APR1400

APPLICANT'S ENVIRONMENTAL REPORT – STANDARD DESIGN CERTIFICATION

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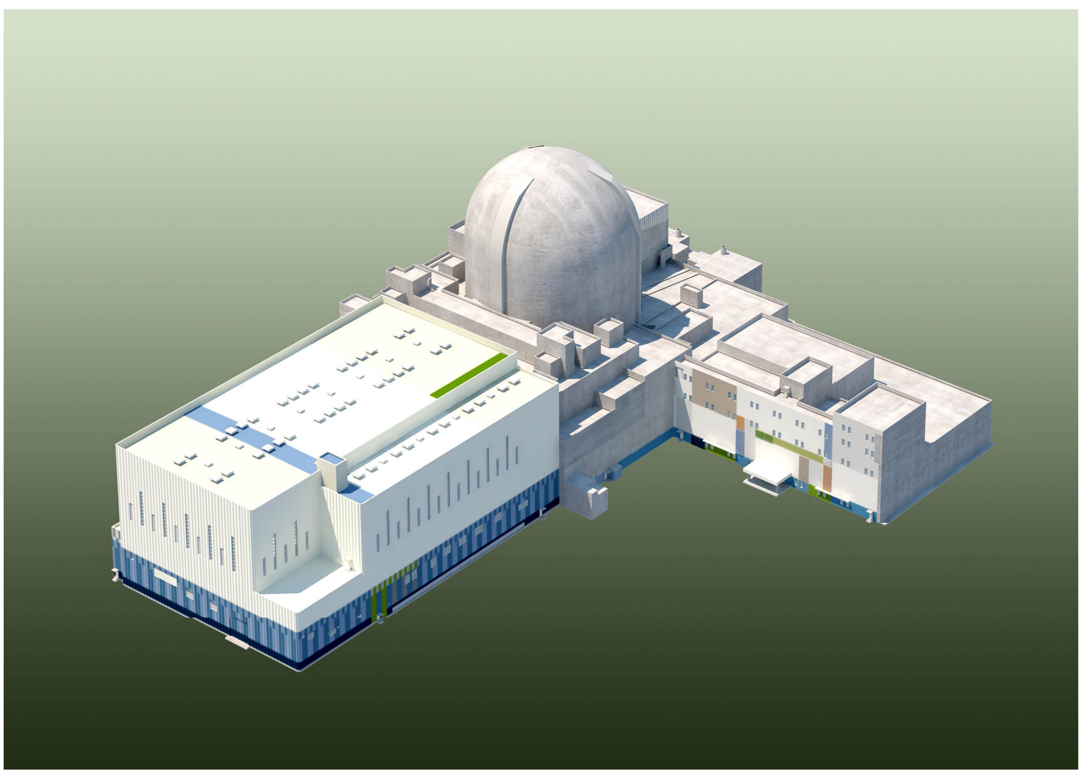

KOREA ELECTRIC POWER CORPORATION

KOREA HYDRO & NUCLEAR POWER CO., LTD

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ACRONYMS AND ABBREVIATIONS

AC	alternating current
AFW	auxiliary feedwater
AFWST	auxiliary feedwater storage tank
AMSAC	anticipated transient without scram (ATWS) mitigation system actuation circuitry
AOC	averted offsite property damage costs
AOE	averted occupational exposures
AOSC	averted onsite costs
AOV	air-operated valve
APE	averted public exposure
APR	advanced power reactor
APR1400	Advanced Power Reactor 1400
ATWS	anticipated transient without scram
CDF	core damage frequency
CE	Combustion Engineering
CFR	Code of Federal Regulations
CO_2	carbon dioxide
COE	cost of enhancement
CST	condensate storage tank
dc	direct current
DC	Design Certification
ECCS	emergency core cooling system
ECW	essential chilled water
EDG	emergency diesel generator
EOP	emergency operating procedure
ESW	essential service water
FV	Fussell-Vesely
H_2	hydrogen
HP/LP	high pressure/low pressure

HVAC	heating, ventilation, and air conditioning
HVT	holdup volume tank
IRWST	in-containment refueling water storage tank
ISLOCA	interfacing system loss-of-coolant accident
KEPCO	Korea Electric Power Corporation
KHNP	Korea Hydro & Nuclear Power, Inc.
LOCA	loss-of-coolant accident
LOOP	loss-of-offsite power
LPSD	low power and shutdown
MCR	main control room
MSIV	main steam isolation valve
NEI	Nuclear Energy Institute
NPV	net present value
NRC	U.S. Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Regulation
P&ID	piping and instrument diagram
POSRV	pilot-operated safety relief valve
PRA	probabilistic risk assessment
PV	present value
PW	present worth
RCP	reactor coolant pump
REM	roentgen equivalent man
RHR	residual heat removal
RPV	reactor pressure vessel
SAMA	severe accident mitigation alternative
SAMDA	severe accident mitigation design alternative
SBO	station blackout
SG	steam generator
SGTR	steam generator tube rupture
SI	safety injection

SLC	secondary liquid control
SRV	safety relief valve
SSC	structure, system, or component
STC	source term category
SW	service water
U.S.C.	U.S. Code

1. INTRODUCTION

This report provides an evaluation of severe accident mitigation design alternatives (SAMDAs) for the Advanced Power Reactor 1400 (APR1400) design. The evaluation was performed to address the potential costs and benefits of SAMDAs for the APR1400 design. Consideration of SAMDAs included identifying a broad range of potential alternatives and then determining whether implementation of the alternative would be feasible and beneficial on a cost-risk reduction basis.

The methods used to identify, screen, and evaluate SAMDAs for the APR1400 Design Certification are described.

This report also describes the calculation of the monetary value of unmitigated base risk and the results of an evaluation of the maximum risk reduction that would be expected from implementing a risk reduction strategy.

This report was developed to conform with the following regulations:

- Section 102 of the National Environmental Policy Act of 1969, as amended (42 U.S.C. § 4332), which requires in part that:

  all agencies of the Federal Government shall … (C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on … (iii) alternatives to the proposed action.

- 10 CFR 52.47(b)(2), which requires that the application include an environmental report as required by 10 CFR 51.55.

- 10 CFR 51.55(a), which states that:

  [e]ach applicant for a standard design certification … shall submit with its application a separate document entitled, "Applicant's Environmental Report—Standard Design Certification." The environmental report 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.

2. METHODOLOGY

The acceptance criterion for severe accident mitigation alternatives (SAMAs) is provided in Section 7.3 of NUREG-1555, "Environmental Standard Review Plan – Severe Accident Mitigation Alternatives" (Reference 5), as follows:

> Completeness and reasonableness, also with respect to the following: (1) the identification of SAMAs applicable to the plant or design under consideration, (2) the estimation of core damage frequency reduction and averted person-rem for each SAMA, (3) the estimation of cost for each SAMA, (4) the ranking of value-impact screening criteria to identify SAMAs for further consideration, and (5) the final disposition of promising SAMAs.

The evaluation of SAMDAs for the APR1400 design certification consists of the steps listed below in conformance with the acceptance criterion described above. The sections of this report where the steps are described are also provided.

1. Determine the base risk presented to the surrounding population and environment from plant operation (Section 3).

2. Calculate the monetary value of the unmitigated base risk (Section 4).

3. Identify potential SAMDAs (Section 5).

4. Screen the identified potential SAMDAs for applicability to APR1400 and the feasibility of implementing them (Section 6).

5. Evaluate the SAMDAs not screened out in Step #4 to determine the expected benefits of implementing them (Section 7).

6. Estimate the cost of implementing the SAMDAs that were evaluated in Step #5 (Section 8).

7. Compare the estimated costs to the expected benefits to determine whether implementing any potential SAMDA would be cost-beneficial (Section 9).

8. Evaluate how uncertainties could affect the cost-benefit analyses.

9. Perform a sensitivity analysis of the results (Section 10).

3. BASE RISK

Base risk is defined as the maximum possible averted risk. The first step in determining base risk is to develop and quantify a Level 1 and Level 2 probabilistic risk assessment (PRA) model for at-power internal events. The results of the model provide risk measured as core damage frequency (CDF) and the characteristics of any expected radionuclide release following a severe accident.

The PRA also includes internal fire, internal flooding, and low-power and shutdown (LPSD) events. Risk from other external events such as high winds and seismic events was determined to be negligible.

The CDFs were determined in the Level 1 PRA as follows:

- At-power internal event PRA = 1.3×10^{-06} per year
- Internal flooding events = 4.2×10^{-07} per year
- Fire-induced accident sequences = 2.1×10^{-06} per year
- LPSD internal event accident sequences = 2.9×10^{-06} per year
- LPSD flood events = 1.8×10^{-08} per year
- LPSD fire = 1.7×10^{-06} per year

The total CDF is 8.5×10-06 per year.

Using the results of the Level 1 PRA, the second step in determining base risk is to identify the characteristics of any expected radionuclide release following a severe accident and then to quantify the expected frequency of release. The Level 2 PRA model categorizes the releases into 21 source term categories (STCs). STCs are distinguished by the magnitude of fission products released, the timing of the fission product release, and the pathway for the release. STC definitions are provided in Table 1a. Risk contributions for each STC for at-power events and low-power shutdown events are presented in Tables 1a and 1b, respectively.

Representative releases were determined for each STC. The SAMDA Technical Report (Reference 4) analyzes representative sequences from each STC and develops timing and release characteristic information for representative fission product groups. This information was used to approximate the radiological release plumes used in the Level 3 PRA.

Offsite consequences were calculated from the Level 3 PRA. For each STC, the Level 3 PRA provided values for the conditional offsite dose and conditional offsite property damage that would result if a fission product release with the plume characteristics used to represent the STC occurred. The total expected dose consequence was obtained by multiplying the conditional offsite dose by the expected frequency for each STC and then summing the expected doses for all STCs.

The conditional dose and expected dose for each STC along with the total expected dose are shown in Tables 2a through 2f. Similarly, the total expected property damage was obtained by multiplying the conditional property damage value by the expected frequency for each STC and then summing the expected property damage values for all STCs. The conditional property costs and expected property costs for each STC along with the total expected property costs are shown in Tables 3a through 3f.

4. UNMITIGATED RISK MONETARY VALUE

The unmitigated risk monetary value was calculated using the methodology in Nuclear Energy Institute (NEI) NEI 05-01 (Reference 0) for the performance of cost-benefit analyses. The value of unmitigated risk can be used to represent the maximum benefit that could be achieved if all risk were eliminated for at-power events. The NEI 05-01 methodology was used to determine the net present value (NPV) of public risk according to the following formula:

NPV = (APE + AOC + AOE + AOSC) – COE

Where:

NPV = net present value of current risk ($)

APE = present value of averted public exposure ($)

AOC = present value of averted offsite property damage costs ($)

AOE = present value of averted occupational exposure ($)

AOSC = present value of averted onsite costs ($)

COE = cost of any enhancement implemented to reduce risk ($)

The derivation of each of these costs is described in Subsections 4.1 through 4.5. All equations used in these subsections were taken from NUREG/BR-0184 (Reference 2), which is the basis for the equations in NEI 05-01 (Reference 1).

The values for present worth (PW) and dollars per roentgen equivalent man (REM) were determined as follows:

- Present worth (PW) was determined by:

$$PW = \frac{1 - e^{-rt}}{r}$$

Where:

r = discount rate = 7% per year

t = plant life = 60 years

PW = present worth of a string of annual payments of $1 = $14.07

- Dollars per REM: The conversion factor used for assigning a monetary value to averted onsite and offsite exposures is $2,000/person-rem, which is consistent with the U.S. Nuclear Regulatory Commission's (NRC's) regulatory guidelines used in NEI 05-01.

4.1 Averted Public Exposure

Expected offsite doses from the internal event PRA accident sequences are presented in Tables 2a through 2f. Costs associated with these doses were calculated using the following equation:

$$APE = (F_S D_{PS} - F_A D_{PA}) R \frac{1 - e^{-rt_f}}{r}$$

Where:

APE	=	present value of averted public exposure ($)
R	=	monetary equivalent of unit dose ($2,000/person-rem)
$F_S D_{PS}$	=	baseline accident offsite dose frequency (person-rem per year from Tables 2a through 2f)
$F_A D_{PA}$	=	accident offsite dose frequency after mitigation (0 person-rem per year)
r	=	real discount rate (7% per year)
t_f	=	plant life (60 years)

Using the values given above, averted public exposure (APE) was calculated for internal events, internal flooding events, and internal fire events (for both at-power and LPSD operating conditions). Each calculation is detailed below.

APE for at-power internal events: $APE_{(IE)}$

$= (5.05E\text{-}01 \text{ person-rem per year} – 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$14,212$

APE for at-power internal flooding events: $APE_{(Fld)}$

$= (7.89 \times 10^{-02} \text{ person-rem per year} - 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$2,220$

APE for at-power internal fire events: $APE_{(Fire)}$

$= (7.11 \times 10^{-01} \text{ person-rem per year} - 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$20,009$

APE for LPSD internal events: $APE_{(SDIE)}$

$= (6.51 \times 10^{-01} \text{ person-rem per year} - 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$18,320$

APE for LPSD internal flooding events: $APE_{(SDFld)}$

$= (3.29 \times 10^{-02} \text{ person-rem per year} - 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$926$

APE for LPSD internal fire events: $APE_{(SDFire)}$

$= (7.50 \times 10^{-01} \text{ person-rem per year} - 0)*(\$2,000/\text{person-rem})*((1 - e^{-(0.07*60)})/(0.07 \text{ per year}))$

$= \$21,107$

Total APE costs are the sum of the six individual costs calculated above:

$APE_{Tot} = APE_{(IE)} + APE_{(Fld)} + APE_{(Fire)} + APE_{(SDIE)} + APE_{(SDFld)} + APE_{(SDFire)}$

APE_{Tot} = \$14,212 + \$2,220 + \$20,009 + \$18,320 + \$926 + \$21,107

APE_{Tot} = \$76,794

4.2 Averted Offsite Property Damage Costs

Annual expected offsite economic risk is shown in Tables 3a through 3f. The costs associated with averted offsite property damage costs (AOC) were calculated using the following equation:

$$AOC = \left(F_S P_{DS} - F_A P_{DA}\right)\frac{1-e^{-rt_f}}{r}$$

Where:

AOC	=	present value of averted offsite property damage costs (\$)
$F_S P_{DS}$	=	baseline accident frequency * property damage (cost per year from Tables 3a through 3f)
$F_A P_{DA}$	=	accident frequency * property damage after mitigation (0 events per year)
r	=	real discount rate (7% per year)
t_f	=	plant life (60 years)

Using these values, AOC was calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

AOC for at-power internal events: $AOC_{(IE)}$

= (\$1,391 per year – 0) * (1 – $e^{-(0.07*60)}$) / (0.07 per year)

= \$19,571

AOC for at-power internal flooding events: $AOC_{(Fld)}$

$= (\$196 \text{ per year} - 0) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$2,762$

AOC for at-power internal fire events: $AOC_{(Fire)}$

$= (\$1,926 \text{ per year} - 0) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$27,096$

AOC for LPSD internal events: $AOC_{(SDIE)}$

$= (\$1,822 \text{ per year} - 0) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$25,388$

AOC for LPSD Internal Flooding Events: $AOC_{(SDFld)}$

$= (\$74 \text{ per year} - 0) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$1,041$

AOC for LPSD internal fire events: $AOC_{(SDFire)}$

$= (\$2,049 \text{ per year} - 0) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$28,829$

Total AOC are the sum of the six individual costs calculated above or:

$$AOC_{Tot} = AOC_{(IE)} + AOC_{(Fld)} + AOC_{(Fire)} + AOC_{(SDIE)} + AOC_{(SDFld)} + AOC_{(SDFire)}$$

$$AOC_{Tot} = \$19,571 + \$2,762 + \$27,096 + \$25,388 + \$1,041 + \$28,829$$

$$AOC_{Tot} = \$104,687$$

4.3 Averted Occupational Exposure

The two types of occupational exposure due to accidents are immediate and long-term exposure. Immediate exposure occurs at the time of and during the management of the accident. Long-term exposure is associated with the cleanup and refurbishment or decommissioning of the damaged facility. The value of avoiding both types of exposure is considered when evaluating risk.

The occupational exposure associated with severe accidents is assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These estimates are consistent with the "best estimate" values presented in Section 5.7.3 of NUREG/BR-0184 (Reference 0). In calculating base risk, the accident-related onsite exposures were calculated using the best estimate exposure components applied over the onsite cleanup period. For onsite cleanup, the accident-related onsite exposures were calculated over a 10-year period. Costs associated with immediate dose, long-term dose, and total dose were calculated for internal events, internal flooding events, and internal fire events (for both at-power and LPSD operating conditions).

4.3.1 Averted Immediate Occupational Exposure Costs

Per the guidance of NEI 05-01, costs associated with immediate occupational doses from an accident were calculated using the following equation:

$$W_{IO} = (F_S D_{IOS} - F_A D_{IOA}) R \frac{1 - e^{-rt_f}}{r}$$

Where:

W_{IO} = present value of averted immediate occupational exposure ($)

F_S = baseline accident frequency (events per year from Tables 1a and 1b)

F_A = accident frequency after mitigation (0 events per year)

D_{IOS} = baseline expected immediate onsite dose (3,300 person-rem/event)

D_{IOA} = expected occupational exposure after mitigation (3,300 person-rem/event)

R = monetary equivalent of unit dose ($2,000/person-rem)

r = real discount rate (7% per year)

t_f = plant life (60 years)

Using these values, W_{IO} was calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

W_{IO} for at-power internal events: $W_{IO(IE)}$

= $((1.31 \times 10^{-06}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $122

W_{IO} for at-power internal flooding events: $W_{IO(Fld)}$

= $((4.24 \times 10^{-07}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $39

W_{IO} for at-power internal fire events: $W_{IO(Fire)}$

= $((2.07 \times 10^{-06}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $192

W_{IO} for LPSD internal events: $W_{IO(SDIE)}$

= $((2.93 \times 10^{-06}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $270

W_{IO} for LPSD internal flooding events: $W_{IO(SDFld)}$

= $((1.84 \times 10^{-08}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $2

W_{IO} for LPSD internal fire events: $W_{IO(SDFire)}$

= $((1.74 \times 10^{-06}$ events per year) * (3,300 person-rem/event) – 0)

* ($2,000/person-rem) * $(1 - e^{-(0.07*60)})$ / (0.07 per year)

= $162

4.3.2 Averted Long-Term Occupational Exposure Costs

Per the guidance of NUREG/BR-0184, costs associated with long-term occupational doses from an accident were calculated using the following equation:

$$W_{LTO} = (F_S D_{LTOS} - F_A D_{LTOA}) R * \frac{1-e^{-rt_f}}{r} * \frac{1-e^{-rm}}{rm}$$

Where:

W_{LTO} = present value of averted long-term occupational exposure ($)

F_S = baseline accident frequency (events per year from Tables 1a and 1b)

F_A = accident frequency after mitigation (0 events per year)

D_{LTOS} = baseline expected long-term onsite dose (20,000 person-rem/event)

D_{LTOA} = expected occupational exposure after mitigation (20,000 person-rem/event)

R = monetary equivalent of unit dose ($2,000/person-rem)

r = real discount rate (7% per year)

m = years over which long-term doses accrue (10 years from NUREG/BR-0184)

t_f = plant life (60 years)

Using these values, W_{LTO} was calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

W_{LTO} for at-power internal events: $W_{LTO(IE)}$

= $((1.31 \times 10^{-06}$ events per year * 20,000 person-rem/event) – 0)
* ($2,000/person-rem) * ((1 – $e^{-(0.07*60)}$) / (0.07 per year))
* ((1 – $e^{-(0.07*10)}$) / (0.07 per year * 10 years))

= $530

W_{LTO} for at-power internal flooding events: $W_{LTO(Fld)}$

$$= ((4.24\times10^{-07} \text{ events per year} * 20{,}000 \text{ person-rem/event}) - 0)$$
$$* (\$2{,}000/\text{person-rem}) * ((1 - e^{-(0.07*60)}) / (0.07 \text{ per year}))$$
$$* ((1 - e^{-(0.07 * 10)}) / (0.07 \text{ per year} * 10 \text{ years}))$$
$$= \$172$$

W_{LTO} for at-power internal fire events: $W_{LTO(Fire)}$

$$= ((2.07\times10^{-06} \text{ events per year} * 20{,}000 \text{ person-rem/event}) - 0)$$
$$* (\$2{,}000/\text{person-rem}) * ((1 - e^{-(0.07*60)}) / (0.07 \text{ per year}))$$
$$* ((1 - e^{-(0.07*10)}) / (0.07 \text{ per year} * 10 \text{ years}))$$
$$= \$838$$

W_{LTO} for LPSD internal events: $W_{LTO(SDIE)}$

$$= ((2.93\times10^{-06} \text{ events per year} * 20{,}000 \text{ person-rem/event}) - 0)$$
$$* (\$2{,}000/\text{person-rem}) * ((1 - e^{-(0.07*60)}) / (0.07 \text{ per year}))$$
$$* ((1 - e^{-(0.07*10)}) / (0.07 \text{ per year} * 10 \text{ years}))$$
$$= \$1{,}178$$

W_{LTO} for LPSD internal flooding events: $W_{LTO(SDFld)}$

$$= ((1.84\times10^{-08} \text{ events per year} * 20{,}000 \text{ person-rem/event}) - 0)$$
$$* (\$2{,}000/\text{person-rem}) * ((1 - e^{-(0.07*60)}) / (0.07 \text{ per year}))$$
$$* ((1 - e^{-(0.07*10)}) / (0.07 \text{ per year} * 10 \text{ years}))$$
$$= \$7$$

W_{LTO} for LPSD internal fire events: $W_{LTO(SDFire)}$

$$= ((1.74\times10^{-06} \text{ events per year} * 20{,}000 \text{ person-rem/event}) - 0)$$
$$* (\$2{,}000/\text{person-rem}) * ((1 - e^{-(0.07*60)}) / (0.07 \text{ per year}))$$
$$* ((1 - e^{-(0.07*10)}) / (0.07 \text{ per year} * 10 \text{ years}))$$
$$= \$704$$

4.3.3 Total Averted Occupational Exposure Costs

As described in Section 4.3, the total cost associated with averted occupational exposure (AOE) is the sum of the costs associated with averted immediate exposure and the costs associated with the averted long-term exposure:

$AOE = W_{IO} + W_{LTO}$

Total averted onsite exposure costs were calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

AOE for at-power internal events:
$AOE_{(IE)} = \$122 + \$530 = \$652$

AOE for at-power internal flooding events: $AOE_{(Fld)}$
$= \$39 + \$172 = \$211$

AOE for at-power fire events: $AOE_{(Fire)}$
$= \$192 + \$838 = \$1{,}030$

AOE for LPSD internal events: $AOE_{(SDIE)}$
$= \$270 + \$1{,}178 = \$1{,}448$

AOE for LPSD internal flooding events: $AOE_{(SDFld)}$
$= \$2 + \$7 = \$9$

AOE for LPSD internal fire events: $AOE_{(SDFire)}$
$= \$162 + \$704 = \$866$

Total averted occupational exposure costs are the sum of the six individual costs calculated above:

$$AOE_{Tot} = AOE_{(IE)} + AOE_{(Fld)} + AOE_{(Fire)} + AOE_{(SDIE)} + AOE_{(SDFld)} + AOE_{(SDFire)}$$

$$AOE_{Tot} = \$652 + \$211 + \$1{,}030 + \$1{,}448 + \$9 + \$866$$

$$AOE_{Tot} = \$4{,}216$$

4.4 Averted Onsite Costs

NUREG/BR-0184 defines three types of costs associated with onsite property damage from an accident: cleanup and decontamination, long-term replacement power, and repair and refurbishment. The value of avoiding each type of cost was considered when evaluating risk. Total averted onsite property damage costs are the sum of these three types of costs. Calculation of onsite property damage costs is detailed in the sections that follow.

4.4.1 Averted Cleanup and Decontamination Costs

The estimated cleanup cost for severe accidents is defined in NUREG/BR-0184, Section 5.7.6.1, as $\$1.5\times10^9$/accident (undiscounted). Using the value of $\$1.5\times10^9$/event and assuming, as in NUREG/BR-0184, that the total sum is paid in equal installments over a 10 years, the present value of the 10 payments for cleanup and decontamination costs can be calculated as follows:

$$PV_{CD} = \left(\frac{C_{CD}}{m}\right)\left(\frac{1-e^{-rm}}{r}\right)$$

Where:

PV_{CD} = present value of averted onsite cleanup costs exposure over cleanup period ($)

C_{CD} = total value of averted onsite cleanup costs ($)

r = real discount rate (7% per year)

m = years over which long-term doses accrue (10 years)

PV_{CD} = $((\$1.5\times10^9/\text{event}) \,/\, (10 \text{ years})) * ((1 - e^{-(0.07*10)}) \,/\, 0.07)$

PV_{CD} = $\$1.08\times10^9$

The present value of the costs over the cleanup period was considered over the duration of the plant life. The net present value of averted cleanup costs over the plant life can be calculated using the following equation:

$$U_{CD} = \left(F_S - F_A\right) PV_{CD} \frac{1 - e^{-rt_f}}{r}$$

Where:

U_{CD} = present value of averted onsite cleanup costs ($)

F_S = baseline accident frequency (events per year from Tables 1a and 1b)

F_A = accident frequency after mitigation (0 events per year)

PV_{CD} = present value of averted onsite cleanup costs exposure over cleanup period ($)

r = real discount rate (7% per year)

t_f = plant life (60 years).

Using these values, U_{CD} was calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

U_{CD} for at-power internal events: $U_{CD(IE)}$

= $(1.31 \times 10^{-06}$ events per year – 0) * ($\$1.08 \times 10^{9}$)

* (1 – $e^{-(0.07*60)}$) / (0.07 per year)

= $19,884

U_{CD} for at-power internal flooding events: $U_{CD(Fld)}$

= $(4.24 \times 10^{-07}$ events per year – 0) * ($\$1.08 \times 10^{9}$)

* (1 – $e^{-(0.07*60)}$) / (0.07 per year)

= $6,436

U_{CD} for at-power internal fire events: $U_{CD(Fire)}$

= $(2.07 \times 10^{-06}$ events per year – 0) * ($\$1.08 \times 10^{9}$)

* (1 – $e^{-(0.07*60)}$) / (0.07 per year)

= $31,419

U_{CD} for LPSD internal events: $U_{CD(SDIE)}$

$= (2.93 \times 10^{-06} \text{ events per year} - 0) * (\$1.08 \times 10^{9}) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$44{,}169$

U_{CD} for LPSD internal flooding events: $U_{CD(SDFld)}$

$= (1.84 \times 10^{-08} \text{ events per year} - 0) * (\$1.08 \times 10^{9}) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$279$

U_{CD} for LPSD internal fire events: $U_{CD(SDFire)}$

$= (1.74 \times 10^{-06} \text{ events per year} - 0) * (\$1.08 \times 10^{9}) * (1 - e^{-(0.07*60)}) / (0.07 \text{ per year})$

$= \$26{,}410$

4.4.2 Averted Replacement Power Costs

Replacement power costs, U_{RP}, are an additional contributor to onsite costs and can be calculated in accordance with NUREG/BR-0184, Section 5.7.6.2. Since replacement power is needed for the time period following a severe accident until the end of the expected generating plant life, long-term power replacement calculations were used. APR1400 is expected to have a net electrical output of 1,400 MWe.

Replacement power cost calculations performed in NUREG/BR-0184 are based on the 910 MWe reference plant. In applying the methodology used in NUREG/BR-0184 to the APR1400 design, the equation was scaled for the 1,400 MWe output of the APR1400 design. For discount rates between 5 percent and 10 percent, NUREG/BR-0184 recommends that the present value of replacement power be calculated as follows:

$$PV_{RP} = \left(\frac{(\$1.2E+8)\dfrac{(Rated\ power)}{(910MWe)}}{r} \right) \left(1 - e^{-rt_f}\right)^2$$

Where:

PV_{RP} = present value of replacement power for a single event ($)

r = real discount rate (7% per year)

t_f = plant life (60 years)

Rated power = 1,400 MWe

Using these values:

$$PV_{RP} = ((1.2\times10^{8} *(1{,}400\ \text{MWe} / 910\ \text{MWe})) / (0.07\ \text{per year}) * (1 - e^{-(0.07*60)})^{2}$$

$$PV_{RP} = \$2.56\times10^{9}$$

The replacement power costs PV_{RP} ($\$2.56\times10^{9}$) was adjusted to 2013 dollars by applying a ratio of the average U.S. Bureau of Labor Statistics Producer Price Index for Electric Power from the years 1993 and 2013. The Producer Price Index for Electric Power for 2013 is 193.3, and the Producer Price Index for Electric Power for 1993 is 128.6 (Reference 0). The 2013 dollars scaling factor was calculated as 193.3/128.6, which equals 1.50.

The replacement power costs PV_{RP} was also adjusted to reflect the true need for replacement capacity availability based on current operations. In lieu of the suggested 60 percent to 65 percent range reported in NUREG/BR-0184 (Reference 0), the more realistic capacity factor of 95 percent was used. The adjustment was applied as a simple multiplier derived by dividing 95 percent by 60 percent to get a value of 1.58.

$$PV_{RP} = \$2.56\times10^{9} * (1.50) * (1.58) = \$6.06\times10^{9}$$

To obtain the expected costs of a single event over the plant life, the following equation was used:

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

Where:

U_{RP} = present value of averted onsite cleanup costs ($)

F_S = baseline accident frequency (events per year from Tables 1a and 1b)

F_A = accident frequency after mitigation (0 events per year)

PV_{RP} = present value of replacement power for a single event ($)

r = real discount rate (7% per year)

t_f = plant life (60 years)

Using these values, U_{RP} was calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

U_{RP} for at-power internal events: $U_{RP(IE)}$

$$= (1.31\times10^{-06} \text{ per year} - 0) * ((\$6.06\times10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^2$$

$$= \$110{,}124$$

U_{RP} for at-power internal flooding events: $U_{RP(Fld)}$

$$= (4.24\times10^{-07} \text{ per year} - 0) * ((\$6.06\times10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^2$$

$$= \$35{,}643$$

U_{RP} for at-power internal fire events: $U_{RP(Fire)}$

$$= (2.07\times10^{-06} \text{ per year} - 0) * ((\$6.06\times10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^2$$

$$= \$174{,}012$$

U_{RP} for LPSD internal events: $U_{RP(SDIE)}$

$$= (2.93\times10^{-06} \text{ per year} - 0) * ((\$6.06\times10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^2$$

$$= \$244{,}626$$

U_{RP} for LPSD internal flooding events: $U_{RP(SDFld)}$

$$= (1.84 \times 10^{-08} \text{ per year} - 0) * ((\$6.06 \times 10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^{2}$$

$$= \$1{,}547$$

U_{RP} for LPSD internal fire events: $U_{RP(SDFire)}$

$$= (1.74 \times 10^{-06} \text{ per year} - 0) * ((\$6.06 \times 10^{9}) / (0.07 \text{ per year})) * (1 - e^{-(0.07*60)})^{2}$$

$$= \$146{,}271$$

4.4.3 Averted Repair and Refurbishment Costs

It was assumed that the plant would not be repaired or refurbished; averted repair and refurbishment costs are therefore zero.

4.4.4 Total Averted Onsite Costs

Total averted onsite cost (AOSC) is the sum of cleanup and decontamination costs, replacement power costs, and repair and refurbishment costs. Total averted onsite costs were calculated as follows:

$$AOSC = U_{CD} + U_{RP} + 0$$

Total averted onsite costs were calculated for internal events, internal flooding events, and internal fire events for both at-power and LPSD operating conditions. Each of these calculations is detailed below.

AOSC for at-power internal events: $AOSC_{(IE)}$

$$= \$19{,}884 + \$110{,}124 = \$130{,}008$$

AOSC for at-power internal flooding events: $AOSC_{(Fld)}$

$$= \$6{,}436 + \$35{,}643 = \$42{,}079$$

AOSC for at-power internal fire events: $AOSC_{(Fire)}$

$$= \$31{,}419 + \$174{,}012 = \$205{,}431$$

AOSC for LPSD internal events: $AOSC_{(SDIE)}$

$= \$44,169 + \$244,626 = \$288,795$

AOSC for LPSD internal flooding events: $AOSC_{(SDFld)}$

$= \$279 + \$1,547 = \$1,826$

AOSC for LPSD internal fire events: $AOSC_{(SDFire)}$

$= \$26,410 + \$146,271 = \$172,681$

Total averted onsite costs are the sum of the six individual costs calculated above or:

$$AOSC_{Tot} = AOSC_{(IE)} + AOSC_{(Fld)} + AOSC_{(Fire)} + AOSC_{(SDIE)} + AOSC_{(SDFld)} + AOSC_{(SDFire)}$$

$$AOSC_{Tot} = \$130,008 + \$42,079 + \$205,431 + \$288,795 + \$1,826 + \$172,681$$

$$AOSC_{Tot} = \$840,820$$

4.5 Cost of Enhancement

The cost of enhancement is used when measures are taken to reduce risk. By definition, such measures are taken at the beginning of any period considered, and no discounting for the cost of enhancement (COE) was therefore performed. For baseline risk, no measures were taken to reduce risk; therefore:

$$COE = \$0$$

4.6 Total Unmitigated Baseline Risk

The total present worth net value of public risk was calculated according to the following formula:

$$NPV = (APE + AOC + AOE + AOSC) - COE$$

Using the values calculated in Subsections 4.1 through 4.5, the total baseline risk was calculated as follows:

NPV = (\$76,794 + \$104,687 + \$4,216 + \$840,820) – \$0

NPV = \$1,026,517

This value can be viewed as the maximum risk benefit attainable if all core damage scenarios are eliminated over the 60-year plant life.

5. IDENTIFICATION OF SAMDAS

The list of SAMDA items evaluated for the APR1400 design is given in Table 4.

The first source used to identify SAMDA items is NEI 05-01 (Reference 1). Generic industry SAMDAs that were considered are the 153 items listed in Table 14 of NEI 05-01.

The second source used to identify SAMDA items is APR1400 design-specific SAMDA items that be decided through expert panel for APR1400 SAMDA. The 29 items for APR1400 design-specific SAMDA are described in Table 4.

The third source used to identify SAMDA items is the result of PRA for APR1400. The evaluation of APR1400-specific items related to PRA results began with an importance analysis of the core damage cutsets. The following events were reviewed to identify potential SAMDAs: basic events with a Fussell-Vesely (FV) importance of greater than 0.5 percent, a total of 118 basic events for at-power internal events, 64 for at-power internal flooding events, 92 for at-power internal fire events, 73 for LPSD internal events, 53 for LPSD internal flooding events, and 141 for LPSD internal fire events. Basic events without physical meaning, such as complement events and constants, were identified and excluded because they would have no impact on the SAMDA analysis. A list of the basic events, their importance, and their disposition with respect to SAMDA items is given in Tables 5a through 5f of the APR1400 SAMDA Technical Report (Reference 4).

In addition to the basic event importance review, the top 100 cutsets for each analysis were reviewed to identify any basic events that were not included in the importance analysis review. Basic events identified in the top 100 cutsets that were not included in the importance analysis review are provided in Tables 6a through 6f of the APR1400 SAMDA Technical Report (Reference 4).

6. SAMDA SCREENING

As described in NEI 05-01 (Reference 1), items can be screened for several reasons. First, items that were not applicable to the APR1400 design were eliminated (e.g., items associated with equipment that is not included in the APR1400 design). Items eliminated as not applicable are listed as "Not Applicable" in the "Qualitative Screening" column of Table 4.

Items that are already effectively implemented in the APR1400 design were then identified. These items are listed as "Already Implemented" in the "Qualitative Screening" column of Table 4 along with a description of the implementation.

Other SAMDA items were eliminated because they would not be feasible to implement. An item was considered infeasible if the cost of implementation exceeded the maximum potential benefit (calculated according to Subsection 4.6). Items screened out as infeasible to implement are listed as "Excessive Implementation Cost" in the "Qualitative Screening" column of Table 4.

NEI 05-01 allows items that would provide low benefit to be eliminated. An item was considered low benefit if it was from a non-risk-significant system and a change in reliability would have negligible impact on the risk profile. Since this analysis is for the APR1400 Design Certification, any item listed as having potentially low benefit is listed as "Needs Further Evaluation / Potentially Very Low Benefit" in the "Qualitative Screening" column of Table 4 along with the reason. This determination was based on engineering judgment.

Finally, one SAMDA can be combined with others per NEI 05-01. SAMDA ID 151 is described as "Increase training and operating experience feedback to improve operator response." Since this analysis is for the APR1400 Design Certification, SAMDAs regarding operator actions are designated as "N/A – Enhancement due to procedures/training are not applicable to the Design Certification stage of plant development."

The benefit and cost evaluations in Sections 8 through 10 examine the impacts of the items. If appropriate, the items were combined in the benefit or cost evaluations. For items that were combined because they would provide the same benefit, a note indicating which items were analyzed together is provided in Table 4.

In addition, 23 items of APR1400 design-specific SAMDA is screened out as "Already Implemented," and 6 items of APR1400 design-specific SAMDA is screened out as "Not Applicable." The qualitative screening for the 29 items is described in Table 4.

7. SAMDA BENEFIT EVALUATION

The potential SAMDAs that were not eliminated were evaluated to determine the potential benefits from implementing them. The potential benefits were evaluated, but detailed modifications were not necessarily considered because design details are determined only once a design option is chosen. Rather, SAMDA benefits were evaluated using bounding techniques to estimate any risk reduction that would be possible.

The evaluation of potential benefits was performed using the methodology described in NEI 05-01 (Reference 1) and was as follows: (1) the potential reduction in the CDF, if any, was estimated, (2) the reduction in source term release was estimated, (3) and the potential benefit to offsite consequences in monetary terms was determined.

7.1 Key Structures, Systems, or Components from Importance Analysis

The important basic events (i.e., FV > 0.5 percent) from the at-power and LPSD PRA event importance analyses were reviewed. Based on the information provided in Section 4 and Section 7 of the APR1400 SAMDA Technical Report (Reference 4), the total maximum cost reduction calculated for any of the important basic events would be lower because eliminating all offsite consequences is not feasible. A design change is expected to cost more than the total maximum cost reduction and would not provide a positive benefit.

Most of the averted public exposure (APE) is caused by steam generator tube rupture (SGTR) and interfacing system loss-of-coolant-accident (ISLOCA) events (see Tables 2a through 2f), and most of AOC is also caused by SGTR and ISLOCA events (see Tables 3a through 3f). Improved performance of the structures, systems, or components (SSCs) from the importance analysis would have a negligible effect on reducing risk from SGTR and ISLOCA events.

The cost-benefit of the events associated with 93 important SSCs has been reviewed (see Section 7 of Reference 4), and the review indicates that no further SAMDA cost-benefit evaluation is needed.

7.2 Other Events from Top 100 Cutsets

The basic events that are included in the top 100 cutsets but were not in the at-power and LPSD event importance analyses were reviewed in a manner similar to the review of the basic events included in the importance analysis. The results of the review of all of these basic events show that the maximum possible reduction in AOE and AOSC costs from eliminating the effects of all of the basic events unavailability is approximately $21,000. Although the benefit of the change to offsite risks was not calculated, these costs (APE and AOC) total only $182,000. Therefore, an estimated maximum total benefit of approximately $203,000 would be achievable.

The total maximum benefit would be lower because all offsite consequences would not be eliminated. Therefore, a design change is expected to cost more than this amount ($203,000) and as a result, would not provide a positive benefit.

8. SAMDA COST EVALUATION

Based on the information in Sections 4 and 7, the total maximum benefit calculated for improving the equipment associated with the important basic events (i.e., FV > 0.5 percent) is small and lower than the cost of any plant design change to improve performance of the component. Therefore, a design change would not provide a positive benefit.

As a result, no further SAMDA cost evaluation is needed.

9. SAMDA COST-BENEFIT EVALUATION

As described in Sections 7 and 8, all design changes to reduce risk would provide small or negligible benefit, and the cost of any associated design change would greatly exceed any potential benefit. Therefore, no cost-benefit calculations are necessary.

10. SENSITIVITY ANALYSIS USING A 3 PERCENT DISCOUNT RATE

The parameters that influence the cost-benefit analyses of the SAMDAs were examined to determine whether a change in value for one of the parameters would change the conclusions of the evaluation. Equations for each of the four types of averted costs contain a term for the real discount rate and evaluation period (see Section 4). Therefore, a change in either of those terms would have a direct impact on the averted costs calculated.

NEI 05-01 (Reference 1) recommends using a 7 percent discount rate for the cost-benefit analyses and suggests that a 3 percent discount rate be used for the sensitivity analyses of the maximum benefit and the SAMDAs that were not eliminated to indicate the degree of the sensitivity of the results to the choice of discount rate. Additionally, for this sensitivity analysis, NUREG/BR-0184 (Reference 2) recommends calculating the averted replacement power costs by using a linear interpolation between $\$1.9 \times 10^{10}$ for a discount rate of 1 percent and $\$1.2 \times 10^{10}$ for a discount rate of 5 percent. The replacement power cost was also adjusted to 2013 dollars for the more realistic capacity factor of 95 percent.

The total NPV of public risk was calculated to be $1,152,850 (Reference 4). This value can be viewed as the maximum risk benefit attainable if all core damage scenarios are eliminated over the 60-year plant life, using the 3 percent discount rate. Using the maximum benefit calculated for the 3 percent discount rate, the SAMDA items in Table 4 were reviewed and screened again. No changes to the screening results were identified using the higher maximum benefit value.

11. CONCLUSIONS

The analyses described in this report were of conceptual alternatives for mitigating severe accident impacts in the APR1400 design. Preliminary screening eliminated all SAMDA candidates from further consideration based on non-applicability to the design, design features that have already been implemented, non-applicability to a Design Certification stage, or cost.

The analysis using a 7 percent discount rate shows that no design changes to reduce risk associated with contributors to plant risk would be cost-beneficial. A second baseline maximum benefit calculation using a 3 percent discount rate shows only minor variations in the calculated benefits. Therefore, it is concluded that no changes to the APR1400 design would provide a positive cost-benefit.

12. REFERENCES

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

2. NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," U.S. Nuclear Regulatory Commission, 1997.

3. Bureau of Labor Statistics, Producer Price Index for the Commodity of Electric Power, Producer Price Index – Commodities: Series Id: WPU054, 2013/1993. Available at http://data.bls.gov/timeseries/WPU054?data_tool=XGtable; retrieved October 26, 2014.

4. APR1400-E-P-NR-14006-P, "Severe Accident Mitigation Design Alternatives for APR1400," Rev. 0, Korea Electric Power Corporation and Korea Hydro & Nuclear Power Co., Ltd., December 2014.

5. NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," Section 7.3, "Severe Accident Mitigation Alternatives," Rev. 1, U.S. Nuclear Regulatory Commission, July 2007.

6. APR1400-E-N-NR-14001-P, "Design Features to Address GSI-191," Rev. 0, Korea Electric Power Corporation and Korea Hydro & Nuclear Power Co., Ltd., December 2014.

Table 1a

Source Term Category Summary for At-Power Events

STC	Description	STC Frequency (per year)		
		Internal	Flood	Fire
1	SGTR bypass of containment without fission product scrubbing	5.33E-08	6.21E-09	8.31E-08
2	SGTR bypass of containment with fission product scrubbing	2.41E-08	0.00E+00	0.00E+00
3	ISLOCAs without fission product scrubbing	5.31E-11	0.00E+00	0.00E+00
4	ISLOCAs with fission product scrubbing	6.49E-11	0.00E+00	0.00E+00
5	Containment isolation failure with containment spray	2.46E-09	7.40E-10	2.38E-08
6	Containment isolation failure without containment spray	1.23E-09	6.08E-09	2.60E-08
7	Containment failure before core damage with small (leak) failure of containment	1.14E-08	9.38E-10	4.36E-09
8	Containment failure before core damage with large (rupture) failure of containment	1.30E-08	1.03E-09	6.16E-09
9	Core melt arrested in the reactor vessel	3.67E-07	4.24E-08	2.83E-07
10	No containment failure after core melt	7.64E-07	3.28E-07	9.62E-07
11	Containment basemat failure	1.33E-08	5.33E-09	5.56E-07
12	Early containment failure with small (leak) failure of containment	0.00E+00	0.00E+00	0.00E+00
13	Early containment failure with large (rupture) failure of containment	1.80E-09	7.82E-10	3.71E-09
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	4.28E-11	1.60E-11	2.39E-09
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	0.00E+00	0.00E+00
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	7.30E-12	3.78E-12	5.71E-10
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	2.70E-08	1.43E-08	3.99E-08
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	4.19E-10	1.56E-10	2.34E-08
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	4.01E-09	2.76E-09	6.51E-09
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	1.19E-11	6.19E-12	9.34E-10
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	2.96E-08	1.57E-08	4.38E-08
Total		1.31E-06	4.24E-07	2.07E-06

Table 1b

Source Term Category Summary for Low-Power Shutdown Events

STC	Description	STC Frequency (per year)		
		Internal	Flood	Fire
1	SGTR bypass of containment without fission product scrubbing	1.46E-08	0.00E+00	7.52E-09
2	SGTR bypass of containment with fission product scrubbing	6.62E-09	0.00E+00	3.4E-09
3	ISLOCAs without fission product scrubbing	2.79E-08	0.00E+00	2.5E-08
4	ISLOCAs with fission product scrubbing	1.78E-11	0.00E+00	9.16E-12
5	Containment isolation failure with containment spray	6.75E-10	0.00E+00	3.47E-10
6	Containment isolation failure without containment spray	1.06E-08	1.84E-08	1.31E-08
7	Containment failure before core damage with small (leak) failure of containment	3.13E-09	0.00E+00	1.61E-09
8	Containment failure before core damage with large (rupture) failure of containment	3.61E-08	0.00E+00	6.86E-08
9	Core melt arrested in the reactor vessel	1.01E-07	0.00E+00	5.18E-08
10	No containment failure after core melt	2.55E-06	0.00E+00	1.46E-06
11	Containment basemat failure	1.02E-07	0.00E+00	6.19E-08
12	Early containment failure with small (leak) failure of containment	0.00E+00	0.00E+00	0.00E+00
13	Early containment failure with large (rupture) failure of containment	4.94E-10	0.00E+00	2.54E-10
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	1.18E-11	0.00E+00	6.04E-12
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	0.00E+00	0.00E+00
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	2.00E-12	0.00E+00	1.03E-12
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	7.41E-09	0.00E+00	3.81E-09
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.15E-10	0.00E+00	5.91E-11
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	1.10E-09	0.00E+00	5.66E-10
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	4.08E-08	0.00E+00	3.52E-08
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	8.13E-09	0.00E+00	4.18E-09
Total		2.91E-06	1.84E-08	1.74E-06

Table 2a (1 of 2)

Offsite Exposure by Source Term Category for At-Power Internal Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	5.33E-08	6.34E+04	6.34E+06	3.38E-01
2	SGTR bypass of containment with fission product scrubbing	2.41E-08	3.03E+02	3.03E+04	7.30E-04
3	ISLOCAs without fission product scrubbing	5.31E-11	9.42E+04	9.42E+06	5.00E-04
4	ISLOCAs with fission product scrubbing	6.49E-11	8.00E+04	8.00E+06	5.19E-04
5	Containment isolation failure with containment spray	2.46E-09	3.52E+03	3.52E+05	8.66E-04
6	Containment isolation failure without containment spray	1.23E-09	1.79E+04	1.79E+06	2.20E-03
7	Containment failure before core damage with small (leak) failure of containment	1.14E-08	4.48E+04	4.48E+06	5.11E-02
8	Containment failure before core damage with large (rupture) failure of containment	1.30E-08	5.77E+04	5.77E+06	7.50E-02
9	Core melt arrested in the reactor vessel	3.67E-07	1.73E+01	1.73E+03	6.35E-04
10	No containment failure after core melt	7.64E-07	4.17E+01	4.17E+03	3.19E-03
11	Containment basemat failure	1.33E-08	1.94E+02	1.94E+04	2.58E-04
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	1.80E-09	3.31E+04	3.31E+06	5.96E-03
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	4.28E-11	1.76E+03	1.76E+05	7.53E-06
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	7.30E-12	5.01E+03	5.01E+05	3.66E-06
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	2.70E-08	1.20E+02	1.20E+04	3.24E-04

Table 2a (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	4.19E-10	2.84E+03	2.84E+05	1.19E-04
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	4.01E-09	5.82E+03	5.82E+05	2.33E-03
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	1.19E-11	7.94E+03	7.94E+05	9.45E-06
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	2.96E-08	7.85E+03	7.85E+05	2.32E-02
Total		1.31E-06			5.05E-01

Table 2b (1 of 2)

Offsite Exposure by Source Term Category for At-Power Internal Flooding Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	6.21E-09	6.34E+04	6.34E+06	3.94E-02
2	SGTR bypass of containment with fission product scrubbing	0.00E+00	-	-	-
3	ISLOCAs without fission product scrubbing	0.00E+00	-	-	-
4	ISLOCAs with fission product scrubbing	0.00E+00	-	-	-
5	Containment isolation failure with containment spray	7.40E-10	3.52E+03	3.52E+05	2.60E-04
6	Containment isolation failure without containment spray	6.08E-09	1.79E+04	1.79E+06	1.09E-02
7	Containment failure before core damage with small (leak) failure of containment	9.38E-10	4.48E+04	4.48E+06	4.20E-03
8	Containment failure before core damage with large (rupture) failure of containment	1.03E-09	5.77E+04	5.77E+06	5.94E-03
9	Core melt arrested in the reactor vessel	4.24E-08	1.73E+01	1.73E+03	7.34E-05
10	No containment failure after core melt	3.28E-07	4.17E+01	4.17E+03	1.37E-03
11	Containment basemat failure	5.33E-09	1.94E+02	1.94E+04	1.03E-04
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	7.82E-10	3.31E+04	3.31E+06	2.59E-03
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	1.60E-11	1.76E+03	1.76E+05	2.82E-06
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	3.78E-12	5.01E+03	5.01E+05	1.89E-06
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	1.43E-08	1.20E+02	1.20E+04	1.72E-04

Table 2b (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.56E-10	2.84E+03	2.84E+05	4.43E-05
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	2.76E-09	5.82E+03	5.82E+05	1.61E-03
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	6.19E-12	7.94E+03	7.94E+05	4.91E-06
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	1.57E-08	7.85E+03	7.85E+05	1.23E-02
Total		4.24E-07			7.89E-02

Table 2c (1 of 2)

Offsite Exposure by Source Term Category for At-Power Internal Fire Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	8.31E-08	6.34E+04	6.34E+06	5.27E-01
2	SGTR bypass of containment with fission product scrubbing	0.00E+00	-	-	-
3	ISLOCAs without fission product scrubbing	0.00E+00	-	-	-
4	ISLOCAs with fission product scrubbing	0.00E+00	-	-	-
5	Containment isolation failure with containment spray	2.38E-08	3.52E+03	3.52E+05	8.38E-03
6	Containment isolation failure without containment spray	2.60E-08	1.79E+04	1.79E+06	4.65E-02
7	Containment failure before core damage with small (leak) failure of containment	4.36E-09	4.48E+04	4.48E+06	1.95E-02
8	Containment failure before core damage with large (rupture) failure of containment	6.16E-09	5.77E+04	5.77E+06	3.55E-02
9	Core melt arrested in the reactor vessel	2.83E-07	1.73E+01	1.73E+03	4.90E-04
10	No containment failure after core melt	9.62E-07	4.17E+01	4.17E+03	4.01E-03
11	Containment basemat failure	5.56E-07	1.94E+02	1.94E+04	1.08E-02
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	3.71E-09	3.31E+04	3.31E+06	1.23E-02
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	2.39E-09	1.76E+03	1.76E+05	4.21E-04
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	5.71E-10	5.01E+03	5.01E+05	2.86E-04
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.99E-08	1.20E+02	1.20E+04	4.79E-04

Table 2c (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	2.34E-08	2.84E+03	2.84E+05	6.65E-03
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	6.51E-09	5.82E+03	5.82E+05	3.79E-03
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	9.34E-10	7.94E+03	7.94E+05	7.42E-04
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	4.38E-08	7.85E+03	7.85E+05	3.44E-02
Total		2.07E-06			7.11E-01

Table 2d

Offsite Exposure by Source Term Category for LPSD Internal Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	1.46E-08	6.34E+04	6.34E+06	9.26E-02
2	SGTR bypass of containment with fission product scrubbing	6.62E-09	3.03E+02	3.03E+04	2.01E-04
3	ISLOCAs without fission product scrubbing	2.79E-08	9.42E+04	9.42E+06	2.63E-01
4	ISLOCAs with fission product scrubbing	1.78E-11	8.00E+04	8.00E+06	1.42E-04
5	Containment isolation failure with containment spray	6.75E-10	3.52E+03	3.52E+05	2.38E-04
6	Containment isolation failure without containment spray	1.06E-08	1.79E+04	1.79E+06	1.90E-02
7	Containment failure before core damage with small (leak) failure of containment	3.13E-09	4.48E+04	4.48E+06	1.40E-02
8	Containment failure before core damage with large (rupture) failure of containment	3.61E-08	5.77E+04	5.77E+06	2.08E-01
9	Core melt arrested in the reactor vessel	1.01E-07	1.73E+01	1.73E+03	1.75E-04
10	No containment failure after core melt	2.55E-06	4.17E+01	4.17E+03	1.06E-02
11	Containment basemat failure	1.02E-07	1.94E+02	1.94E+04	1.98E-03
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	4.94E-10	3.31E+04	3.31E+06	1.64E-03
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	1.18E-11	1.76E+03	1.76E+05	2.08E-06
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	2.00E-12	5.01E+03	5.01E+05	1.00E-06
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	7.41E-09	1.20E+02	1.20E+04	8.89E-05

Table 2d (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.15E-10	2.84E+03	2.84E+05	3.27E-05
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	1.10E-09	5.82E+03	5.82E+05	6.40E-04
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	4.08E-08	7.94E+03	7.94E+05	3.24E-02
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	8.13E-09	7.85E+03	7.85E+05	6.38E-03
Total		2.91E-06			6.57E-01

Table 2e (1 of 2)

Offsite Exposure by Source Term Category for LPSD Internal Flooding Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	0.00E+00	-	-	-
2	SGTR bypass of containment with fission product scrubbing	0.00E+00	-	-	-
3	ISLOCAs without fission product scrubbing	0.00E+00	-	-	-
4	ISLOCAs with fission product scrubbing	0.00E+00	-	-	-
5	Containment isolation failure with containment spray	0.00E+00	-	-	-
6	Containment isolation failure without containment spray	1.84E-08	1.79E+04	1.79E+06	3.29E-02
7	Containment failure before core damage with small (leak) failure of containment	0.00E+00	-	-	-
8	Containment failure before core damage with large (rupture) failure of containment	0.00E+00	-	-	-
9	Core melt arrested in the reactor vessel	0.00E+00	-	-	-
10	No containment failure after core melt	0.00E+00	-	-	-
11	Containment basemat failure	0.00E+00	-	-	-
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	0.00E+00	-	-	-
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	0.00E+00	-	-	-
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	0.00E+00	-	-	-

Table 2e (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	0.00E+00	-	-	-
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	0.00E+00	-	-	-
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	0.00E+00	-	-	-
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	0.00E+00	-	-	-
Total		1.84E-08			3.29E-02

Table 2f (1 of 2)

Offsite Exposure by Source Term Category for LPSD Internal Fire Events

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
1	SGTR bypass of containment without fission product scrubbing	7.52E-09	6.34E+04	6.34E+06	4.77E-02
2	SGTR bypass of containment with fission product scrubbing	3.40E-09	3.03E+02	3.03E+04	1.03E-04
3	ISLOCAs without fission product scrubbing	2.50E-08	9.42E+04	9.42E+06	2.36E-01
4	ISLOCAs with fission product scrubbing	9.16E-12	8.00E+04	8.00E+06	7.33E-05
5	Containment isolation failure with containment spray	3.47E-10	3.52E+03	3.52E+05	1.22E-04
6	Containment isolation failure without containment spray	1.31E-08	1.79E+04	1.79E+06	2.34E-02
7	Containment failure before core damage with small (leak) failure of containment	1.61E-09	4.48E+04	4.48E+06	7.21E-03
8	Containment failure before core damage with large (rupture) failure of containment	6.86E-08	5.77E+04	5.77E+06	3.96E-01
9	Core melt arrested in the reactor vessel	5.18E-08	1.73E+01	1.73E+03	8.96E-05
10	No containment failure after core melt	1.46E-06	4.17E+01	4.17E+03	6.09E-03
11	Containment basemat failure	6.19E-08	1.94E+02	1.94E+04	1.20E-03
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-	-
13	Early containment failure with large (rupture) failure of containment	2.54E-10	3.31E+04	3.31E+06	8.41E-04
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	6.04E-12	1.76E+03	1.76E+05	1.06E-06
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	1.03E-12	5.01E+03	5.01E+05	5.16E-07
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.81E-09	1.20E+02	1.20E+04	4.57E-05

Table 2f (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Person-Sv Offsite	Conditional Person-REM Offsite	Expected Person-REM/yr Offsite
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	5.91E-11	2.84E+03	2.84E+05	1.68E-05
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	5.66E-10	5.82E+03	5.82E+05	3.29E-04
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	3.52E-08	7.94E+03	7.94E+05	2.79E-02
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	4.18E-09	7.85E+03	7.85E+05	3.28E-03
Total		1.74E-06			7.50E-01

Table 3a (1 of 2)

Offsite Property Damage Costs by Source Term Category for At-Power Internal Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	5.33E-08	1.86E+10	991
2	SGTR bypass of containment with fission product scrubbing	2.41E-08	5.00E+07	1
3	ISLOCAs without fission product scrubbing	5.31E-11	2.77E+10	1
4	ISLOCAs with fission product scrubbing	6.49E-11	2.09E+10	1
5	Containment isolation failure with containment spray	2.46E-09	3.91E+08	1
6	Containment isolation failure without containment spray	1.23E-09	4.02E+09	5
7	Containment failure before core damage with small (leak) failure of containment	1.14E-08	1.00E+10	114
8	Containment failure before core damage with large (rupture) failure of containment	1.30E-08	1.56E+10	203
9	Core melt arrested in the reactor vessel	3.67E-07	3.17E+07	12
10	No containment failure after core melt	7.64E-07	3.01E+07	23
11	Containment basemat failure	1.33E-08	4.24E+07	1
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-
13	Early containment failure with large (rupture) failure of containment	1.80E-09	5.67E+09	10
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	4.28E-11	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	7.30E-12	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	2.70E-08	3.34E+07	1

Table 3a (2 of 2)

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	4.19E-10	1.05E+08	0
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	4.01E-09	3.60E+08	1
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	1.19E-11	6.68E+08	0
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	2.96E-08	8.42E+08	25
Total				1,391

Table 3b

Offsite Property Damage Costs by Source Term Category for At-Power Internal Flooding Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	6.2E-09	1.86E+10	116
2	SGTR bypass of containment with fission product scrubbing	0.0E+00	-	-
3	ISLOCAs without fission product scrubbing	0.0E+00	-	-
4	ISLOCAs with fission product scrubbing	0.0E+00	-	-
5	Containment isolation failure with containment spray	7.4E-10	3.91E+08	0
6	Containment isolation failure without containment spray	6.1E-09	4.02E+09	24
7	Containment failure before core damage with small (leak) failure of containment	9.4E-10	1.00E+10	9
8	Containment failure before core damage with large (rupture) failure of containment	1.0E-09	1.56E+10	16
9	Core melt arrested in the reactor vessel	4.2E-08	3.17E+07	1
10	No containment failure after core melt	3.3E-07	3.01E+07	10
11	Containment basemat failure	5.3E-09	4.24E+07	0
12	Early containment failure with small (leak) failure of containment	0.0E+00	-	-
13	Early containment failure with large (rupture) failure of containment	7.8E-10	5.67E+09	4
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	1.6E-11	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.0E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	3.8E-12	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	1.4E-08	3.34E+07	0
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.6E-10	1.05E+08	0
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	2.8E-09	3.60E+08	1
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	6.2E-12	6.68E+08	0
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	1.6E-08	8.42E+08	13
Total				196

Table 3c

Offsite Property Damage Costs by Source Term Category for At-Power Internal Fire Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	8.31E-08	1.86E+10	1546
2	SGTR bypass of containment with fission product scrubbing	0.00E+00	-	-
3	ISLOCAs without fission product scrubbing	0.00E+00	-	-
4	ISLOCAs with fission product scrubbing	0.00E+00	-	-
5	Containment isolation failure with containment spray	2.38E-08	3.91E+08	9
6	Containment isolation failure without containment spray	2.60E-08	4.02E+09	105
7	Containment failure before core damage with small (leak) failure of containment	4.36E-09	1.00E+10	44
8	Containment failure before core damage with large (rupture) failure of containment	6.16E-09	1.56E+10	96
9	Core melt arrested in the reactor vessel	2.83E-07	3.17E+07	9
10	No containment failure after core melt	9.62E-07	3.01E+07	29
11	Containment basemat failure	5.56E-07	4.24E+07	24
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-
13	Early containment failure with large (rupture) failure of containment	3.71E-09	5.67E+09	21
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	2.39E-09	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	5.71E-10	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.99E-08	3.34E+07	1
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	2.34E-08	1.05E+08	2
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	6.51E-09	3.60E+08	2
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	9.34E-10	6.68E+08	1
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	4.38E-08	8.42E+08	37
Total				1,926

Table 3d

Offsite Property Damage Costs by Source Term Category for LPSD Internal Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	1.46E-08	1.86E+10	272
2	SGTR bypass of containment with fission product scrubbing	6.62E-09	5.00E+07	0
3	ISLOCAs without fission product scrubbing	2.79E-08	2.77E+10	773
4	ISLOCAs with fission product scrubbing	1.78E-11	2.09E+10	0
5	Containment isolation failure with containment spray	6.75E-10	3.91E+08	0
6	Containment isolation failure without containment spray	1.06E-08	4.02E+09	43
7	Containment failure before core damage with small (leak) failure of containment	3.13E-09	1.00E+10	31
8	Containment failure before core damage with large (rupture) failure of containment	3.61E-08	1.56E+10	563
9	Core melt arrested in the reactor vessel	1.01E-07	3.17E+07	3
10	No containment failure after core melt	2.55E-06	3.01E+07	77
11	Containment basemat failure	1.02E-07	4.24E+07	4
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-
13	Early containment failure with large (rupture) failure of containment	4.94E-10	5.67E+09	3
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	1.18E-11	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	2.00E-12	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	7.41E-09	3.34E+07	0
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.15E-10	1.05E+08	0
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	1.10E-09	3.60E+08	0
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	4.08E-08	6.68E+08	27
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	8.13E-09	8.42E+08	7
Total				1,804

Table 3e

Offsite Property Damage Costs by Source Term Category for LPSD Internal Flooding Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	0.00E+00	-	-
2	SGTR bypass of containment with fission product scrubbing	0.00E+00	-	-
3	ISLOCAs without fission product scrubbing	0.00E+00	-	-
4	ISLOCAs with fission product scrubbing	0.00E+00	-	-
5	Containment isolation failure with containment spray	0.00E+00	-	-
6	Containment isolation failure without containment spray	1.84E-08	4.02E+09	74
7	Containment failure before core damage with small (leak) failure of containment	0.00E+00	-	-
8	Containment failure before core damage with large (rupture) failure of containment	0.00E+00	-	-
9	Core melt arrested in the reactor vessel	0.00E+00	-	-
10	No containment failure after core melt	0.00E+00	-	-
11	Containment basemat failure	0.00E+00	-	-
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-
13	Early containment failure with large (rupture) failure of containment	0.00E+00	-	-
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	0.00E+00	-	-
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	0.00E+00	-	-
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	0.00E+00	-	-
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	0.00E+00	-	-
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	0.00E+00	-	-
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	0.00E+00	-	-
Total				74

Table 3f

Offsite Property Damage Costs by Source Term Category for LPSD Internal Fire Events

STC	Description	STC Frequency (per year)	Conditional Property Costs ($)	Expected Property Costs ($)
1	SGTR bypass of containment without fission product scrubbing	7.52E-09	1.86E+10	140
2	SGTR bypass of containment with fission product scrubbing	3.40E-09	5.00E+07	0
3	ISLOCAs without fission product scrubbing	2.50E-08	2.77E+10	693
4	ISLOCAs with fission product scrubbing	9.16E-12	2.09E+10	0
5	Containment isolation failure with containment spray	3.47E-10	3.91E+08	0
6	Containment isolation failure without containment spray	1.31E-08	4.02E+09	53
7	Containment failure before core damage with small (leak) failure of containment	1.61E-09	1.00E+10	16
8	Containment failure before core damage with large (rupture) failure of containment	6.86E-08	1.56E+10	1070
9	Core melt arrested in the reactor vessel	5.18E-08	3.17E+07	2
10	No containment failure after core melt	1.46E-06	3.01E+07	44
11	Containment basemat failure	6.19E-08	4.24E+07	3
12	Early containment failure with small (leak) failure of containment	0.00E+00	-	-
13	Early containment failure with large (rupture) failure of containment	2.54E-10	5.67E+09	1
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	6.04E-12	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.00E+00	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	1.03E-12	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.81E-09	3.34E+07	0
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	5.91E-11	1.05E+08	0
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	5.66E-10	3.60E+08	0
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	3.52E-08	6.68E+08	24
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	4.18E-09	8.42E+08	4
Total				2,049

Table 4 (1 of 30)

Initial List of Candidate Improvements for the APR1400 SAMDA Analysis

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power			
1	Provide additional dc battery capacity.	Extended dc power availability during an SBO.	Section 7 evaluates the potential maximum benefit for 125 Vdc power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
2	Replace lead-acid batteries with fuel cells.	Extended dc power availability during an SBO.	Section 7 evaluates the potential maximum benefit for 125 Vdc power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
3	Add additional battery charger or portable diesel-driven battery charger to existing dc system.	Improved availability of dc power system.	Section 7 evaluates the potential maximum benefit for 125 Vdc power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
4	Improve dc bus load shedding.	Extended dc power availability during an SBO.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
5	Provide dc bus cross-ties.	Improved availability of dc power system.	Section 7 evaluates the potential maximum benefit for 125 Vdc power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
6	Provide additional dc power to the 120/240V vital ac system.	Increased availability of the 120V vital ac bus.	Section 7 evaluates the potential maximum benefit for 120V power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
7	Add an automatic feature to transfer the 120V vital ac bus from normal to standby power.	Increased availability of the 120V vital ac bus.	Section 7 evaluates the potential maximum benefit for 120V power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
8	Increase training on response to loss of two 120 Vac buses, which causes inadvertent actuation signals.	Improved chances of successful response to loss of two 120 Vac buses.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
9	Provide an additional diesel generator.	Increased availability of onsite emergency ac power.	Excessive Implementation Cost

Table 4 (2 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power (cont.)			
10	Revise procedure to allow bypass of diesel generator trips.	Extended diesel generator operation.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
11	Improve 4.16 kV bus cross-tie ability.	Increased availability of onsite ac power.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
12	Create ac power cross-tie capability with other unit (multi-unit site).	Increased availability of onsite ac power.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development. Also, the Design Certification does not consider duel unit capability
13	Install an additional, buried off-site power source.	Reduced probability of loss of offsite power.	Excessive Implementation Cost
14	Install a gas turbine generator.	Increased availability of onsite ac power.	Excessive Implementation Cost
15	Install tornado protection on gas turbine generator.	Increased availability of onsite ac power.	Excessive Implementation Cost
16	Improve uninterruptible power supplies.	Increased availability of power supplies supporting front-line equipment.	Section 7 evaluates the potential maximum benefit for 120V and 4.16 kV power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
17	Create a cross-tie for diesel fuel oil (multiunit site).	Increased diesel generator availability.	Not Applicable – Design Certification does not consider duel unit capability
18	Develop procedures for replenishing diesel fuel oil.	Increased diesel generator availability.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
19	Use fire water system as a backup source for diesel cooling.	Increased diesel generator availability.	Section 7 evaluates the potential maximum benefit for EDG events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.

Table 4 (3 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power (cont.)			
20	Add a new backup source of diesel cooling.	Increased diesel generator availability.	Section 7 evaluates the potential maximum benefit for EDG events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
21	Develop procedures to repair or replace failed 4 kV breakers.	Increased probability of recovery from failure of breakers that transfer 4.16 kV nonemergency buses from unit station service transformers.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
22	In training, emphasize steps in recovery of offsite power after an SBO.	Reduced human error probability during off-site power recovery.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
23	Develop a severe weather conditions procedure.	Improved offsite power recovery following external weather-related events.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
24	Bury offsite power lines.	Improved offsite power reliability during severe weather.	Excessive Implementation Cost
Improvements Related to Core Cooling Systems			
25	Install an independent active or passive high-pressure injection system.	Improved prevention of core melt sequences.	Excessive Implementation Cost
26	Provide an additional high-pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	Excessive Implementation Cost
27	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	Extended HPCI and RCIC operation.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

Table 4 (4 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems (cont.)			
28	Add a diverse low-pressure injection system.	Improved injection capability.	Excessive Implementation Cost
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	Section 7 evaluates the potential maximum benefit for SI and EDG events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
30	Improve ECCS suction strainers.	Enhanced reliability of ECCS suction.	Already Implemented – Insights from Generic Safety Issue (GSI)-191 considered in the APR1400 design in Reference 6, the strainers are designed to minimize a potential plugging, and the trash rack located at the ingress of the holdup volume tank (HVT) pre-screens any larger size debris entering the in-containment refueling water storage tank.
31	Add the ability to manually align emergency core cooling system recirculation.	Enhanced reliability of ECCS suction.	Already Implemented – The IRWST eliminates the need to switch to recirculation.
32	Add the ability to automatically align emergency core cooling system to recirculation mode upon refueling water storage tank depletion.	Enhanced reliability of ECCS suction.	Already Implemented – The IRWST eliminates the need to switch to recirculation.
33	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	Extended reactor water storage tank capacity in the event of a steam generator tube rupture.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

Table 4 (5 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems (cont.)			
34	Provide an in-containment reactor water storage tank.	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 in-containment reactor water storage tank and thereby eliminates the need to realign the safety injection pumps for long-term post-LOCA recirculation.	Already Implemented – The design includes an in-containment reactor water storage tank
35	Throttle low-pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	Extended reactor water storage tank capacity.	Already Implemented – The discharged water through the break collects in the holdup volume tank (HVT), which is then transferred to the in-containment reactor water storage tank which eliminates the need to throttle low pressure injection pumps.
36	Emphasize timely recirculation alignment in operator training.	Reduced human error probability associated with recirculation failure.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
37	Upgrade the chemical and volume control system to mitigate small LOCAs.	For a plant like the Westinghouse AP600, where the chemical and volume control system cannot mitigate a small LOCA, an upgrade would decrease the frequency of core damage.	Excessive Implementation Cost

Table 4 (6 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems (cont.)			
38	Change the in-containment reactor water storage tank suction from four check valves to two check and two air-operated valves.	Reduced common mode failure of injection paths.	Section 7 evaluates the potential maximum benefit for SI events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and low-pressure safety injection systems.	Section 7 evaluates the potential maximum benefit for SI events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
40	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in a station blackout.	Improved chance of successful operation during station blackout events in which high area temperatures may be encountered (no ventilation to main steam areas).	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Already Implemented – Safety depressurization and vent system
42	Make procedure changes for reactor coolant system depressurization.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

Table 4 (7 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water			
43	Add redundant dc control power for SW pumps.	Increased availability of SW.	Section 7 evaluates the potential maximum benefit for ESW filter events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
44	Replace ECCS pump motors with air-cooled motors.	Elimination of ECCS dependency on component cooling system.	Already Implemented – SI pump motors are air cooled by room coolers.
45	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	Reduced frequency of loss of component cooling water and service water.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
46	Add a service water pump.	Increased availability of cooling water.	Excessive Implementation Cost
47	Enhance the screen wash system.	Reduced potential for loss of SW due to clogging of screens.	Section 7 evaluates the potential maximum benefit for ESW filter events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
48	Cap downstream piping of normally closed component cooling water drain and vent valves.	Reduced 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.	Already Implemented – The design includes the caps for downstream piping of normally closed component cooling water drain and vent valves. See 1-461 series drawings.
49	Enhance loss of component cooling water (or loss of service water) procedures to facilitate stopping the reactor coolant pumps.	Reduced potential for reactor coolant pump seal damage due to pump bearing failure.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

Table 4 (8 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water (cont.)			
50	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the reactor coolant system prior to seal LOCA.	Reduced probability of reactor coolant pump seal failure.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
51	Additional training on loss of component cooling water.	Improved success of operator actions after a loss of component cooling water.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
52	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	Reduced effect of loss of component cooling water by providing a means to maintain the charging pump seal injection following a loss of normal cooling water.	Not Applicable – Two charging pumps are air cooled. Additional auxiliary charging pump is a positive displacement type and requires no external cooling.
53	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heat-up time.	Increased time before loss of component cooling water (and reactor coolant pump seal failure) during loss of essential raw cooling water sequences.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	Section 7 evaluates the potential maximum benefit for charging pump events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	Excessive Implementation Cost

Table 4 (9 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water (cont.)			
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	Excessive Implementation Cost
57	Use existing hydro test pump for reactor coolant pump seal injection.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	Already Implemented – The design uses an advanced RCP seal design.
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	Excessive Implementation Cost
60	Prevent makeup pump flow diversion through the relief valves.	Reduced frequency of loss of reactor coolant pump seal cooling if spurious high pressure injection relief valve opening creates a flow diversion large enough to prevent reactor coolant pump seal injection.	Section 7 evaluates the potential maximum benefit for seal failure events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
61	Change procedures to isolate reactor coolant pump seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	Reduced frequency of core damage due to loss of seal cooling.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

Table 4 (10 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water (cont.)			
62	Implement procedures to stagger high pressure safety injection pump use after a loss of service water.	Extended high pressure injection prior to overheating following a loss of service water.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
63	Use fire-prevention system pumps as a backup seal injection and high-pressure makeup source.	Reduced frequency of reactor coolant pump seal LOCA.	Section 7 evaluates the potential maximum benefit for seal failure events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
Improvements Related to Feedwater and Condensate			
65	Install a digital feedwater upgrade.	Reduced chance of loss of main feedwater following a plant trip.	Section 7 evaluates the potential maximum benefit for AFW-related events. None of the important events are related to the need for extra AFWST inventory. Therefore, the potential benefit for this item is negligible.
66	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	Increased availability of feedwater.	Section 7 evaluates the potential maximum benefit for AFW-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
67	Install an independent diesel for the condensate storage tank makeup pumps.	Extended inventory in CST during an SBO.	Section 7 evaluates the potential maximum benefit for AFW-related events. None of the important events are related to the need for extra AFWST inventory. Therefore, the potential benefit for this item is negligible.

Table 4 (11 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate (cont.)			
68	Add a motor-driven feedwater pump.	Increased availability of feedwater.	Already Implemented – The design has two turbine-driven AFW pumps and two motor-driven AFW pumps.
69	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	Reduced dual turbine-driven pump maintenance unavailability.	Already Implemented – See 1-526 series P&IDs, manual valves installed up and downstream of steam inlet stop valve (HP/LP)
70	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	Eliminates the need for local manual action to align nitrogen bottles for control air following a loss of off-site power.	Not Applicable – Steam control valves are electro-hydraulically operated
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	Section 7 evaluates the potential maximum benefit for AFW-related events. None of the important events are related to the need for extra AFWST inventory. Therefore, the potential benefit for this item is negligible.
72	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	Improved success probability during a station blackout.	Already Implemented – Turbine-driven AFW pumps are designed to operate in severe environments.
73	Proceduralize local manual operation of auxiliary feedwater system when control power is lost.	Extended auxiliary feedwater availability during a station blackout. Also provides a success path should auxiliary feedwater control power be lost in non-station blackout sequences.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
74	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	Extended auxiliary feedwater availability.	Section 7 evaluates the potential maximum benefit for 125 Vdc power events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.

Table 4 (12 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate (cont.)			
75	Use fire water system as a backup for steam generator inventory.	Increased availability of steam generator water supply.	Section 7 evaluates the potential maximum benefit for AFW-related events. None of the important events are related to the need for extra AFWST inventory. Therefore, the potential benefit for this item is negligible.
76	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	Allows greater inventory for the auxiliary feedwater pumps by preventing condensate storage tank flow diversion to the condenser.	Already Implemented – Condensate storage tank makeup to condenser AOVs fail closed (1-531 (1/5) P&ID).
77	Provide a passive, secondary-side heat rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events	Excessive Implementation Cost
78	Modify the startup feedwater pump so that it can be used as a backup to the emergency feedwater system, including during an SBO scenario.	Increased reliability of decay heat removal.	Section 7 evaluates the potential maximum benefit for AFW-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	Already Implemented – The success criterion for feed and bleed cooling is one POSRV.

Table 4 (13 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Heating, Ventilation, and Air Conditioning			
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	Section 7 evaluates the potential maximum benefit for HVAC-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
81	Add a diesel building high temperature alarm or redundant louver and thermostat.	Improved diagnosis of a loss of diesel building HVAC.	Section 7 evaluates the potential maximum benefit for HVAC-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
82	Stage backup fans in switchgear rooms.	Increased availability of ventilation in the event of a loss of switchgear ventilation.	Section 7 evaluates the potential maximum benefit for HVAC-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
83	Add a switchgear room high temperature alarm.	Improved diagnosis of a loss of switchgear HVAC.	Already Implemented –The temperature switch is provided in the switchgear room. The cubicle cooler in the switchgear room operates automatically by the temperature switch to provide additional cooling as needed. The temperature in the switchgear room is indicated, and high-high temperature is announced in the MCR and RSR.
84	Create ability to switch emergency feedwater room fan power supply to station batteries in a station blackout.	Continued fan operation in a station blackout.	Already Implemented – Turbine-driven AFW pumps are designed to operate in severe environments.

Table 4 (14 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Instrument Air and Nitrogen Supply			
85	Provide cross-unit connection of uninterruptible compressed air supply.	Increased ability to vent containment using the hardened vent.	Not Applicable – The submitted design is a single-unit design and enhancement due to a cross-unit connection is not a part of the Design Certification design.
86	Modify procedure to provide ability to align diesel power to more air compressors.	Increased availability of instrument air after a LOOP.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
87	Replace service and instrument air compressors with more reliable compressors that have self-contained air cooling by shaft-driven fans.	Elimination of instrument air system dependence on service water cooling.	Instrument air is a negligible contribution to plant risk. Therefore, any design change related to instrument air would provide a negligible benefit.
88	Install nitrogen bottles as backup gas supply for safety relief valves.	Extended SRV operation time.	Not Applicable – The design uses pilot-operated safety relief valves that do not require air to operate.
89	Improve SRV and MSIV pneumatic components.	Improved availability of SRVs and MSIV.	The PRA shows a small potential maximum benefit to this modification, given the low importance of MSIV events, As a result, this SAMDA would not provide a positive benefit.
Improvements Related to Containment Phenomena			
90	Create a reactor cavity flooding system.	Enhanced debris cool ability, reduced core concrete interaction, and increased fission product scrubbing.	Already Implemented – The design includes a cavity-flooding system.

Table 4 (15 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena (cont.)			
91	Install a passive containment spray system.	Improved containment spray capability.	Implementation of this SAMDA would not affect CDF and would only cause a reduction in offsite risk costs, which would limit potential benefit or a maximum of $182,000. In reality, the total maximum benefit would be much lower because all offsite consequences would not be eliminated. Therefore, this design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
92	Use the fire water system as a backup source for the containment spray system.	Improved containment spray capability.	Already Implemented – The design includes emergency containment spray backup system (ECSBS).
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	Excessive Implementation Cost
94	Install a filtered containment vent to remove decay heat. Option 1: Gravel bed filter Option 2: Multiple venturi scrubber.	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	Excessive Implementation Cost
95	Enhance fire protection system and standby gas treatment system hardware and procedures.	Improved fission product scrubbing in severe accidents.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	Excessive Implementation Cost

Table 4 (16 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena (cont.)			
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of 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 basemat.	Excessive Implementation Cost
98	Create a core melt source reduction system.	Increased cooling and containment of molten core debris. 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.	Excessive Implementation Cost
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	Excessive Implementation Cost
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.	Excessive Implementation Cost
101	Provide a reactor vessel exterior cooling system.	Increased potential to cool a molten core before it causes vessel failure by submerging the lower head in water.	Excessive Implementation Cost

Table 4 (17 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena (cont.)			
102	Construct a building to be connected to primary/ secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	Excessive Implementation Cost
103	Institute simulator training for severe accident scenarios.	Improved arrest of core melt progress and prevention of containment failure.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	Not Applicable – Enhancement due to procedure revisions are not applicable to the Design Certification stage of plant development.
105	Delay containment spray actuation after a large LOCA.	Extended reactor water storage tank availability.	Not Applicable – Enhancement due to procedure revisions are not applicable to the Design Certification stage of plant development.
106	Install automatic containment spray pump header throttle valves.	Extended time over which water remains in the reactor water storage tank, when full containment spray flow is not needed.	Already Implemented – All ECCS pumps take suction from the IRWST.
107	Install a redundant containment spray system.	Increased containment heat removal ability.	Excessive Implementation Cost
108	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.	Reduced hydrogen detonation potential.	Already Implemented – The H2 control system includes two redundant passive autocatalytic recombiners system.

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena (cont.)			
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	Already Implemented – The H2 control system includes two redundant passive autocatalytic recombiners system.
110	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.	Reduced probability of containment failure.	Implementation of this SAMDA would not affect CDF and would only cause a reduction in offsite risk costs, which would limit potential benefit or a maximum of $182,000. In reality, the total maximum benefit would be much lower because all offsite consequences would not be eliminated. Therefore, this design change would be expected to cost more than this amount and, as a result, not provide a positive benefit.
Improvements Related to Containment Bypass			
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	Already Implemented – Refer to 441-series P&ID.
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	Already Implemented – Refer to 441-series P&ID.
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	Not Applicable – Enhancement due to procedural revisions is not applicable to the Design Certification stage of plant development.
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	Already Implemented – Containment isolation system provides automatic and leak-tight closure of those valves required to close for containment integrity
115	Locate residual heat removal (RHR) inside containment.	Reduced frequency of ISLOCA outside containment.	Excessive Implementation Cost
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	Excessive Implementation Cost

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass (cont.)			
117	Revise EOPs to improve ISLOCA identification.	Increased likelihood that LOCAs outside containment are identified as such. A plant had a scenario in which an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
118	Improve operator training on ISLOCA coping.	Decreased ISLOCA consequences.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development.
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	Excessive Implementation Cost
120	Replace steam generators with a new design.	Reduced frequency of steam generator tube ruptures.	Excessive Implementation Cost
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	Excessive Implementation Cost
122	Install a spray system to depressurize the primary system during a steam generator tube rupture.	Enhanced depressurization capabilities during steam generator tube rupture.	Excessive Implementation Cost

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass (cont.)			
123	Proceduralize use of pressurizer vent valves during steam generator tube rupture sequences.	Backup method to using pressurizer sprays to reduce primary system pressure following a steam generator tube rupture.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
124	Provide improved instrumentation to detect steam generator tube ruptures, such as Nitrogen-16 monitors).	Improved mitigation of steam generator tube ruptures.	Already Implemented – The H2 control system includes two redundant passive autocatalytic recombiners system.
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	Excessive Implementation Cost
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources.	Reduced consequences of a steam generator tube rupture.	Excessive Implementation Cost
127	Revise emergency operating procedures to direct isolation of a faulted steam generator.	Reduced consequences of a steam generator tube rupture.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
128	Direct steam generator flooding after a steam generator tube rupture, prior to core damage.	Improved scrubbing of steam generator tube rupture releases.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	Excessive Implementation Cost

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to ATWS			
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	Section 7 evaluates the potential maximum benefit for ATWS-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	Section 7 evaluates the potential maximum benefit for ATWS-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
132	Provide an additional control system for rod insertion (e.g., AMSAC).	Improved redundancy and reduced ATWS frequency.	Section 7 evaluates the potential maximum benefit for ATWS-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
133	Install an ATWS-sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	Excessive Implementation Cost
134	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.	Affords operators more time to perform actions. 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., SLC injection, lower water level, depressurize RPV) than if the main condenser is unavailable, resulting in lower human error probabilities.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements Related to ATWS (cont.)			
135	Revise procedure to allow override of low-pressure core injection during an ATWS event.	Allows immediate control of low-pressure core injection. On failure of high pressure core injection and condensate, some plants direct reactor depressurization followed by 5 minutes of automatic low-pressure core injection.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	Section 7 evaluates the potential maximum benefit for ATWS-related events. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
137	Provide capability to remove power from the bus powering the control rods.	Decreased time required to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS, which has rapid pressure excursion).	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
Improvements Related to Internal Flooding			
138	Improve inspection of rubber expansion joints on main condenser.	Reduced frequency of internal flooding due to failure of circulating water system expansion joints.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
139	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	Prevents flood propagation.	Not Applicable – This item relates to a specific vulnerability at one station.

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Improvements to Reduce Seismic Risk			
140	Increase seismic ruggedness of plant components.	Increased availability of necessary plant equipment during and after seismic events.	Seismic risk is considered negligible to the APR1400 plant design.
141	Provide additional restraints for CO_2 tanks.	Increased availability of fire protection given a seismic event.	Seismic risk is considered negligible to the APR1400 plant design.
Improvements to Reduce Fire Risk			
142	Replace mercury switches in fire protection system.	Decreased probability of spurious fire suppression system actuation.	Implementation of this SAMDA would only affect fire risk (at-power and LPSD), which would limit the potential benefit, or a maximum of $380,000. In reality, the total maximum benefit would be much lower because all fire consequences would not be eliminated. Therefore, this design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
143	Upgrade fire compartment barriers.	Decreased consequences of a fire.	Section 7 evaluates the potential maximum benefit for fire barrier failures. A design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
144	Install additional transfer and isolation switches.	Reduced number of spurious actuations during a fire.	Implementation of this SAMDA would only affect fire risk (at-power and LPSD), which would limit the potential benefit or a maximum of $380,000. In reality, the total maximum benefit would be much lower because all fire consequences would not be eliminated. Therefore, this design change is expected to cost more than this amount and as a result, would not provide a positive benefit.
145	Enhance fire brigade awareness.	Decreased consequences of a fire.	Not Applicable – Enhancement due to procedures/training is not applicable to the Design Certification stage of plant development.
146	Enhance control of combustibles and ignition sources.	Decreased fire frequency and consequences.	Not Applicable – Enhancement due to procedures/training is not applicable to the Design Certification stage of plant development.

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
Other Improvements			
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break)	Large break LOCAs are a negligible contribution to plant risk. Therefore, any design change related to instrument air would provide a negligible benefit.
148	Enhance procedures to mitigate large break LOCA.	Reduced consequences of a large break LOCA.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
149	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	Improved prevention of core melt sequences by making operator actions more reliable.	Not Applicable – Enhancements to improve procedural compliance are not applicable to the Design Certification stage of plant development.
150	Improve maintenance procedures.	Improved prevention of core melt sequences by increasing reliability of important equipment.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
151	Increase training and operating experience feedback to improve operator response.	Improved likelihood of success of operator actions taken in response to abnormal conditions.	Not Applicable – Enhancement due to training is not applicable to the Design Certification stage of plant development. (combined with the operator action SAMDAs)
152	Develop procedures for transportation and nearby facility accidents.	Reduced consequences of transportation and nearby facility accidents.	Not Applicable – Enhancement due to procedure revisions is not applicable to the Design Certification stage of plant development.
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	Secondary line breaks are a negligible contribution to plant risk. Therefore, any design change related to instrument air would provide a negligible benefit.

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items			
APR1400 – 1	Improve reliability of the onsite AC power	Installed gas turbine generator, instead of diesel generator, to increase reliability of the onsite AC power. The gas turbine generator provides diversity to EDGs.	Already Implemented
APR1400 – 2	Extended DC power availability	Installed a standby battery charger for each 125 V DC battery to improve reliability of 125 V DC power.	Already Implemented
APR1400 – 3	Enhance AC and DC power capability during extended SBO	Installed provision for the mobile gas turbine generators to increase AC and DC power capabilities during extended SBO.	Already Implemented – As a part of post Fukushima action
APR1400 – 4	Enhance reliability of low pressure safety injection function	Installed fluidic device in SIT to enhance core cooling capability during large break LOCA by extending SIT injection duration.	Already Implemented
APR1400 – 5	Enhance core cooling capability during extended SBO	Installed provision to connect two mobile core cooling pumps that enables high and low pressure injections into RCS during extended SBO.	Already Implemented – As a part of post Fukushima action

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items (cont.)			
APR1400 – 6	Enhance reliability of Safety Depressurization and Vent System (SDVS)	Changed the design by replacing pressurizer safety valves (PSVs) and safety depressurization valves (SDVs) with pilot operated safety relief valves (POSRVs) that provide safety relief and pressure depressurization functions. POSRVs provide enhanced reliability of SDVs with 4 additional relieving paths in addition to 2 SDV paths.	Already Implemented
APR1400 – 7	Enhance rapid depressurization (RD) capability to eliminate high pressure melt ejection.	Installed POSRVs to provide rapid depressurization (RD) to eliminate high pressure melt ejection potential during severe accidents by depressurizing RCS with additional pressure relief paths.	Already Implemented
APR1400 – 8	Improve ECCS suction reliability	Enhanced ECCS strainers in IRWST such that strainer blockage minimized. This design addresses GSI-191 strainer plugging issue.	Already Implemented
APR1400 – 9	Minimize debris accumulation in containment during accident condition	Installed reflective metallic insulation (RMI), which eliminates large amount of debris accumulation in containment during accident condition. This design addresses GSI-191 strainer plugging issue.	Already Implemented

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items (cont.)			
APR1400 – 10	Improve secondary heat removal control	Changed auxiliary feedwater (AF) modulating valve actuator from MOV to SOV which increased reliability of AF flow control function.	Already Implemented
APR1400 – 11	Enhance secondary cooling capability during extended SBO	Installed provision to connect two mobile cooling pumps that enables secondary cooling during extended SBO.	Already Implemented – As a part of post Fukushima action
APR1400 – 12	Minimize SC pump suction vortexing vulnerability during mid-loop operation	Improved SC pump suction level to minimize vortexing with increased RCS water level during mid-loop operation using improved design of SG inlet/outlet nozzles.	Already Implemented
APR1400 – 13	Develop operational procedure and train operators for CCW division cross tie operation	Develop procedure and train operators to establish division crosstie of CCW system to prevent loss of RCP seal cooling.	Not Applicable – This item is not in scope of Design Certification.
APR1400 – 14	Provide room cooling diversity during accident condition	Improved Emergency HVAC system capability to be used as a diverse backup capability to ECW. Auxiliary building controlled area emergency exhaust ACU is used as diverse cooling of ECCS equipment rooms by removing heated air from the ECCS equipment rooms during a loss of ECW.	Already Implemented

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items (cont.)			
APR1400 – 15	Improve room cooling reliability	Changed key SSCs to air-cooled, instead of water-cooled, and installed safety-grade cubicle coolers.	Already Implemented
APR1400 – 16	Improve reliability of hydrogen mitigation	Installed passive autocatalytic recombiners (PARs) as passive means to remove hydrogen accumulated in containment.	Already Implemented
APR1400 – 17	Eliminate hydrogen accumulation in IRWST during severe accident	Installed three-way valve in SDVS discharge line to reduce hydrogen accumulation in IRWST.	Already Implemented
APR1400 – 18	Reduce steam discharge impact on IRWST wall during accident condition	Enhanced the spargers in IRWST to minimize the steam discharge impact load on the IRWST wall during accident condition.	Already Implemented
APR1400 – 19	Reduce auxiliary building flooding vulnerability	Located the dedicated CCW HX building outside of auxiliary building which eliminates a potential unlimited water source.	Already Implemented
APR1400 – 20	Increase seismic capability of inner barrel assembly of reactor	Developed the inner barrel assembly to strengthen seismic capability.	Already Implemented

Table 4 (29 of 30)

SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items (cont.)			
APR1400 – 21	Eliminate MSO vulnerability of cables	Four physical quadrant design in auxiliary building and divisional separation of electrical cables minimizes MSO vulnerability. In addition, MSO evaluation was completed, where all potential MSO cables are to be either cable wrapped or physically separated away from each other to eliminate MSO vulnerability.	Not Applicable – This item is not in scope of Design Certification.
APR1400 – 22	Enhance plant capability against LOLA	Installed fire protection system ring headers underground to prevent potential damage from LOLA event.	Already Implemented
APR1400 – 23	Strengthen shutdown capability against aircraft impact	Remote Control Console (RCC) provides means of controls, indications and alarm to achieve plant hot shutdown against aircraft impact as a backup to MCR and Remote Shutdown Panel (RSP). The RCC is installed at an area where concurrent failure with the MCR and RSP is prevented.	Already Implemented
APR1400 – 24	Strengthen physical security alarm system	Installed physically separated Central Alarm Station (CAS) and Secondary Alarm Station (SAS) away from each other to strengthen the Physical Security Program.	Already Implemented

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SAMDA ID	Potential Enhancement	Result of Potential Enhancement	Qualitative Screening
APR1400 Design-Specific Items (cont.)			
APR1400 – 25	Enhance plant capability against LOLA and extended SBO	Installed additional spent fuel pool cooling pump and installed level instrumentation.	Already Implemented – As a part post Fukushima action
APR1400 – 26	Develop operational procedure and train operators for SBLOCA and SGTR	–	Not Applicable – This item is not in scope of Design Certification
APR1400 – 27	Develop operational procedure and train operators for manual operation of ECSBS	–	Not Applicable – This item is not in scope of Design Certification
APR1400 – 28	Develop operational procedure and train operators for extended SBO	–	Not Applicable – This item is not in scope of Design Certification
APR1400 – 29	Develop operational procedure and train operators for mid-loop operation during refueling outage	–	Not Applicable – This item is not in scope of Design Certification

Note. Section 7 of this report, which is referenced in the Qualitative Screening column of this table, provides only a high-level summary. Detailed analyses are provided in Section 7 of Reference 4.