or low temperature alarms in the Diesel Hall and EDG controls / electrical room. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
HV-03	Stage backup fans in switchgear rooms.	Not Required for Design Certification	At this time the U.S. EPR design of the stage backup fans in the switchgear rooms is not complete. The final design of the will be developed during the detail design phase for the U.S. EPR design. Therefore, this SAMDA is beyond the scope of the U.S. EPR Design Certification application.
HV-04	Add a switchgear room high temperature alarm.	Already Implemented	The U.S. EPR design has high temperature alarms in the switchgear rooms. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
HV-05	Create ability to switch EFW room fan power supply to station batteries in an SBO.	Already Implemented	The U.S. EPR design has an Alternate Alternating Current (AAC) source (SBO diesel generator), to power certain electrical loads during a SBO, therefore, it doesn't have to rely on station batteries to power these loads during SBO conditions. The EFW room fan power supply will be powered by the AAC source (SBO Diesel Generator) during SBO conditions for the U.S. EPR. Most U.S. nuclear power plants don't have an AAC source and rely totally on their batteries for electrical power during a SBO. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
Enhancements Related to Instrument Air and Nitrogen Supply			
IA-01	Provide cross-unit connection of uninterruptible compressed air supply.	Not Applicable	The U.S. EPR design does not vent containment through a hardened vent. This SAMDA was intended for BWR type plants; therefore, this SAMDA is not applicable to the U.S. EPR design.
IA-02	Modify procedure to provide ability to align diesel power to more air compressors.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
IA-03	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Not Required for Design Certification	At this time the U.S. EPR design of the service and instrument air compressor cooling mechanism is not complete. The final design of the will be developed during the detail design phase for the U.S. EPR design. Therefore, this SAMDA is beyond the scope of the U.S. EPR Design Certification application.
IA-04	Install nitrogen bottles as backup gas supply for SRVs.	Not Applicable	Main steam relief isolation valves (MSRIV) are controlled by self-medium operated pilot valves; the MSRVs are controlled by motor driven glove valves; the MSSV are controlled by spring loaded valves; therefore, this SAMDA is not applicable for the U.S. EPR design.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
IA-05	Improve SRV and MSIV pneumatic components.	Not Applicable	MSRIVs are controlled by self-medium operated pilot valves, the MSRV are controlled by motor driven glove valves, MSIVs are controlled by a gate valve, and the MSSV are controlled by spring loaded valves; therefore, this SAMDA is not applicable for the U.S. EPR design.
Enhancements to Reduce Seismic Risk			
SR-01	Increase seismic ruggedness of plant components.	Already Implemented	A seismic margin assessment was completed for the U.S. EPR design. The NRC guidance from SECY-93-087 indicates that the seismic margin needs to be 1.67 times the safe shutdown earthquake. From this assessment it was concluded that the U.S. EPR design meets the 1.67 times safe shutdown earthquake for the plant high confidence of low probability of failure (review level earthquake). Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
SR-02	Provide additional restraints for CO_2 tanks.	Already Implemented	The U.S. EPR gaseous suppression system uses 3MTM NovecTM 1230 fire protection fluid instead of CO_2. The tanks for the gaseous suppression system are Seismic II qualified in order to ensure the tanks are restrained properly. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
Other Enhancements			
OT-01	Install digital large break LOCA protection system.	Already implemented	The U.S. EPR design has LDS that detects, quantifies, and determines the location of leakage from the reactor RCPB and select portions of the MSS and the MFW system. The system continuously monitors the environment for the slightest amount of leakage and provides operators with an early warning of conditions. Therefore the intent of this SAMDA is considered to have already been implemented for the U.S. EPR design.
OT-02	Enhance procedures to mitigate large break LOCA.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
OT-03	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
OT-04	Improve maintenance procedures.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
OT-05	Increase training and operating experience feedback to improve operator response.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
OT-06	Develop procedures for transportation and nearby facility accidents.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
OT-07	Install secondary side guard pipes up to the MSIVs.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $1,100,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($70,600) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR design based on the results of this evaluation.

6.0 RESULTS AND SUMMARY

A total of 167 SAMDA candidates developed from industry and U.S. EPR documents were evaluated in this analysis.

- Twenty-one SAMDA candidates were not applicable to the U.S. EPR design.
- Sixty-seven SAMDA candidates were already implemented into the U.S. EPR design either as suggested in the SAMDA or an equivalent replacement that fulfilled the intent of the SAMDA. These SAMDA candidates are summarized in Table 6-1.
- Four SAMDA candidates were combined with another SAMDA because they had the same intent.
- Fifty SAMDA candidates were categorized as not required for design certification because they were related to a procedural or surveillance action. These SAMDA candidates are summarized in Table 6-2.
- One SAMDA candidate was categorized as very low benefit.
- Twenty-four SAMDA candidates were categorized as excessive implementation cost.
- None of the SAMDA candidates were categorized as consider for further evaluation.

As demonstrated by the PRA, the low probability of core damage events in the U.S. EPR design coupled with reliable severe accident mitigation features provide significant protection to the public and the environment. A detailed analysis of specific SAMDA candidates from previous industry studies and from U.S. EPR PRA insights was performed against broad acceptance criteria. None of the SAMDA candidates met the criteria; therefore, the overall conclusion is that no additional plant modifications are cost beneficial to implement due to the robust design of the U.S. EPR plant with respect to prevention and mitigation of severe accidents.

Table 6-1 SAMDA Candidates – Already Implemented

SAMDA ID	Potential Enhancement
AC/DC-01	Provide additional DC battery capacity.
AC/DC-03	Add additional battery charger or portable, diesel-driven battery charger to existing DC system.
AC/DC-04	Improve DC bus load shedding.
AC/DC-05	Provide DC bus cross-ties.
AC/DC-06	Provide additional DC power to the 120/240V vital AC system.
AC/DC-07	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.
AC/DC-09	Provide an additional diesel generator.
AC/DC-11	Improve 4.16 kV bus cross-tie ability.
AC/DC-14	Install a gas turbine generator.
AC/DC-16	Improve uninterruptible power supplies.
AC/DC-24	Bury off-site power lines.
AT-01	Add an independent boron injection system.
AT-02	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.
AT-07	Install motor generator set trip breakers in control room.
AT-08	Provide capability to remove power from the bus powering the control rods.
CB-01	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.
CB-04	Install self-actuating containment isolation valves.
CB-10	Replace SGs with a new design.
CB-12	Install a redundant spray system to depressurize the primary system during an SGTR.
CB-14	Provide improved instrumentation to detect SGTR, such as Nitrogen-16 monitors.
CB-16	Install a highly reliable (closed loop) SG shell-side heat removal system that relies on natural circulation and stored water sources.
CB-20	Install relief valves in the CCWS.
CC-01	Install an independent active or passive high pressure injection system.
CC-04	Add a diverse low pressure injection system.
CC-05	Provide capability for alternate injection via diesel-driven fire pump.
CC-06	Improve ECCS suction strainers.
CC-07	Add the ability to manually align ECCS recirculation.
CC-10	Provide an IRWST.
CC-15	Replace two of the four electric safety injection pumps with diesel-powered pumps.

SAMDA ID	Potential Enhancement
CC-17	Create a reactor coolant depressurization system.
CC-21	Modify the containment sump strainers to prevent plugging.
CP-01	Create a reactor cavity flooding system.
CP-03	Use the fire water system as a backup source for the containment spray system.
CP-07	Provide post-accident containment inerting capability.
CP-08	Create a large concrete crucible with heat removal potential to contain molten core debris.
CP-11	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.
CP-13	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.
CP-17	Install automatic containment spray pump header throttle valves.
CP-20	Install a passive hydrogen control system.
CP-21	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.
CP-22	Install a secondary containment filtered ventilation.
CW-01	Add redundant DC control power for SW pumps.
CW-02	Replace ECCS pump motors with air-cooled motors.
CW-04	Add a SW pump.
CW-05	Enhance the screen wash system.
CW-06	Cap downstream piping of normally closed component cooling water drain and vent valves.
CW-10	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.
CW-15	Use existing hydro test pump for RCP seal injection.
CW-16	Install improved RCP seals.
CW-17	Install an additional component cooling water pump.
EPR-01	Provide an additional SCWS train.
EPR-05	Add redundant pressure sensors to the pressurizer and SG.
FR-03	Install additional transfer and isolation switches.
FR-05	Enhance control of combustibles and ignition.
FW-01	Install a digital feed water upgrade.
FW-02	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.
FW-04	Add a motor-driven feedwater pump.
FW-07	Install a new condensate storage tank (auxiliary feedwater storage tank).
FW-11	Use fire water system as a backup for SG inventory.
FW-15	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.
HV-01	Provide a redundant train or means of ventilation to the switch gear rooms.
HV-02	Add a diesel building high temperature alarm or redundant louver and thermostat.
HV-04	Add a switchgear room high temperature alarm.
HV-05	Create ability to switch EFW room fan power supply to station batteries in an SBO.

SAMDA ID	Potential Enhancement
SR-01	Increase seismic ruggedness of plant components.
SR-02	Provide additional restraints for CO_2 tanks.
OT-01	Install digital large break LOCA protection system.

Table 6-2 SAMDA Candidates – Not Required for Design Certification

SAMDA ID	Potential Enhancement
AC/DC-08	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.
AC/DC-10	Revise procedure to allow bypass of diesel generator trips.
AC/DC-12	Create AC power cross-tie capability with other unit (multi-unit site).
AC/DC-17	Create a cross-tie for diesel fuel oil (multi-unit site).
AC/DC-18	Develop procedures for replenishing diesel fuel oil.
AC/DC-21	Develop procedures to repair or replace failed 4 kV breakers.
AC/DC-22	In training, emphasize steps in recovery of off-site power after an SBO.
AC/DC-23	Develop a severe weather conditions procedure.
AT-05	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.
AT-06	Revise procedure to allow override of low pressure core injection during an ATWS event.
CB-03	Increase leak testing of valves in ISLOCA paths.
CB-07	Revise EOPs to improve ISLOCA identification.
CB-08	Improve operator training on ISLOCA coping.
CB-09	Institute a maintenance practice to perform a 100% inspection of SG tubes during each refueling outage.
CB-13	Proceduralize use of pressurizer vent valves during SGTR sequences.
CB-17	Revise EOP to direct isolation of a faulted SG.
CB-18	Direct SG flooding after an SGTR, prior to core damage.
CC-03	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.
CC-09	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.
CC-12	Emphasize timely recirculation alignment in operator training.
CC-18	Make procedure changes for RCS depressurization.
CP-14	Institute simulator training for severe accident scenarios.
CP-15	Improve leak detection procedures.
CP-16	Delay containment spray actuation after a large LOCA.
CW-03	Enhance procedural guidance for use of cross-tied component cooling or SW pumps.
CW-07	Enhance loss of component cooling water (or loss of SW) procedures to facilitate stopping the RCPs.
CW-08	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the RCS prior to seal LOCA.
CW-09	Additional training on loss of component cooling water.
CW-11	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heatup time.

SAMDA ID	Potential Enhancement
CW-19	Change procedures to isolate RCP seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.
CW-20	Implement procedures to stagger high pressure safety injection pump use after a loss of SW.
EPR-02	Training for operator actions during SLOCA scenarios.
EPR-03	Operator training to initiate RHR system.
EPR-04	Training for operator actions during SGTR scenarios.
EPR-06	Provide operator training on manually actuating the EBS.
EPR-07	Provide operator training to cross tie Division 1 to Division 2 or Division 4 to Division 3 during both a station black out and non-SBO event.
FL-01	Improve inspection of rubber expansion joints on main condenser.
FR-01	Replace mercury switches in fire protection system.
FR-04	Enhance fire brigade awareness.
FW-09	Proceduralize local manual operation of auxiliary feedwater system when control power path is lost.
FW-13	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.
FW-16	Perform surveillances on manual valves used for backup auxiliary feedwater pump suction
HV-03	Stage backup fans in switchgear rooms.
IA-02	Modify procedure to provide ability to align diesel power to more air compressors.
IA-03	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.
OT-02	Enhance procedures to mitigate large break LOCA.
OT-03	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.
OT-04	Improve maintenance procedures.
OT-06	Increase training and operating experience feedback to improve operator response.
OT-07	Develop procedures for transportation and nearby facility accidents.

7.0 REFERENCES

1. Nuclear Energy Institute NEI 05-01, Revision A, "Severe Accident Mitigation Alternatives (SAMA) Analysis, Guidance Document," November 2005.

2. NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," January 1997.