Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

RSP-0304

R322.3 Incorporating Ageing Effects into PSA Applications

Revision 0

Final Report
ENCO FR-(14)-10

March 2014

enco
Provider of independent Nuclear Safety expertise

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

R322.3
Incorporating Ageing Effects into PSA Applications

Final Report
ENCO FR-(14)-10

March 2014

Prepared by:
enco

Prepared for:
Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

DOCUMENT REVIEW AND APPROVAL COVER SHEET

PROJECT Nr.:

PROJECT TITLE: R322.3 Incorporating Ageing Effects into PSA Applications

PERFORMED BY: ENCO

TASK: All Project Tasks: 1, 2, and 3

DELIVERABLE: D4. Final Project Report

PREPARED FOR: Canadian Nuclear Safety Commission - Commission canadienne de sûreté nucléaire

DATE released	REVISION	PREPARED/ REVISED by:	REVIEWED by:	APPROVED by:
22.04.2014	0	(signature on file) Ivan Vrbanic Tibor Szikszai Ivica Basic Date: 30.05.2014.	(signature on file) Jaroslav Pachner Ioana Popa Date: 03.06.2014.	(signature on file) Bojan Tomic Date: 04.06.2014.

ABSTRACT

This report is intended to support Canadian Nuclear Safety Commission (CNSC) in addressing aging effects in the Probabilistic Safety Assessment and in risk-informed decision-making in the area of aging management. It documents an Ageing Probabilistic Safety Assessment case study and its results that were performed for CNSC using a CANDU base-line Level 1 and Level 2 PSA and inputs from Phases 1 and 2 of the CNSC project on Incorporating Aging Effects into PSA Applications.

Probabilistic Safety Assessment (PSA) is one of the most effective tools for the risk-informed decision-making, however, current PSAs do not explicitly account for aging of nuclear power plant (NPP) components that may be manifested by increasing component failure rates. In order to be more realistic, aging-related models and the effects of test and maintenances in controlling aging degradation of NPP components important to safety should be taken into account in PSAs. PSA that explicitly incorporates aging effects and is capable of generating age-dependent risk profile of the plant is referred to as Aging PSA (APSA). The scope of APSA expands the existing PSA scope by adding new active and passive components. Experience in the area of APSA is limited worldwide. The present case study is among the very first attempts made to incorporate the aging effects into an integrated full scope plant specific PSA model, and to observe its impact on the overall PSA results, by making projections to the future.

The overall study documented in this report included the following main tasks: screening of systems, structures and components (SSC) and associated ageing mechanisms for incorporation into the PSA model; establishing time-dependent models for component aging failure rates; PSA modeling of SSCs and related ageing mechanisms in the base-line PSA provided by CNSC; and quantification of the developed PSA model and a comparative analysis of results with and without modelling of aging effects.

A linear time-dependent model for aging failure rates was chosen for the study. A sensitivity case performed with an exponential model showed a slightly higher 'severe core damage frequency' and 'large release frequency' than the results based on the linear model. The key parameter in the linear time dependent aging failure rate model is an 'aging failure acceleration'. The aging failure accelerations for all relevant components were established. To account, quantitatively, for the impact of aging management activities on the time-dependent failure rates, the proportional age reduction model was applied in this study using two additional parameters: 'age improvement factor' and 'aging management activity time period'.

Main results of PSA modeling of component aging include the following points:

- In the reference PSA risk profile, the *initiating event with largest contribution to core damage risk is the total loss of service water.*
- *Results are very sensitive to* changes in the aging improvement factors and aging acceleration rates, i.e. *the effectiveness of aging management.*
- *Results indicate risk importance of aging of cables and the positive effect of an effective aging management program.*
- *Results provide an indication only, rather than a projection of 'severe core damage frequency' and 'large release frequency' into the future* as they are conditional on a large number of assumptions; the most important issue is the lack of plant data that could be used for establishing plant-specific time dependent failure rates.

- *In general, it is not considered possible, to make "accurate" projections of quantitative risk measures into the longer term future.*

Therefore, the results of this case study should be considered with caution, given the nature of the pseudo plant specific failure rates and uncertainties associated with the overall model.

Taking into account the lessons learned from the project, the report presents suggestions to the CNSC staff for possible future work to facilitate further development of a practical APSA that could be used for quantifying aging impact on NPP safety. They include APSA applications aimed at (a) predicting the aging risk profile (significant aging risk contributors) in the reasonably near future by making use of relevant operational data, and (b) exploring the effectiveness of component-specific aging management programs by using relevant operational data, e.g. from 'system health reports'.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AFW	Auxiliary Feed Water
AHU	Air Handling Unit
AM	Aging Management
AOT	Allowable Outage Time
AOV	Air Operated Valve
APSA	Aging PSA
BE	Basic Event
BWR	Boiling Water Reactor
CB	Circuit Breaker
CCDF	Conditional CDF
CCDP	Conditional Core Damage Probability. In the context of this report, the term CCDP implies Severe Core Damage Probability.
CCF	Common Cause Failure
CD	Core Damage
CDF	Core Damage Frequency. In the context of this report, the term CDF implies Severe Core Damage Frequency, SCDF.
CLRP	Conditional Large Release Probability
ECC(S)	Emergency Core Cooling (System)
ECI	Emergency Coolant Injection
EDG	Emergency Diesel Generator
EPS	Emergency Power System
EWS	Emergency Water System
FW(LB)	Feed Water (Line Break)
HPECI	High Pressure ECI
HVAC	Heating, Ventilation and Air Conditioning
HX	Heat Exchanger
IE	Initiating Event
JCO	Justification for Continued Operation
LCO	Limiting Condition for Operation
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
LRF	Large Release Frequency
LWR	Light Water Reactor

MCR	Main Control Room
MFW	Main Feed water
MOV	Motor Operated Valve
MSLB	Main Steam Line Break
O	Operating. Refers to a system configuration in the context of aging induced accident scenario
PAR	Proportional Age Reduction
PHT	Primary Heat Transport
PL(N)GS	Point Lepreau (Nuclear) Generating Station
PSA	Probabilistic Safety Analysis
PWR	Pressurized Water Reactor
RB	Reactor Building
RSW	Raw Service Water
SAMG	Severe Accident Management Guidelines
SCDF	Severe Core Damage Frequency
SD	Standby – Demand. Refers to a system configuration in the context of aging induced accident scenario
SDS1(2)	Shutdown System 1 (2)
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
SLB	Steam Line Break
SM	Standby – Monitored. Refers to a system configuration in the context of aging induced accident scenario
SSC	Systems, Structures and / or Components
STI	Surveillance Test Interval
TIRGALEX	Technical Integration Review Group for Aging and Life Extension
VB	Vacuum Building
VVER	Water-Water Power Reactor (Russian version of PWR)

1. INTRODUCTION

1.1 Background

The Canadian Nuclear Safety Commission (CNSC) performs regulatory oversight of licensees programs for management of ageing of structures, systems, and components (SSCs) important to safety in Canadian nuclear power plants (NPPs) and other nuclear facilities, in order to ensure that safety and performance remain within acceptable limits throughout the facility's life.

Probabilistic Safety Assessment (PSA) is one of the most effective tools for the risk-informed decision-making. Thus, it is important to have credible and defensible PSAs representing adequately the actual risk profile of the plants. However, the current standard PSAs do not explicitly model aging. For instance, reliability models of components are based on the "component constant failure rate" assumption, which is not valid for some components in the long term. Consequently, in order to be more realistic, aging-related models and the effects of test and maintenances in controlling the aging degradation of SSCs important to safety should be taken into account in PSAs. PSA that explicitly incorporates aging effects and is capable of generating age-dependent risk profile of the plant is referred to as Aging PSA (APSA).

At present, the experience in this area is limited worldwide; e.g., there is no commonly accepted approach, studies are performed by relatively isolated organizations, and relevant publications are scarce. In order to address this shortcoming, the CNSC initiated in 2007 a project on Incorporating Aging Effects into PSA Applications. Current work documented in this report is a continuation of the work performed in Phases 1 and 2 of the project.

1.2 Objective

The objective of the study was to determine an appropriate regulatory approach and to acquire an expertise in addressing aging effects in the Probabilistic Risk Assessment which will provide CNSC with a credible tool for risk-informed decision-making in the area of aging management.

1.3 Scope of Work

Scope of work was to perform a case study Aging PSA using a CANDU base-line Level 2 PSA provided by CNSC and evaluate impact on the PSA results.

The overall study documented in this report included three main tasks:

- Screening of SSCs and associated ageing mechanisms (using results from Phase 1 and 2 of the project) for incorporation into the PSA model.
- PSA modelling of SSCs and related ageing mechanisms in the base-line PSA provided by CNSC.

  Note: Since no time dependent aging failure rates for the SSCs were available as an input from Phase 1 and 2, they had to be established as a part of this task.
- Quantification of the developed PSA model and a comparative analysis of results with and without modelling of aging effects.

1.4 Structure of the report

Section 2 describes the overall approach to incorporating ageing effects into PSA taken in this study. Section 3 presents initial screening and characterization of relevant systems, structures and component (SSC) categories with respect to the aging induced accident scenario categories, for the purpose of mapping to the PSA model. This characterization was a continuation of the screening process performed in in Phases 1 and 2 ([2], [3]). The aspects related to modelling and quantifying the risk from aging induced scenarios is further discussed in Appendix 10.1.

Sections 4 and 5 are devoted to establishing time-dependent models for the aging failure rates, incorporating, also the expected effectiveness of aging management. Supporting data evaluations for establishing the time dependent aging failure rates are described in Appendix 10.2.

Incorporation of aging impacts into the PSA model, and related calculations of PSA model parameters, is described in section 6. This section also describes the aging risk quantification procedure.

Section 7 describes the aging risk quantification results. The lists of top minimal cutsets, resulting from the PSA model quantification process, are provided in Appendix 10.4.

A sensitivity case was performed using different set of time dependent aging failure rates. This sensitivity case is described in Appendix 10.3, including the establishing of aging failure rates and the results of risk quantification.

Section 8 provides summary of work performed and conclusions and insights, including potential future work.

2. APPROACH

2.1 General Approach

Several methods have been described and discussed in the relevant literature concerning the incorporation of aging effects into the PSA (references [5] through [21]). The approach selected for this project, as described below, is consistent with methods used in the industry. It consists of screening the SSCs potentially subject to the ageing mechanisms, mapping ageing induced impacts to the PSA model and representing them in the PSA model by adding new or editing existing failure events (basic events).

The overall approach consists of the following general steps:

1. Take relevant SSCs identified in the Phase I as a starting point. The relevant SSCs to be addressed in the aging risk assessment were identified in the Phase I report, [2], Table 6-1.
2. For each item (relevant SSC), identify and define aging induced impacts (accident scenarios) or SSC configurations, which are categorized as 1) “operating” (O), 2) “standby – demand” (SD) or 3) “standby – monitored” (SM). Regarding the definition of these three categories, refer to the section 2.2 below.
3. For each identified ageing induced impact / scenario, define SSC failure mode(s) and corresponding basic event(s), which will represent the ageing impact in the PSA model. The PSA model will be used to quantify the SSC ageing risk impact in terms of an

increase to the risk metrics, i.e. *ΔCDF* and *ΔLRF* equations. The risk equations and PSA models for the three categories of aging-induced impacts / accident scenarios are discussed in the section 2.3 below.

4. In step 4, based on the SSC failure mode / basic event cases established in step 3, identify:

    a) Required aging failure rates evaluations. (Aging failure rate model is described in the section 2.4 below. The purpose of these evaluations is to obtain the parameters needed to quantify the aging failure rate models.)

    b) Required PSA modifications, such as new basic event to be added to the model or the existing basic events to be modified.

5. Perform identified evaluations and PSA model modifications. Steps 5 can be conducted on two tracks, in order to facilitate a timely progression of the project:

    5.1 Evaluate and establish relevant aging failure rates, necessary for quantification of representative basic events;

    5.2 Modify PSA model by adding new representative basic events and / or editing the existing ones. Since the aging failure rates are being estimated in parallel, some surrogate failure rates can be used initially. Perform initial PSA quantifications, just to demonstrate that risk metrics can be computed by the modified PSA model.

6. Apply the results from aging failure rates evaluations (5.1) to modified PSA model (5.2). Calculate sets of time-dependent probabilities / frequencies for all aging-related basic events, for the selected time points.

7. For selected time points, run PSA model for *CDF* and *LRF*. Obtain *CDF / LRF* projections.

8. Define and perform sensitivity cases.

9. Evaluate and interpret the results. Document.

Flow chart for the selected approach is shown in Figure 2-1.

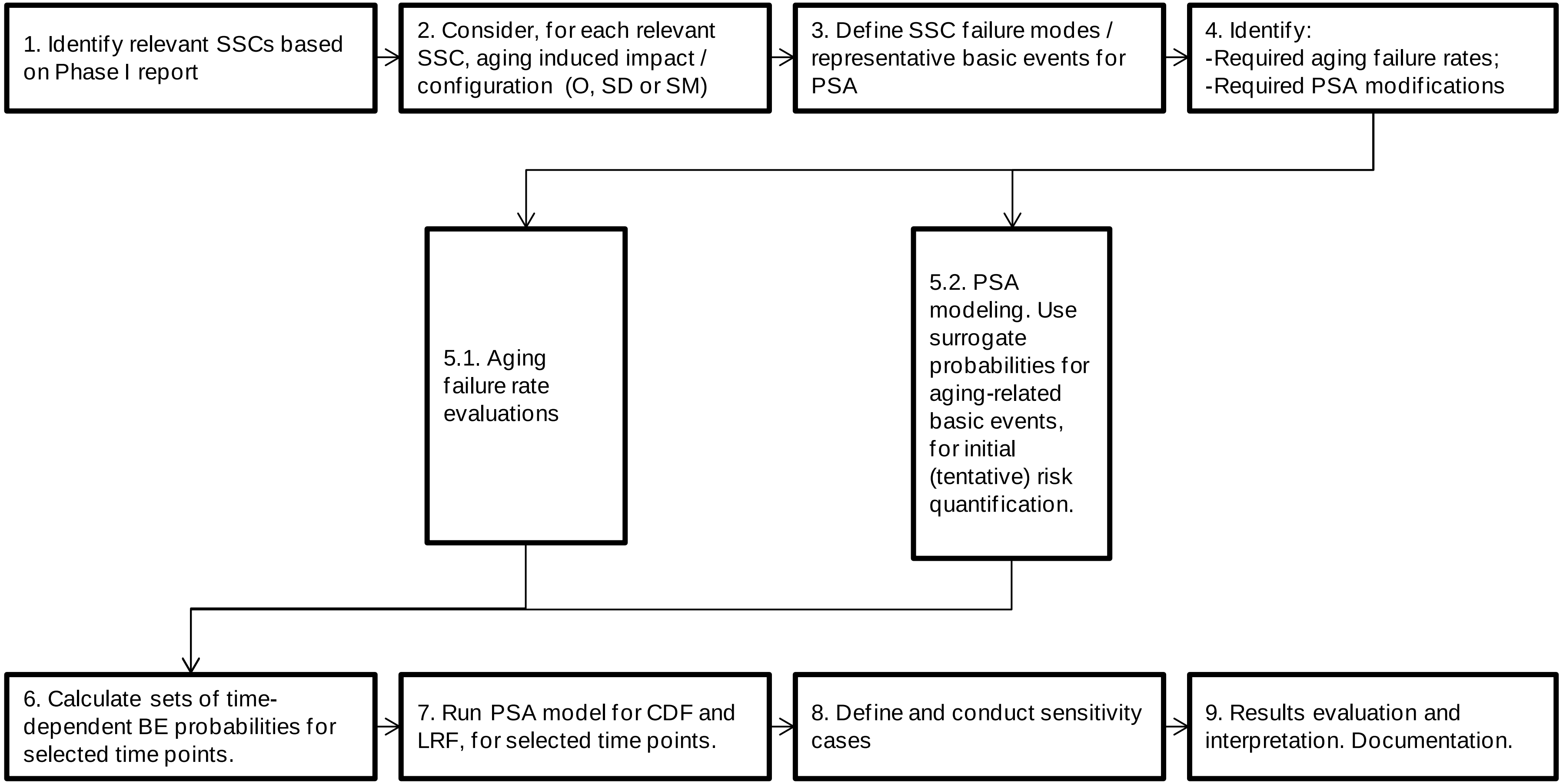


Figure 2-1: Flow Chart for General Approach

2.2 Aging Induced Accident Scenarios

Aging impacts or aging induced accident scenarios are dependent on a configuration / function of SSC which is affected by the considered aging mechanism. These configurations, with corresponding impacts / induced scenarios can, generally, fall into the following three categories.

“Operating” (O) configuration: Aging produces directly induced PSA initiator

Examples of this scenario category can include aging induced leakage / rupture at:

- Pressure tubes (In-core LOCA);
- PHT (LOCA);
- SG tubes (SGTR, multi-SGTR);
- Steam line…

It needs to be pointed that the scenario can, beside a direct initiator, include side effects resulting, possibly, in unavailability of relevant mitigation equipment, e.g. due to sprinkling or steaming the surrounding area. It is noted that indirect effects associated with aging related failures of piping (such as pipe ruptures or leaks) were not considered explicitly for the purpose of this aging risk study. This kind of consideration would require extensive plant walkdown, which was out of scope of the present study. Those aspects were covered to the extent they are presented in the baseline PSA model (e.g. hostile environment in plant rooms / areas following a steam line break initiator…).

“Standby – demand” (SD) configuration: Aging produces non-observable impact with latent unavailability

The examples of this scenario type can include:

- ECCS, pumps discharge side. Pipe wall thinning due to aging (although, no perforation). Demand on the system. Pumps start. Pressure transient. Discharge side piping rupture.
- Transformer. Aging degradation of, e.g., insulation. SI signal. SI equipment start. High demand on transformer. Short circuit.

Like in the first category, the impact can produce some side effects. Those can include sprinkling / flooding of the surrounding area or, even, flood propagation to other areas, resulting in unavailability of additional mitigation equipment. Side effects can, also, produce a reactor trip. In this case, the scenario basically becomes Type one. Or, one calk talk about the combination of O and SD scenarios.

“Standby – monitored” (SM) configuration: Aging produces observable impact on monitored equipment.

Examples of this scenario type can include aging induced leakage / rupture at:

- Dousing Tank;

- Liquid Poison Tank;
- (Leakage at any tank or associated piping, which is observable by, e.g., level monitoring and alarms).

Typically, plant response in this case would be:

- Entering a Limiting Condition for Operation (LCO);
- Performing a repair and corrective actions in order to remove the aging induced impact. This may or may not be possible to complete within the Allowable Outage Time (AOT) associated with LCO. If it is not, a Justification for Continued Operation (JCO) may be requested and granted.
- If JCO not requested or granted, plant would need to go to a forced shutdown.

It needs to be noted that this type of scenario could, also, lead to an indirect initiator, e.g. due to sprinkling (as a result of pipe rupture / leakage) of equipment related to a reactor trip. Or, manual reactor trip can be performed by an operator. In this case, the scenario basically becomes O category.

2.3 Risk Equations for Aging Induced Accident Scenarios

Following below are ΔCDF equations (i.e. equations to calculate an increase in CDF induced by aging impacts) for the three categories of aging induced accident scenarios discussed above. Corresponding equations apply to ΔLRF .

<u>"Operating" (O): Directly induced PSA initiator</u>

In the case of directly induced PSA initiator, CDF increase, $\Delta f_{CD}(t)$, can be estimated as:

$$\Delta f_{CD}(t) = \Delta f_{IE}(t) \times P_{CCD,IE} \qquad \text{Eq. 2-1}$$

where:

$\Delta f_{IE}(t)$ Increase in induced initiating event (IE) frequency corresponding to the aging failure rate $\lambda_{ag}(t)$. (I.e., $\Delta f_{IE}(t) = \lambda_{ag}(t)$.)

$P_{CCD,IE}$ Conditional core damage probability (CCDP) for considered IE, obtained from the PSA calculation (run on the appropriately modified PSA model).

This aging-induced impact / scenario are modelled in a PSA by adding a new representative basic event for aging-induced occurrence of an initiator, or by editing the existing basic event and appropriately increasing the assigned initiator frequency. The PSA modelling is further discussed and illustrated in Appendix 10.1.

<u>"Standby – demand" (SD): Non-observable impact with latent unavailability</u>

In the case that aging induces a non-observable impact which implies latent unavailability of a SSC important to safety, the general equation for a CDF increase is:

$$\Delta f_{CD}(t) = f_{deg\,rad}(t) \times \; f_{CCD,config} \times T_{ex} \qquad \text{Eq. 2-2}$$

where:

$f_{deg\,rad}(t)$	Frequency for degraded state / condition of considered SSC, corresponding to the aging failure rate, $\lambda_{ag}(t)$ (i.e. $f_{deg\,rad}(t) = \lambda_{ag}(t)$). Note: this is a new failure mode, not existing in the base case PSA. Therefore, it represents a change (an increase) in its entirety.
$f_{CCD,config}$	Conditional CDF (CCDF) for induced (by aging related failure) configuration (e.g. conditional CDF given ECCS function unavailable). It can be obtained from the PSA calculation (run on the appropriately modified PSA model). Sometimes, it is obtained from the risk importance measures from the PSA.
T_{ex}	Exposure time. In this case, the exposure time is taken to be a half of a time between two operability or functionality tests. For example, T_{ex} can be:

$$\frac{STI}{2}\ ;\ \frac{time\ \ between\ \ plant\ \ outages}{2}\ ; \ldots$$

where STI means a surveillance test interval.

The crucial thing in this scenario is whether a real demand (i.e. an initiator) comes before the degradation is discovered by a functionality test.

If this condition is never tested or inspected, then the exposure time is the actual time (as measured since $t = 0$) at which the risk (e.g. CDF) is being calculated.

The basis for this exposure time, as well as for the risk equation itself, is described in Appendix 10.1, which provides a discussion and an illustration of the PSA modelling for this aging impact category.

Note: sometimes, in this kind of PSA application, the above exposure time is, conservatively, taken to be the whole STI, instead of its half.

<u>“Standby – monitored” (SM): Observable impact on monitored equipment.</u>

For the case when aging induces an observable impact on monitored equipment, CDF increase can be estimated as:

$$\Delta f_{CD}(t) = f_{fail}(t) \times f_{CCD,config} \times T_{ex} \qquad \text{Eq. 2-3}$$

where:

$f_{fail}(t)$	frequency of induced failures, corresponding to the aging failure rate, $\lambda_{ag}(t)$. (i.e. $f_{fail}(t) = \lambda_{ag}(t)$) (Note: Like in the previous case, this is a new failure mode, not existing in the base case PSA. Therefore, it represents a change (an increase) in its entirety.)

$f_{CCD,config}$ conditional CDF (CCDF) for induced (by aging related failure) configuration (e.g. conditional CDF given Dousing Tank unavailable). It is obtained from the PSA calculation (run on the appropriately modified PSA model).

T_{ex} Exposure time. It can be assumed, as discussed in the previous section, that this scenario would mean entering an LCO. If the repair can be done within an associated AOT (i.e. repair time < AOT), then exposure time corresponds to repair time. For such a case, it can be conservatively taken that $T_{ex} = T_{AOT}$, where T_{AOT} represents allowable outage time.

If the repair cannot be performed within an AOT, it is assumed that plant would go to a forced shutdown. It is not considered credible that a JCO would be granted for cases involving LCOs from Technical Specifications or, at least, not for any period significantly larger than an AOT. Additionally, an administrative shutdown may be ordered to verify the conditions at other SSCs that may be susceptible to the same aging mechanism.

During the shutdown time, the CCDF specific for shutdown conditions would apply. The risk contribution $\Delta f_{CD,shutdown} \times T_{repair}$ will be considered to be significantly smaller than the contribution $\Delta f_{CD,at-power} \times T_{AOT}$, for the reason that this would be an administratively controlled shutdown. While it is true that base case (long term averaged) CDF contribution from shutdown modes is comparable (or even larger than) the CDF contribution from power mode, it needs to be considered that this (base case) shutdown CDF comes from some specific configurations imposed by plant shutdown operations and activities. It is expected, however, that those configurations would not be administratively allowed during this specific shutdown / outage time which would be devoted to repair / inspections of aging impacts. Therefore, only the residual or background shutdown core damage risk would remain.

The above assumption regarding small risk contribution of repair during shutdown may be reconsidered for some specific ageing induced accident scenarios. Otherwise, the assumption will be applied that $T_{ex} = T_{AOT}$.

Combination of O with SD or SM Scenario Category

The combinations of scenarios are discussed in Appendix 10.1.

Characterization of relevant SSCs with respect to the above described aging induced accident scenario categories is presented in section 3.

2.4 Aging Failure Rate Model

Aging failure rate $\lambda_{ag}(t)$ to be input into the above risk equations in order to quantify the aging induced risk will be, for a particular SSC, derived on the basis of the following general linear model:

$$\lambda(t) = \lambda_0 + \lambda_{ag}(t) = \lambda_0 + at \quad \text{Eq. 2-4}$$

where:

$\lambda(t)$	Total failure rate of considered SSC (/hr);
λ_0	Base case failure rate. This is failure rate used in the base case PSA model at $t = 0$. For new (at $t = 0$) components, it can be considered to be a time-independent failure rate (or failure rate which does not account for aging effects). For "aged" components (i.e. those which have spent certain time in operation), it can simply be considered as an initial failure rate, i.e. failure rate "found" in the PSA model at $t = 0$. (Note: $t = 0$ relates to the zero time selected for the Aging PSA.) In such a case, it represents an averaged failure rate which reflects past failures, either aging-related or others. (/hr) Note: For linear model there is no actual difference between interpretation of λ_0 as time-independent failure rate and its interpretation as averaged failure rate at $t = 0$.
$\lambda_{ag}(t)$	Aging induced failure rate contribution after $t = 0$, $\lambda_{ag}(t) = at$ (/hr);
a	Aging failure acceleration (after $t = 0$), expressed in /hr/yr.
t	Age of considered SSC, measures from $t = 0$. Assuming that SSC is subject to operational conditions all the time and that there are no aging management measures applied, the age would correspond to the calendar time.

For the purpose of selection of appropriate aging failure rate model for this study, considering its scope and limitations, a number of existing references were screened. The screened literature includes the U.S. NRC – sponsored studies from the late 80s / early 90s ([5] through [8]) which became the major references for much of the later work on aging PSAs, some other NRC's studies from the 90s (such as [9]) and European aging PSA studies from the last decade (EUR studies, [13] through [21]).

Linear model is one of the oldest aging rate models with a lot of work being based on it. It was used as a basis for the referential TIRGALEX study, [5].

Actually, most of the later studies (following TIRGALEX study) with parametric aging failure rate models were based on exploring the following types of time-dependent models:

- Linear;
- Log-linear / exponential;
- Weibull-based models.

See, for example, NUREG/CR-5378, [7], EUR study [13]and Phase I report [2].

There is no physical basis for preferring any one model over the others, e.g. [7]. In the earlier mentioned studies, the model selection was made on the basis of data evaluation (time histories) and testing, statistically, the hypotheses on the different models. One of the conclusions of the study [7] was that all three assumed models (which were linear, exponential and Weibull's) produce very similar results within the time range of plant data observation and when extrapolated to the near future (few years). (Linear model was only found less suitable for uncertainty characterization. This, however, may come from statistical modelling, rather than from aging physics considerations.)

(It needs to be noted here that some more recent studies consider more sophisticated (or complex) models. However, use of those models is still under research and, per our opinion, it cannot be said with certainty to which extent will it be possible to estimate the needed model parameters and, therefore, to which extent will those models be feasible for practical engineering.)

Parameter "*a*" in the linear aging rate model can be assessed, with due consideration to uncertainties, based on the insights from the existing studies in the literature, and can, even, be shaped to some extent by considering some of the CANDU PSA plant-specific parameters (e.g. failure rates for considered SSCs).

From the above considerations, linear model is considered to be the most appropriate for the purpose of the present study, considering, also, the limitations in input data.

Additionally, a sensitivity case can be provided based on log-linear / exponential model, for the longer time prediction. This can be done by using the following bases and assumptions:

- Use established linear model to estimate the expected number of failures during the plant operation up to this point. Actually, having in mind the (low) aging failure rates, this would be likelihood of a failure, rather than a number of failures.
- Assume alternative model, e.g. log-linear / exponential. Assume that number of aging failures / aging failure likelihood should be the same as with the linear model. This was, actually, demonstrated in the study [7].
- Based on such assumption, establish the parameter(s) of an alternative model.
- Alternative model can be used for a sensitivity case considering longer time predictions.

Details on the sensitivity case with exponential time dependent failure rate model are further discussed in Appendix 10.3.

Use of linear model with insights from a sensitivity case based on the alternative exponential model is considered to provide an adequate basis for characterization of the time dependent aging failure rates for the present study.

Establishing of aging failure rates for the relevant SSCs, in accordance with the model described by Eq. 2-4, is described in section 4.

Time dependent aging failure rate model needs, additionally, to reflect the aging management activities. Incorporation of aging management effectiveness into the aging failure rate model is discussed and described in section 5.

3. CHARACTERIZATION OF RELEVANT SSCS WITH RESPECT TO THE AGING INDUCED ACCIDENT SCENARIO CATEGORIES

Table 3-1 below shows all SSCs / components identified in the Phase I report, [2] as relevant from the perspective of aging risk considerations. Starting from the left side, the first four columns are reproduced from the Phase I report:

#	All relevant components were divided into 165 groups / types;
Components	Type of components considered;
System / Subsystem	Relevant systems and subsystems were identified in which the respective component type needs to be considered. (Identifying numbers were added, as compared to the Phase I table, where multiple system / subsystem entries applied.)
APSA Ranking	In Phase I report, each of 165 component types was ranked from Aging PSA (APSA) perspective with respect to PSA / risk importance and maintenance effectiveness regarding the aging.

Starting from this initial characterization, each component type in each system / subsystem was further characterized in the following manner (as given in the three columns on the right side of the table):

Aging Risk Impact	Applicable categories of aging induced scenarios, discussed in the previous section, were identified, i.e. O, SD or / and SM.
PSA Modelling	Changes to the PSA model, required in order to address the respective SSC / aging-induced scenario were generally described, such as: *Aging-induced initiator - loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator.* *Demand failure - address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices.* (Note: Refer to Appendix 10.1, regarding CCF modelling approach.)
Basic event / Failure mode Cases	For the respective SSC / aging-induced scenario, cases were identified of basic events / failure modes to be incorporated into the PSA model. Those cases were simply coded in the form of AGXX-XX, where XX-XX refers to the numbering identification of corresponding SSC (in the second column). Note: These codes are not meant to be identifiers for basic events in the PSA model. They are just for identification of cases where basic events are required to be added to (or edited in) the PSA model.

Table 3-1: Characterization of Relevant SSCs with Respect to the Aging Induced Accident Scenario Categories and PSA Impact

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
1.	Bearing Plates	1.1 Containment	1,H	SD. Level 2.	Assume loss of Containment integrity. Exposure time: assume interval between Containment Leak Tests. Conservative: remaining life.	AG1-1: failure of Containment integrity by aging-induced degradation of bearing plates
		1.2 Relief Duct			It is considered that Relief Ducting is relevant under normal plant operation and is isolated under emergency condition. Isolation is considered under other category. Screened out on low risk impact.	Screened out.
		1.3 Vacuum Building			Vacuum Building considered not applicable for PLNGS.	N/A
2.	Check Valves	2. Raw Service Water	1,H	O; SD for standby train.	Aging-induced initiator (O configuration): loss of Raw Service Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD configuration: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG2(O): Loss of Raw Service Water due to aging-induced degradation of check valves. AG2(SD): Failure of standby Raw Service Water train on demand due to aging-induced degradation of check valves
3.	Concrete Fan Coolers	3. Reactor Building Cooling	1,H	SD (Level 2)	It is considered that cooling of concrete structures in the RB is relevant under normal plant operation. Failure of Concrete Fan Coolers would result in a forced plant shutdown. Screened out on low risk impact.	Screened out.
4.	Concrete Tank	4.1 Containment	1,H	SM (Level	Considered that associated aging risk is	Addressed under 26.1.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		4.2 Vacuum Building		2)	covered under the item 26.1 for the Containment (Structural Concrete). Note: As compared to other concrete, this configuration / scenario can be assumed to be "SM", based on the monitoring of tank level and associated indication. Therefore, exposure time would be AOT. This implies lower risk as compared to other concrete structures in the Containment. Vacuum Building. considered not applicable for PLGS.	
5.	Connections - Equipment Support Anchors, Bolts and Welds	5.1 Containment 5.2 Reactor Building	1,H	SD (Level 2)	Address by a single basic event. Exposure time: assume interval between Containment Leak Tests. Conservative: remaining life.	AG5: Failure of Containment integrity due to aging-induced loss of Connections - Equipment Support Anchors, Bolts and Welds
6.	Disconnect Switches	6. Emergency Coolant Injection	1,H	SD	Addressed under electrical systems.	Addressed under electrical systems.
7.	Ducting	7. RB Cooling	1,H	N/A	It is considered that ducting is relevant under normal plant operation and is isolated under emergency condition. Isolation is considered under other category. Ducting is screened out on low risk impact.	Screened out.
8.	Expansion Joints	8. Raw Service Water	1,H	Same as 2.	Analogous to 2.	Analogous to 2. Basic events AG8(O) and AG8(SD).

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
9.	Flex Hoses	9. Recirculated Cooling Water	1,H	O; SD for standby train.	Aging-induced initiator (O configuration): loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD configuration: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG9(O): Loss of Recirculated Cooling Water due to aging-induced degradation of flex hoses. AG9(D): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of flex hoses
10.	Foundations (Concrete and Steel)	10.1 Containment	1,H	SD	Group into two groups: 1) Containment integrity (10.1 and 10.2); 2) EWS (10.6 and 10.7). Conservatively: exposure time is remaining plant life. Vacuum Building (10.3 and 10.5) considered not applicable for PLNGS. Screen out Relief Ducts (10.4) as under 1.2.	AG10(G1): Loss of containment integrity due to aging-induced degradation of foundations (concrete and steel) in Containment / RB.
		10.2 Reactor Building				AG10(G2): Failure of EWS due to aging-induced degradation of foundations (concrete and steel).
		10.3 VB Emergency Water Tank & Spray				
		10.4 Relief Ducts				
		10.5 Vacuum Building				
		10.6 Emergency Water Supply				
		10.7 EWS Intake Structure				

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
11.	Instrument Air Valves	11. Boiler Emergency Cooling	1,H	SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG11: Failure of Boiler Emergency Cooling due to aging-induced degradation of Instrument Air Valves.
12.	Isolation Valve	12.1 Containment 12.2 RB Containment Isolation	1,H	SD	Address by a single basic event, considering also CCFs (for particular paths). Exposure time: based on STI. Assume 3 months. Conservative case: based on the Containment leak test period.	AG12: Failure of Containment isolation due to aging-induced degradation of Isolation Valves.
13.	Large Air Coolers-Bellows	13. Reactor Building Cooling System	1,H	Same as 3.	Analogous to 3. Screened out.	Analogous to 3. Screened out.
14.	Large Air Ducts	14.1 Containment 14.2 RB Containment Isolation	1,H	SD	Screened out by the same reasoning as under 7. Note that "penetrations" and "isolation valve" categories, as relevant for the containment isolation, are considered separately.	Screened out.
15.	Liners - Steel	15.1 Containment 15.2 Reactor Building	1,H	SD	Exposure time: assume interval between Containment Leak Tests. Conservative: remaining life. Combine with 22.1.	AG15: Loss of containment integrity due to aging-induced degradation of steel liner.
16.	Motor Operated Valves	16. Raw Service Water	1,H	Same as 2.	Analogous to 2.	Analogous to 2. Basic events AG16(O) and AG16(SD).
17.	Penetrations - Openings for Electrical Cable Trays, Manways, Piping,	17.1 Containment 17.2 Reactor Building	1,H	SD	Address by a single basic event. Exposure time: assume interval between Containment Leak Tests. Conservative:	AG17: Loss of containment integrity due to aging-induced degradation of

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
	Equipment, Airlocks	17.3 Vacuum Building			remaining life. Vacuum Building considered not applicable for PLNGS.	penetrations.
18.	Piping	18.1 Containment	1,H	SD	For piping inside the Containment, assumed to be covered under the respective system. For piping relevant for Containment integrity and isolation, considered covered under 17.1.	Covered under other categories.
		18.2 Standby Generator		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG18-2: Failure of Standby Generator on demand due to aging-induced degradation of piping.
		18.3 Raw Service Water		O; SD for standby train.	Analogous to 2.	AG18-3(O): Loss of Raw Service Water due to aging-induced degradation of piping. AG18-3(SD): Failure of standby Raw Service Water train on demand due to aging-induced degradation of piping.
		18.4 Emergency Water Supply		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG18-4: Failure of EWS due to aging-induced degradation of piping.
19.	Polyethylene Ball	Liquid Injection Shutdown System	1,H	SD	Considered to be of lower risk impact as compared to the other failure modes for this system. Screened out.	Screened out.
20.	Power Supplies-90 V/40V/65V D.C.	Emergency Coolant Injection	1,H	N/A	Low voltage instrument loop power supplies - considered to be subject to replacing and screened out.	Screened out.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
21.	Pressure Regulating Valves	Recirculated Cooling Water	1,H	O; SD for standby train.	O: Aging-induced initiator: loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG21(O): Loss of Recirculated Cooling Water due to aging-induced degradation of Pressure Regulating Valves. AG21(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of Pressure Regulating Valves.
22.	Pre-Stressed Steel - Tendons, Cable and Rods	22.1 Containment	1,H	SD	Containment / Reactor Building - various steel elements and structures. Group of SSCs to address failure of Containment integrity due to aging induced degradation of various steel elements and structures.	AG22-1: Failure of Containment integrity due to aging induced degradation of various steel elements and structures.
		22.2 Vacuum Building		N/A	Vacuum Building considered not applicable for PLNGS.	N/A
23.	Pumps	Raw Service Water	1,H	O, SD	O: Loss of operating pump (new BE or edit representative BE; depends on the existing PSA model). SD: failure of standby pump. Exposure time based on trains cycling. Assume 3 months.	AG23(O): Loss of operating Raw Service Water pump, aging-induced (Note: probability can be applied to account for the failure of other train's pump to map it to the total loss of the system, in order to simplify.). AG23(SD): Failure of standby Raw Service Water pump due to aging-induced degradation.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
24.	Restriction Orifices	24.1 Emergency Core Cooling and Recovery	1,H	SD	Considered to be covered under piping (65.2)	Addressed under other categories.
		24.2 Emergency Water Supply		SD	Considered to be covered under piping (18.4)	Addressed under other categories.
25.	Strainers	Recirculated Cooling Water	1,H	O, SD	Considered to be of small risk impact as compared to other aging induced degradations in the Recirculated Cooling Water System. Strainer is subject to maintenance / inspection and associated failure modes (e.g. flow blockage) are slow developing.	Screened out.
26.	Structural Concrete - Concrete Walls and Slabs	26.1 Containment	1,H	SD	Containment - various concrete elements and structures. Group of SSCs to address failure of Containment integrity due to aging induced degradation of various concrete elements and structures.	AG26-1: Failure of Containment integrity due to aging induced degradation of various concrete elements and structures.
		26.2 Reactor Building		SD	Reactor Building - various concrete elements and structures. Group of SSCs to address failure of RB integrity due to aging induced degradation of various concrete elements and structures.	AG26-2: Failure of RB integrity due to aging induced degradation of various concrete elements and structures.
		26.3 Vacuum Building		N/A	Vacuum Building considered not applicable for PLNGS.	N/A
27.	Structural Steel - Structural Steel Beams, Columns, Plates	27.1 Containment	1,H	SD	Combine with 22.1.	Combine with 22.1.
		27.2 Reactor Building				

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
28.	Tanks	28.1 Emergency Power Supply	1,H	SM	Considered that degradation which could lead to loss of inventory / leakage would be observed by indication of fuel tank level. Exposure time based on AOT. Consider one week, conservatively.	AG28-1: Unavailability of Emergency Power Supply Tank (fuel) due to aging induced degradation
		28.2 Emergency Water Supply		SM	Considered that degradation which could lead to loss of inventory / leakage would be observed by indication of tank level. Exposure time based on AOT. Consider one week, conservatively.	AG28-2: Unavailability of EWS Tank due to aging induced degradation
		28.3 Liquid Injection Shutdown System		SM	Considered that degradation which could lead to loss of inventory / leakage would be observed by indication of tank level. Exposure time based on AOT. Consider one week, conservatively.	AG28-3: Unavailability of Liquid Injection Shutdown System due to aging induced degradation of Tank
29.	4.16kV Motor Starters	29.1 Emergency Coolant Injection	2,H	N/A	Considered under specific motor operated equipment groups.	N/A
		29.1 Emergency Water Supply (EWS)		N/A	Considered under specific motor operated equipment groups.	N/A
30.	Air Conditioning Units	Class 1 and II Power	2,H	SD	Separate basic events for Class I and Class II. Consider CCF as relevant. Failure of power on demand (safety signal). Note that O or SM could also apply. However, they are considered to have small risk impact in comparison to SD. Load on AHUs during normal operation (O scenario) is much lower than in the case of safety demand.	AG30(O1): Failure of AHUs for Class I Power on demand (safety signal) due to aging-induced degradation; AG30(O2): Failure of AHUs for Class II Power on demand (safety signal) due to aging-induced degradation
31.	Air Operated Valves	31.1 Moderator	2,H	N/A	Screen on low risk impact. (Forced shutdown.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		31.2 Auxiliary Boiler Feedwater and Condensate		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG31-2: Failure of AFW due to aging-induced degradation of AOVs.
		31.3 Boiler Level Control		O	Loss of Main Feedwater with possible unavailability of Emergency Feedwater due to loss of control.	AG31-3: Loss of MFW Due to aging induced loss of Boiler level control caused by degradation of AOVs
		31.4 Emergency Coolant Injection		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG31-4: Failure of ECI due to aging-induced degradation of AOVs.
		31.5 Primary Heat Transport		O	Assume external leakage as a critical failure mode. Address as aging induced external LOCA.	AG31-5: Aging induced external LOCA due to degradation of AOVs in PHT
		31.6 Shutdown Cooling System		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG31-6: Aging induced loss of shutdown cooling caused by degradation of AOVs.
		31.7 Boiler Blowoff System		O	Assume reactor trip caused by transient induced by aging-related failures of Blowoff System, as an enveloping event.	AG31-7: Transient caused by failure of Boiler Blowoff System due to aging-induced degradation of air operated valves.
		31.8 Emergency Coolant Injection		SD	As under 31.4.	As under 31.4.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		31.9 Containment		N/A	For valves inside the Containment, assumed to be covered under the respective system. For AOVs relevant for Containment integrity and isolation, considered to be covered under categories for Isolation Valves (e.g. under 12).	Addressed under other categories.
		31.10 Instrument Air		O, SD	O: single basic event representing aging-induced initiator (transient) (or edit the existing representative BE). SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices / compressor cycling practices. Assume 3 months.	AG31-10(O): Aging induced transient due to degradation of air operated valves in Instrument Air system. AG31-10(SD): Failure of Instrument Air due to aging induced degradation of air operated valves.
		31.11 Recirculated Cooling Water		O; SD for standby train.	Aging-induced initiator (O configuration): loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD configuration: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG31-11(O): Loss of Recirculated Cooling Water due to aging-induced degradation of AOVs. AG31-11(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of AOVs.
32.	Airlocks	Containment	2,H	SD	Addressed under 17.1.	Addressed under 17.1.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
33.	Battery-125 V and 28 V	Emergency Power Supply	2,H	SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months. Note: Low voltage (25 V) batteries considered to be subject to replacing on a regular basis.	AG33: Failure of 125 VDC Batteries in EPS due to aging degradation
34.	Box-Up and Steam Isolation Damper	RB Ventilation	2,H	N/A	It is considered that RB Ventilation is relevant under normal plant operation and is isolated under emergency condition. (Isolation is addressed separately.) Screened out on low risk impact.	N/A
35.	Breakers-250 V D.C	35.1 Class III Distribution System	2,H	O, SD	Combine with 36.1.	Combine with 36.1.
		35.2 Class II Distribution System		O, SD	Combine with 36.2.	Combine with 36.2.
		35.3 250V DC Class I Power System		O, SD	Combine with 36.3.	Combine with 36.3.
36.	Breakers-4.16 kV	36.1 Class III Distribution System	2,H	O, SD	O: Loss of Class III Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG36-1(O): Aging-induced loss of Class III Distribution System during normal operation due to degradation of breakers. AG36-1(SD): Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of breakers.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		36.2 Class II Distribution System		O, SD	O: Loss of Class II Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG36-2(O): Aging-induced loss of Class II Distribution System during normal operation due to degradation of breakers. AG36-2(SD): Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of breakers.
		36.3 250V DC Class I Power System		O, SD	O: Loss of 250 V DC Class I Power System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG36-3(O): Aging-induced loss of 250 V DC Class I Power System during normal operation due to degradation of breakers. AG36-3(SD): Failure of 250 V DC Class I Power System on demand (safety signal) due to aging-induced degradation of breakers.
37.	Cables	37.1 Emergency Coolant Injection	2,H	SD	Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-1: Failure of ECI on demand due to aging-induced degradation of cables.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		37.2 Class III Distribution System		O, SD	O: Loss of Class III Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-2(O): Aging-induced loss of Class III Distribution System during normal operation due to degradation of cabling. AG37-2(SD): Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of cables.
		37.3 Class II Distribution System		O, SD	O: Loss of Class II Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-3(O): Aging-induced loss of Class II Distribution System during normal operation due to degradation of cabling. AG37-3(SD): Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of cables.
		37.4 250V DC Class I Power System		O, SD	O: Loss of 250 V DC Class I Power System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-4(O): Aging-induced loss of 250 V DC Class I Power System during normal operation due to degradation of cabling. AG37-4(SD): Failure of 250 V DC Class I Power System on demand (safety signal) due to aging-induced degradation of cables.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		37.5 Standby Generators -		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG37-5: Failure of Standby Generator due to aging induced degradation of cables.
		37.6 Shutdown Cooling System - 600V		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG37-6: Aging induced loss of shutdown cooling caused by degradation of cables.
		37.7 Shutdown System 2 (SDS2)		O, SD	O: Reactor trip. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-7(O): Aging-induced reactor trip caused by degradation of cabling in SDS2. AG37-7(SD): Failure of SDS2 on demand (reactor trip signal) due to aging-induced degradation of cables.
		37.8 Containment -		SD	Cables inside containment - considered to be addressed under respective systems. Cabling in support systems relevant for containment function - considered to be addressed under respective systems, with exception of Containment Isolation, which is to be addressed explicitly: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI for containment isolation. Assume 3 months.	AG37-8: Failure of containment isolation due to aging induced degradation of cables.
		37.9 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		37.10 Shutdown System 1 (SDS1)		O, SD	O: Reactor trip. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG37-10(O): Aging-induced reactor trip caused by degradation of cabling in SDS1. AG37-10(SD): Failure of SDS1 on demand (reactor trip signal) due to aging-induced degradation of cables.
		37.11 Emergency Water Supply (EWS)		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG37-11: Failure of EWS due to aging-induced degradation of cabling.
		37.12 Emergency Power Supply		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG37-12: Failure of Emergency Power Supply due to aging induced degradation of cables.
		37.13 Instrument Air		O, SD	O: single basic event representing aging-induced initiator (transient) (or edit the existing representative BE). SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices / compressor cycling practices. Assume 3 months.	AG37-13(O): Aging induced transient due to degradation of cabling in Instrument Air system. AG37-13(SD): Failure of Instrument Air due to aging induced degradation of cabling.
		37.14 Primary Heat Transport		O	Transient / Reactor trip assumed as enveloping event.	AG37-14: Aging induced reactor trip due to degradation of cabling in PHT system.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		37.15 RB Ventilation		N/A	Considered not to be related to CD / release risk, except for isolation function which is addressed separately. (Function of RB Ventilation is to ensure working conditions in RB under normal plant operation.)	N/A
		37.16 Recirculated Cooling Water		O; SD for standby train.	O: Aging-induced initiator: loss of Recirculation Cooling Water operating train. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG37-16(O): Loss of Recirculated Cooling Water operating train due to aging-induced degradation of cables. AG37-16(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of cables.
38.	Class II 120 VAC Static Bypass Switches	Class II Power	2,H	N/A	Risk impact of bypass switches considered to be low in comparison with other failure modes.	N/A
39.	Class I 250 VDC Rectifier	Class I Power	2,H	O, SD	O: Loss of Class I 250 VDC during normal operation as an enveloping event. SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices / compressor cycling practices. Assume 3 months.	A39(O): Loss of Class I 250 VDC during normal operation due to aging induced degradation of rectifier. AG39(SD): Failure of Class I 250 VDC Rectifiers due to aging degradation
40.	Class I 48 VDC Rectifier	Class I Power	2,H	O, SD	Low voltage rectifiers - considered to be subject to replacing and screened out.	Screened out.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
41.	Class II 600 VAC Inverters	Class II Power	2,H	O, SD	O: Loss of Class II 600 VAC inverters during normal operation as an enveloping event. SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	A41(O): Loss of Class II 600 VAC inverters during normal operation due to aging induced degradation. AG41(SD): Failure of Class II 600 VAC Inverters on demand (safety signal) due to aging degradation
42.	Class I Batteries	Class I Power	2,H	SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices / compressor cycling practices. Assume 3 months.	AG42: Failure of Class I Batteries due to aging degradation
43.	Class II 120 VAC Inverters	Class II Power	2,H	O, SD	O: Loss of Class II 120 VAC inverters during normal operation as an enveloping event. SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	A43(O): Loss of Class II 120 VAC inverters during normal operation due to aging induced degradation. AG43(SD): Failure of Class II 600 VAC Inverters on demand (safety signal) due to aging degradation
44.	Dampers	44.1 Reactor Building (RB Ventilation) 44.2 Reactor Building (RB Cooling)	2,H	N/A	It is considered that dampers are relevant under normal plant operation and are isolated under emergency condition. Screened out on low risk impact.	Screened out.
45.	Depressurization Valves	Shutdown Cooling	2,H	O (Shutdown)	Assume loss of shutdown cooling initiator.	AG45: Aging induced loss of shutdown cooling caused by degradation of Depressurization Valves.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
46.	Dry-type Power Transformers Regulating 9kVA 4.16kV600V	46.1 Class III Distribution System	2,H	O, SD	O: Loss of Class III Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modelled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG46-1(O): Aging-induced loss of Class III Distribution System during normal operation due to degradation of power transformers. AG46-1(SD): Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of power transformers.
		46.2 Class II Distribution System		O, SD	O: Loss of Class II Distribution System during normal operation as an enveloping event. New BE or edit existing BE, depending, also, on how it is modeled in the base case PSA. SD: Address by a single basic event, considering also CCFs (passive component). Exposure time: based on STI. Assume 3 months.	AG46-2(O): Aging-induced loss of Class II Distribution System during normal operation due to degradation of power transformers. AG46-2(SD): Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of power transformers.
		46.3 250V DC Class I Power System		N/A	Considered not applicable.	Considered not applicable.
47.	Embedded Parts	Emergency Core Cooling and Recovery	2,H	N/A	Considered to be addressed under other ECI failure modes.	Addressed under other categories.
48.	Emergency Power Generators	Emergency Power Supply	2,H	SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 1 month.	AG48: Aging induced failure of Emergency Diesel Generators.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
49.	EPS 4.16Kv Busses and Disconnect Switches	UPS, Class II and I, EPS	2,H	O, SD	Define O and SD type event for each class (I, II etc.). O: loss of bus due to aging induced degradation. SD: loss of power on demand (safety signal) due to aging induced bus degradation. Consider CCF (passive component).	AG49(O1): Aging-induced loss of Class I bus. AG49(O2): Aging-induced loss of Class II bus. AG49(O3): Aging-induced loss of Class III bus. AG49(O4): Aging-induced loss of Class IV bus. AG49(SD1): Aging induced loss of Class I power on demand (safety signal) due to busses degradation. AG49(SD2): Aging induced loss of Class II power on demand (safety signal) due to busses degradation. AG49(SD3): Aging induced loss of Class III power on demand (safety signal) due to busses degradation. AG49(SD4): Aging induced loss of Class IV power on demand (safety signal) due to busses degradation.
50.	ECC Motor Vacuum Contactor	UPS, Class II and I, EPS	2,H	N/A	Considered to be addressed under 49.	Considered to be addressed under 49.
51.	Feeders	Primary Heat Transport	2,H	O	Assume ex-core LOCA as enveloping event.	AG51: Aging-induced ex-core LOCA due to degradation of PHT feeders.
52.	Foundations - Foundation Slab Pile Caps	Emergency Water Supply	2,H	SD	Combine with 10.6.	Combine with 10.6.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
53.	Fuel channels	Primary Heat Transport	2,H	O	Assume in-core LOCA as enveloping event.	AG53: Aging-induced in-core LOCA due to degradation of fuel channels.
54.	Generators	54.1 Emergency Power Supply	2,H	SD	Considered to be addressed under 48.	Considered to be addressed under 48.
		54.2 Standby Generators		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 1 month.	AG54-2: Aging induced failure of Standby Generators.
55.	Heat Exchanger	55.1 Emergency Coolant Injection	2,H	SD	Heat exchange function is relevant for the recirculation phase. Leakage or rupture within a HX, if it occurs, can disable injection function, also. Any relevant impact of HX degradation on ECI function is considered to be covered under 55.7, which addresses all relevant phases of emergency core cooling.	Addressed under 55.7.
		55.2 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A
		55.3 Primary Heat Transport		O	Any impact of this component type (i.e. HX) on PHT is considered to be addressed through PHT leakage / rupture failure modes associated with other PHT SSC categories.	Any relevant impact addressed by other categories.
		55.4 Recirculated Cooling Water		O; SD for standby train.	O: Aging-induced initiator: loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3	AG55-4(O): Loss of Recirculated Cooling Water due to aging-induced degradation of HX. AG55-4(SD): Failure of standby Recirculated Cooling Water train on demand due to

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
					months.	aging-induced degradation of HX.
		55.5 Shutdown Cooling		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG55-5: Aging induced loss of shutdown cooling caused by degradation of Heat Exchangers.
		55.6 Dousing System		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG55-6: Failure of Dousing System due to aging induced degradation of HXs.
		55.7 Emergency Core Cooling and Recovery		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG55-7: Failure of ECC due to aging induced degradation of HXs.
56.	Heaters-Immersion-600 Volt	Moderator system	2,H	N/A	Screen on low risk impact. (Forced shutdown.)	N/A
57.	HVAC-Misc Equip & Ducting	RB Ventilation	2,H	N/A	It is considered that RB Ventilation is relevant under normal plant operation and is isolated under emergency condition. (Isolation is addressed separately.) Screened out on low risk impact.	N/A
58.	Independent PCB-S-R	Shutdown System 1 (SDS1)	2,H	SD	Combine with 75.	Combine with 75.
59.	Inverters	UPS, Class II and I, EPS	2,H	N/A	Addressed under 41 and 43.	Addressed under 41 and 43.
60.	Motor Control Centres - 600 V - 208 V	60.1 Class III Distribution System	2,H	N/A	Considered under specific motor operated equipment groups.	Considered under specific motor operated equipment groups.
		60.2 Class II Distribution System				
		60.3 250V DC Class I Power System				

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		60.4 Containment				
		60.5 Emergency Coolant Injection				
		60.6 Emergency Power Supply				
		60.7 Emergency Water Supply				
		60.8 Instrument Air				
		60.9 Moderator system				
		60.10Primary Heat Transport				
		60.11 RB Ventilation				
		60.12 Shutdown System 1				
		60.13 Shutdown System 2				
		60.14 Shutdown Cooling System				
		60.15 Standby Generator				
61.	Motor Operated Valves	61.1 Boiler Level Control	2,H	O	Loss of Main Feedwater with possible unavailability of Emergency Feedwater due to loss of control.	AG61-1: Loss of MFW Due to aging induced loss of Boiler level control caused by degradation of MOVs
		61.2 Primary Heat Transport		O	Assume external leakage as a critical failure mode. Address as aging induced external LOCA.	AG61-2: Aging induced external LOCA due to degradation of MOVs in PHT
		61.3 Emergency Water Supply (EWS)		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG61-3: Failure of EWS due to aging-induced degradation of MOVs.
		61.4 Emergency Coolant Injection		SD	Address by a single basic event, considering also CCFs. Exposure time:	AG61-4: Failure of ECI due to aging-induced

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
					based on STI. Assume 3 months.	degradation of MOVs.
		61.5 Auxiliary Boiler Feedwater and Condensate		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG61-5: Failure of AFW due to aging-induced degradation of MOVs.
		61.6 Containment 61.7 Filtered Air Discharge 61.8 Vacuum Building 61.9 Reactor Building		N/A	For valves inside the Containment / RB, assumed to be covered under the respective system. For MOVs relevant for Containment integrity and isolation, considered to be covered under categories for Isolation Valves (e.g. under 12). Vacuum Building considered not applicable for PLNGS.	Addressed under other categories.
62.	Motorized Strainers	Emergency Water Supply (EWS)	2,H	SD	Considered to be of small risk impact as compared to other aging induced degradations in the EWS system. Strainer is subject to maintenance / inspection and associated failure modes (e.g. flow blockage) are slow developing.	N/A
63.	Motors (4Kv)	63.1 Moderator 63.2 Auxiliary Boiler Feedwater and Condensate 63.3 Primary Heat Transport 63.4 Emergency Coolant Injection 63.5 Emergency Low Pressure Service Water	2,H	N/A	Considered under specific motor operated equipment groups.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		63.6 Emergency Water Systems				
64.	Non-Return or Check Valves	64.1 Moderator	2,H	N/A	Screen on low risk impact. (Forced shutdown.)	N/A
		64.2 Auxiliary Boiler Feedwater and Condensate		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI . Assume 3 months.	AG64-2: Failure of AFW due to aging induced degradation of check valves.
		64.3 Instrument Air		O, SD	O: single basic event representing aging-induced initiator (transient) (or edit the existing representative BE). SD: Address by a single basic event, considering also CCFs. Exposure time: based on STI or maintenance practices / compressor cycling practices. Assume 3 months.	AG64-3(O): Aging induced transient due to degradation of check valves in Instrument Air system. AG64-3(SD): Failure of Instrument Air due to aging induced degradation of check valves.
		64.4 Shutdown System 2		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months. Note: SM case (which may develop to O case, initiator, under some circumstances) is also possible. However, the SD case is considered to be most conservative and to bound the risk significance of other scenarios.	AG64-4: Failure of Shutdown System 2 due to aging induced degradation of check valves.
		64.5 Primary Heat Transport		O	Assume external leakage as a critical failure mode. Address as aging induced external LOCA. Consider possibility that Emergency Cooling Injection train is disabled in the case of interfacing check valve in injection line.	AG64-5: Aging induced external LOCA due to degradation of check valves in PHT system.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		64.6 Emergency Coolant Injection		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI . Assume 3 months.	AG64-6: Failure of ECI due to aging induced degradation of check valves.
		64.7 Shutdown Cooling		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG64-7: Aging induced loss of shutdown cooling caused by degradation of check valves.
		64.8 Containment		SD	Assumed to be addressed under Isolation Valves - Containment (SSC 12.1)	Assumed to be addressed under Isolation Valves - Containment (SSC 12.1)
		64.9 Primary Heat Transport		See 64.5.	See 64.5.	See 64.5.
		64.10 Emergency Water Supply		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG64-10: Failure of EWS due to aging-induced degradation of check valves.
		64.11 Boiler Emergency Cooling System		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG64-11: Failure of Boiler Emergency Cooling system due to aging-induced degradation of check valves.
		64.12 Blowoff System		O	Assume reactor trip caused by transient induced by aging-related failures of Blowoff System, as an enveloping event.	AG64-12: Transient caused by failure of Blowoff System due to aging-induced degradation of check valves.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
65.	Piping	65.1 Dousing System	2,H	SM	"Monitored" configuration considered on account that leakage in the Dousing System would be observed through the level in Dousing Tank during normal plant operation. Exposure time is based on AOT. One week can be taken as, probably, a conservative value.	AG65-1: Failure of Dousing System due to aging-induced degradation of piping
		65.2 Emergency Core Cooling and Recovery		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG65-2: Failure of ECC due to aging induced degradation of piping.
		65.3 Shutdown System 2 (SDS2)		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months. Refer, also, to 64.4.	AG65-3: Failure of Shutdown System 2 due to aging induced degradation of piping
		65.4 Primary Heat Transport		O	Address as aging induced external LOCA. Consider possibility that Emergency Cooling Injection train is disabled in the case of interfacing injection line.	AG65-4: Aging induced external LOCA due to degradation of piping in PHT system.
		65.5 Emergency Power Supply		SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG65-5: Failure of Emergency Power Supply due to loss of fuel supply from fuel tank caused by aging induced degradation of piping
		65.6 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		65.7 Recirculated Cooling Water		O; SD for standby train.	Aging-induced initiator (O configuration): loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD configuration: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG65-7(O): Loss of Recirculated Cooling Water due to aging-induced degradation of piping. AG65-7(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of piping.
		65.8 Blowoff System		O	Assume reactor trip caused by transient induced by aging-related failures of Blowoff System, as an enveloping event.	AG65-8: Transient caused by failure of Blowoff System due to aging-induced degradation of piping.
		65.9 Shutdown Cooling		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG65-9: Aging induced loss of shutdown cooling caused by degradation of piping.
		65.10 PHT Pressure and Inventory System		O	Address together with 65.4.	Address together with 65.4.
		65.11 RB Ventilation		N/A	Considered not to be related to CD / release risk, except for isolation function which is addressed separately. (Function of RB Ventilation is to ensure working conditions in RB under normal plant operation.)	N/A
		65.12 Boiler Emergency Cooling		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG65-12: Failure of Boiler Emergency Cooling system due to aging-induced degradation of piping.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
66.	Piping-Strainers	66.1 Primary Heat Transport	2,H	O	Considered to be addressed under 65.4.	Considered to be addressed under 65.4.
		66.2 Recirculated Cooling Water		O, SD for standby train.	Considered to be addressed under 65.7.	Considered to be addressed under 65.7.
67.	Post Insulators	Switchyard Equipment and Structures	2,H	O	Screened on assumed low risk impact as compared to other failure modes relevant for loss of power. Also, considered to be included under other categories, e.g. "transformers" etc.	Screened out.
68.	Power Supplies-90 V/40V/65V D.C.	Shutdown System 1	2,H	N/A	Low voltage instrument loop power supplies - considered to be subject t to replacing and screened out.	Screened out.
69.	Power Transformers	Emergency Water Supply	2,H	SD	Address by a single basic event, considering also CCFs (for passive components). Exposure time: based on STI. Assume 3 months.	AG69: Failure of EWS due to aging-induced degradation of power transformers.
70.	Pressure Relief Valves	70.1 Primary Heat Transport	2,H	O	Critical failure mode considered to be stuck open. Contribution to induced external LOCA. In calculation of IE frequency, consider frequency of a challenge to open, standby lambda (t) and exposure time, based on the time from last test. Assume order of a year period.	AG70-1: Aging-induced external LOCA due to stuck open pressure relief valve caused by aging degradation.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		70.2 Shutdown System 2 (SDS2)		SM	Critical failure mode considered to be spurious opening. In such a case, the system would be unavailable, due to unavailability of helium tank. This is considered to be monitored configuration, based on the indications / alarms associated with helium tank pressure. Exposure time based on an AOT for SDS2.	AG70-2: Shutdown System 2 unavailable due to aging-induced degradation of pressure-relief valve(s).
		70.3 Containment		N/A	Not considered relevant for containment.	N/A
		70.4 Moderator System		N/A	Screen on low risk impact.	N/A
		70.5 Shutdown System 1		N/A	Considered to be non-relevant failure mode for Shutdown System 1.	N/A
		70.6 Recirculated Cooling Water		SD	Critical failure mode considered to be stuck open. Consider likelihood of a challenge to open upon system actuation on safety signal. Consider standby lambda (t) and exposure time, based on the time from last test. Assume order of a year period. Consider screening out this scenario. Consider CCF, as relevant.	AG70-6: Failure of Recirculated Cooling System due to aging-induced degradation of pressure-relief valve(s).
71.	Pressure Tubes	Primary Heat Transport	2,H	O	Assume in-core LOCA as enveloping event.	AG71: Aging-induced in-core LOCA due to degradation of pressure tubes.
72.	Pre-Stressed Steel	72.1 Containment	2,H	SD	Combine with 22.1.	Combine with 22.1.
		72.2 VB Emergency Water Tank & Spray		N/A	Vacuum Building considered not applicable for PLNGS.	N/A
73.	Pump Motors (600V)	73.1 Shutdown Cooling	2,H	N/A	Considered under specific motor	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		73.2 Emergency water System			operated equipment groups.	
		73.3 Emergency Coolant Injection				
74.	Pumps	74.1 Emergency Low Pressure Service Water	2,H	SD	Considered not to be applicable to PLNGS.	N/A
		74.2 Emergency Core Cooling and Recovery		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-2: Failure of ECC / Recovery due to aging-induced degradation of pumps.
		74.3 Primary Heat Transport		O	Loss of pump's function is assumed as a failure mode. External leakage is considered to be covered under other categories, such as welds etc. Therefore, plant trip assumed as an initiator.	AG74-3: Plant trip due to aging-induced failure of PHT pumps.
		74.4 Emergency Coolant Injection		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-4: Failure of ECI due to aging-induced degradation of pumps.
		74.5 Emergency Power Supply		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-5: Failure of Emergency Power Supply due to loss of EDGs caused by aging induced degradation of fuel pumps.
		74.6 Auxiliary Boiler Feedwater and Condensate		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-6: Failure of AFW due to aging-induced degradation of pumps.
		74.7 Emergency Water Supply		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-7: Failure of EWS due to aging-induced degradation of pumps.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		74.8 HVAC		SD	Considered is induced failure of HVAC following a demand on safety signal. These are assumed to be Chilled Water System Pumps. Address by a single basic event per system, considering also CCFs. Exposure time: based on STI. Assume 3 months. (O or SM could also apply, but those are considered to be of lower risk impact. Failure of HVAC would bring plant to a shutdown. Therefore, SD scenario is considered to be enveloping.)	AG74-8: Failure of HVAC due to aging-induced degradation of Chilled Water System pumps. Note: verify in the PSA model whether Chilled Water Pumps modelled explicitly. If not, this failure mode may need to be added to HVAC where it is modelled to support the frontline systems or other support systems.
		74.9 Class 1 & 2 Electrical and Battery HVAC Systems		SD	Covered under 74.8.	N/A
		74.10 Containment		N/A	For pumps inside the Containment, assumed to be covered under the respective system. For pumps from systems relevant for Containment integrity, also considered to be covered under the respective systems.	Addressed under other categories.
		74.11 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		74.12 Recirculated Cooling Water		O; SD for standby train.	Aging-induced initiator (O configuration): loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD configuration: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG74-12(O): Loss of Recirculated Cooling Water Operating Train due to aging-induced degradation of Pumps. AG74-12(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of pumps.
		74.13 Shutdown System 2		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG74-13: Failure of Shutdown System 2 due to aging induced degradation of pumps.
		Shutdown Cooling		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG74-14: Aging induced loss of shutdown cooling caused by degradation of pumps.
75.	Reactivity Control	Shutdown System 1	2,H	SD	Residual risk from aging of equipment in Shutdown System 1. Group of SSCs.	AG75: Failure of SDS1 on demand due to aging induced degradation of equipment - residual risk
76.	Receptacles / Connectors-Various Voltages A.C. and D.C.	Shutdown System 1	2,H	SD	Combine with 75.	Combine with 75.
77.	Rectifiers-48 Volt D.C	Class III Distribution System	2,H	N/A	Low voltage rectifiers - considered to be	Screened out.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		Class II Distribution System			subject to replacing and screened out.	
		250V DC Class I Power System				
		Emergency Power Supply				
78.	Seals & Sealants	78.1 Containment	2,H	N/A	Seals and sealants considered to be subject to replacements. Screened out on low risk impact as compared to other failure modes. Vacuum Building considered not to be applicable to PLNGS.	N/A
		78.2 VB Emergency Water Tank & Spray				
		78.3 Reactor Building				
		78.4 Relief Duct				
79.	Shut-off Units	Shutdown System 1	2,H	SD	Combine with 75.	Combine with 75.
80.	Solenoid Valves	80.1 Containment	2,H	N/A	For valves inside the Containment, assumed to be covered under the respective system. For valves relevant for Containment integrity and isolation, considered to be covered under categories for Isolation Valves (e.g. under 12).	Addressed under other categories.
		80.2 Shutdown Cooling System		O (Shutdown)	Assume loss of shutdown cooling initiator.	AG80-2: Aging induced loss of shutdown cooling caused by degradation of solenoid valves.
		80.3 Emergency Power Supply		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG80-3: Failure of Emergency Power Supply due to loss of EDG auxiliaries caused by aging induced degradation of solenoid valves.
		80.4 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		80.5 Recirculated Cooling Water		O; SD for standby train.	O: Aging-induced initiator: loss of Recirculation Cooling Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG80-5(O): Loss of Recirculated Cooling Water due to aging-induced degradation of solenoid valves AG80-5(SD): Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of solenoid valves.
81.	Stand Alone Motor Starters-600 V	81.1 Class III Distribution System	2,H	N/A	Considered under specific motor operated equipment groups.	N/A
		81.2 Class II Distribution System				
		81.3 250V DC Class I Power System				
82.	Steam Generators	Primary Heat Transport	2,H	O	Consider two failure modes: 1) Shell side leakage / rupture - map to Main SLB; 2) Tube side leakage / rupture - primary to secondary leak.	AG82(O1): Aging-induced degradation of SG shell side (mapped to MSLB); AG82(O2): Aging-induced SGTR
83.	Structural Concrete-Concrete Dome Exterior Walls Pressure Walls Columns Slabs	83.1 Containment	2,H	SD	Combine with 26.1.	Combine with 26.1.
		83.2 Reactor Building		SD	Combine with 26.2.	Combine with 26.2.
		83.3 VB Emergency Water Tank & Spray		N/A	Vacuum Building considered not applicable for PLNGS.	N/A
		83.4 Emergency Water Supply		SD	Address by a single basic event. Exposure time: based on STI. Assume 3 months.	AG83-4: Failure of EWS due to aging-induced degradation of structural concrete.
		83.5 Emergency Water Supply Intake Structure		SD	Addressed under 83.4.	Addressed under 83.4.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
84.	Switchgear-4.16 kV & 600V	84.1 Emergency Power Supply 84.2 Class III Distribution System 84.3 Class II Distribution System 84.4 250V DC Class I Power System	2,H	N/A	Considered to be addressed under other categories (e.g. circuit breakers etc.) or subject to replacing (e.g. relays). Possible concern regarding the aging of relays may be increased susceptibility (due to aging) to a seismic event, which is out of scope of current study.	Addressed under other categories or screened out.
85.	Tanks	85.1 Boiler Emergency Cooling	2,H	SM	Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG85-1: Unavailability of Boiler Emergency Cooling Tank due to aging induced degradation
		85.2 Containment		N/A	Addressed under respective systems relevant for containment performance.	Addressed under other categories.
		85.3 VB Emergency Water Tank & Spray		N/A	Vacuum Building considered not applicable for PLNGS.	N/A
		85.4 Dousing system		SM	Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG85-4: Unavailability of Dousing System Tank due to aging induced degradation
		85.5 Emergency Coolant Injection		SM	Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG85-5: Unavailability of ECI Tank due to aging induced degradation

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		85.6 Emergency Core Cooling and Recovery		SM	Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG85-6: Unavailability of ECC and Recovery due to aging induced degradation of tank.
		85.7 Emergency Power Supply		SM	Addressed under 28.1.	Addressed under 28.1.
		85.8 Moderator System		N/A	Screen on low risk impact. (Forced shutdown.)	N/A
		85.9 Standby Emergency Generators and Emergency Power Generators		SM	Emergency Power Generators Tanks considered to be addressed under 28.1. Standby Generators Tanks: Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG85-9: Unavailability of Standby Diesel Generators Fuel Tank due to aging induced degradation.
		85.10 Shutdown System 2		O	Addressed under 28.3.	Addressed under 28.3.
		85.11 Poison Injection Tank		O	Addressed under 28.3.	Addressed under 28.3.
86.	Traveling Screens	Emergency Water Supply	2,H	SD	Considered to be of small risk impact as compared to other aging induced degradations in the EWS system. Traveling Screens are subject to maintenance / inspection and associated failure modes (e.g. flow blockage) are slow developing.	N/A
87.	Turbines and its Supports	Turbines	2,H	O	Can be relevant for risk from missiles, which is out of the scope of referential PSA and this study.	Screened out.
88.	Unit Service Transformers	Transformers	2,H	N/A	Considered to be addressed under specific systems.	Considered to be addressed under specific systems.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
89.	UPS Equipment Room	UPS, Class II and I, EPS	2,H	N/A	Considered under specific categories.	N/A
90.	Connections - Anchors, Bolts and Welds	Emergency Water Supply Intake Structure	0,H	SD	Address by a single basic event. Exposure time based on STI. Assume 3 months.	AG90: Failure of EWS due to aging-induced loss of Connections - Equipment Support Anchors, Bolts and Welds
91.	Masonry Walls - Interior Shielding Block Walls	91.1 Containment	0,H	SD	Combined with 26.1.	Combined with 26.1.
		91.2 Reactor Building		SD	Combined with 26.2.	Combined with 26.2.
92.	Miscellaneous Concrete - Trenches, Sumps and Manholes	Emergency Water Supply	0,H	SD	Combined with 83.4.	Combined with 83.4.
93.	Seals & Sealants - Waterstops, Caulking, Expansion Joints, Tank Insulation	94.1 Emergency water Supply	0,H	N/A	Seals and sealants considered to be subject to replacements. Screened out on low risk impact as compared to other failure modes.	N/A
		94.2 Emergency Water Supply Intake Structure				
94.	Structures-Electrical	94.1 Emergency Water Supply	0,H	N/A	Considered to be addressed under specific categories, e.g. cables, transformers, etc.	Addressed under other categories.
		94.2 Instrument Air				
		94.3 Powerhouse Emergency Venting System				
		94.4 Standby Generator				
		94.5 Shutdown System 1				
		94.6 Vacuum Building and FAD Active Drainage				
95.	Tank	Vacuum Building and FAD Active Drainage	0,H	N/A	As under 85.3.	As under 85.3.
96.	Check Valves	Pumphouse Common Systems	1,M	N/A	Screen on low risk impact (Common	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
					Systems).	
97.	Concrete Pads Outside RB Support	Boiler Feedwater System	1,M	O	Assume plant trip due to Loss of FW as an enveloping event.	AG97: Aging induced Loss of FW due to degradation of Concrete Pads outside of RB
98.	Connections - Equipment Support Anchors, Bolts and Welds	HPECI Storage Tank	1,M	SM	Representative single basic event for aging induced unavailability of HPECI Storage Tank due to degradation of different concrete or steel elements (other than tank vessel). Considered to be monitored through the level in the tank. Exposure time based on AOT. Order of several days considered to be conservative.	AG98: Aging-induced unavailability of HPECI Storage Tank due to degradation of different concrete or steel elements (other than tank vessel).
99.	Expansion Joints	99.1 Pumphouse Common Systems	1,M	N/A	Screen on low risk impact. (Common Systems)	N/A
		99.2 Feedwater and Condensate		O	Assume Loss of FW as enveloping event. Single basic event.	AG99-2: Aging-induced Loss of FW due to degradation of Expansion Joints.
100.	Foundations, Concrete - Pile Caps	100.1 Cooling Water Intake and Outfall	1,M	O	Combine with 105.2.	Combine with 105.2.
		100.2 HPECI Storage Tank		SM	Combine with 98.	Combine with 98.
101.	Penetrations-Piping Conduit	HPECI Storage Tank	1,M	SM	Considered to be monitored through the level in the tank. Exposure time based on AOT. Order of several days considered to be conservative.	Combine with 98.
102.	Piping	Pumphouse Common Systems	1,M	N/A	Screen on low risk impact. (Common Systems)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
103.	Pumps	Pumphouse Common Systems	1,M	N/A	Screen on low risk impact. (Common Systems)	N/A
104.	Seals & Sealants	Calandria Vault	1,M	N/A	Seals and sealants considered to be subject to replacements. Screened out on low risk impact as compared to other failure modes.	N/A
105.	Structural Concrete - Concrete Walls and Slabs	105.1 Calandria Vault	1,M	O	Address by single basic event aging-induced degradation of concrete and steel structures / elements of calandria vault. Assume exposure time of the order of several years. Conservative case: remaining life.	AG105-1: Catastrophic structural failure of calandria vault due to aging-induced degradation of concrete or steel elements.
		105.2 Cooling Water Intake and Outfall		O	Assume, conservatively, loss of essential service water initiator, as an enveloping event.	AG105-2: Loss of Raw Service Water caused by aging-induced degradation of Concrete Walls and Slabs
		105.3 HPECI Storage Tank		SM	Combine with 98.	Combine with 98.
106.	Tanks	HPECI Storage Tank	1,M	SM	Degradation leading to leakage considered observable through monitoring of tank level. Exposure time based on AOT. Consider order of several days or one week.	AG106: Unavailability of HPECI Storage Tank due to aging induced degradation
107.	Traveling Screens	Pumphouse Common Systems	1,M	N/A	Screen on low risk impact. (Common Systems)	N/A
108.	Air Operated Valves	108.1 Liquid Zone System	2,M	O	Single basic event representing aging-induced initiator - reactor trip, due to aging caused degradation of air operated valves	AG108-1: Aging induced reactor trip due to loss of power balance caused by degradation of AOVs

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		108.2 Service Water Systems		O; SD for standby train.	O: Aging-induced initiator: loss of Service Water. Separate event (OR-ed to the existing initiator) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG108-2(O): Loss of Service Water due to aging-induced degradation of air operated valves. AG108-2(SD): Failure of standby Service Water train on demand due to aging-induced degradation of air operated valves.
		108.3 Boiler Feedwater System		O	O: single basic event representing aging-induced initiator (Loss of FW) (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG108-3: Aging induced Loss of FW due to degradation of AOVs (including external leakage).
		108.4 Common Water System		N/A	Either screened out on low risk impact (common non-safety systems) or addressed specifically (e.g. safety service water systems).	N/A
109.	Assemblies - Calandria Vessel	Calandria Relief Duct	2,M	SD	"Duct" assumed to be related to normal operation. Screened out.	Screened out.
110.	Breakers-600V	Breathing Air	2,M	SD	Considered to relate to MCR habitability. Screened out on assumed low risk impact in comparison to other failure modes.	N/A
111.	Cable - 4.16 kV, 600V, 125V, 250V - Power Cables	111.1 Annulus Gas	2,M	SM	Screened out on low risk impact. Assumed that indications of system degradation (e.g. loss of pressure) would be observed during normal operation.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		111.2 Boiler Steam and Water		O	O: single basic event representing aging-induced initiator on the steam side (closure of MSIV taken as representative event) and another for the FW side (Loss of FW) (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG111-2(O1): Aging induced MSIV closure due to degradation of power cables. AG111-2(O2): Aging induced Loss of FW due to degradation of power cables.
		111.3 Breathing Air		SD	Considered to relate to MCR habitability. Screened out on assumed low risk impact in comparison to other failure modes.	N/A
		111.4 Crane and Hoist		N/A	Possible impact on load drop accident. Out of the scope of PSA study.	N/A
		111.5 HPECI Supply and Recirculation		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG111-5: Failure of HPECI Supply and Recirculation due to aging-induced degradation of power cables.
		111.6 Stack Monitoring Screening		N/A	Considered not to be related to CD risk as modeled in PSA.	N/A
		111.7 Reactor Regulating System		O	Reactor trip assumed as an enveloping event.	AG111-7: Aging induced reactor trip due to degradation of reactor regulating system cables
		111.8 Feedwater and Condensate		O	Combine with 111.2 - Loss of FW	Combine with 111.2 - Loss of FW

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
112.	Cable Connectors	Safety System Programmable Digital Comparator Computers SDS1, SDS2	2,M	O	Plant trip assumed as enveloping event. Loss of power to computers should produce a fail-safe mode.	AG112: Plant trip due to aging-induced degradation of cable connectors for SDS1/2 computers
113.	Cable Trays	Cables, Conduits and Cable Trays	2,M	N/A	Screened out on assumed low risk impact. Risk impact considered much lower and inspection implementability much higher than for cables.	N/A
114.	Cables	114.1 Common Water Supply	2,M	N/A	Either screened out on low risk impact (common non-safety systems) or addressed specifically (e.g. safety service water systems).	N/A
		114.2 Service Water Systems		O; SD for standby train.	O: Aging-induced initiator: loss of operating Service Water train. Separate event (OR-ed to the existing) or edited existing initiator. Disable recovery in the PSA model. SD: loss of standby train on demand. Exposure time based on train cycling. Assume 3 months.	AG114-2(O): Loss of operating Service Water train due to aging-induced degradation of cabling. AG114-2(SD): Failure of standby Service Water train on demand due to aging-induced degradation of cabling.
		114.3 Site Electrical System		N/A	This is understood to be Plant Lighting System. Considered not directly related to CD risk, although it can have an impact on operators and plant response. Note that cabling degradation in electrical power supply and distribution for safety and operation systems (Class III, etc.) are addressed separately.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		114.4 Condenser Cooling Water (CCW) System		O	Plant trip assumed as enveloping event.	AG114-4: Plant trip due to a loss of Condenser Cooling Water, caused by aging degradation of cables
		114.5 Shield Cooling System		O	Screened out on low risk impact.	N/A
		114.6 Post Accident Monitoring		N/A	Not related to CD risk. Possible impact on SAMG strategies implementation, but considered to be of lower importance for release risk as compared to other failure modes. Also, questionable to which extent SAMGs are represented in the PSA model.	N/A
		114.7 Drains & Waste		N/A	Considered not to be related to CD risk. (System relevant for normal plant operation.)	N/A
		114.8 Liquid Zone System		O	Single basic event representing aging-induced initiator - reactor trip, due to aging caused degradation of cables	AG114-8: Aging induced reactor trip due to loss of power balance caused by degradation of cables in Liquid Zone System.
		114.9 Reactor Regulating System		O	Reactor trip assumed as enveloping event.	AG114-4: Reactor trip due to aging caused degradation of (control) cables in reactor regulating system.
		114.10 Feedwater and Condensate		O	O: single basic event representing aging-induced Loss of FW (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG114-10: Aging induced Loss of FW due to degradation of (control) cables.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		114.11 Powerhouse Ventilation		N/A	Considered to be addressed under HVAC.	N/A
115.	Connectors-Various Voltages A.C. and D.C	RM Deck Receptacles-Connectors	2,M	N/A	Screened out on low risk impact.	Screened out.
116.	Cooling Fans	Safety System Programmable Digital Comparator Computers SDS1, SDS2	2,M	O	Plant trip assumed as enveloping event. Failure of Cooling Fans for SDS1/2 Computers would be annunciated / alarmed, resulting in plant shutdown.	AG116: Plant trip due to aging-induced loss of Colling Fans for SDS1/2 computers
117.	Cranes & Hoists	Cranes & Hoists	2,M	N/A	Possible impact on load drop accident. Out of the scope of PSA study.	N/A
118.	Cyclone Separators	Service Water Systems	2,M	N/A	Considered to have low risk impact as compared to other aging failure modes of Service Water Systems. Screened out.	Screened out.
119.	DG/DAC Chasis	Safety System Programmable Digital Comparator Computers SDS1, SDS2	2,M	N/A	Chasis screened out on low risk impact. It is considered that indication of any relevant degradation would be observed and corrective actions take place.	N/A
120.	Digital Output Transistors	Safety System Programmable Digital Comparator Computers SDS1, SDS2	2,M	N/A	Electronic modules / equipment considered to be subject to replacing.	N/A
121.	Dump Steam ISI welds	Main Steam System	2,M	O	Possible contribution to induced SLB (isolable). Considered to be included under 140.4.	Addressed under other categories
122.	Electrical Motors-4.16 kV	Boiler Feedwater	2,M	N/A	Considered under specific motor operated equipment groups.	N/A
123.	Electrolytic Capacitors	Safety System Programmable Digital Comparator Computers SDS1, SDS2	2,M	N/A	Electronic modules / equipment considered to be subject to replacing.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
124.	Embedded Parts and Supports	Calandria Vault (Calandria Vault-Vault Structure Cooling-Shield Tank)	2,M	O	Combined with 105.1.	Combined with 105.1.
125.	Embedment Ring and End Shield Assemblies	End Shields	2,M	O	Screened out on low risk impact.	N/A
126.	Heat Exchanger	126.1 Deaerator & Storage Tank 126.2 Feedwater and Condensate	2,M	O	Single basic event. Relevant failure mode for safety concerns is external leakage. Loss of FW assumed as enveloping event.	AG126: Aging-induced Loss of FW due to degradation of HXs
127.	Isolation Valves (MOV)	D2O Recovery Condensate System	2,M	N/A	Considered not to be related to CD risk. (System relevant for normal plant operation.)	N/A
128.	Liners - Concrete liner, Epoxies, Vinyl Membrane, Stainless Steel	Irradiation Fuel Bay	2,M	N/A	Out of scope of the study.	Out of scope of the study.
129.	Liners - Steel Liners	Calandria Vault (Vault Structure Cooling Shield Tank)	2,M	O	Combined with 105.1.	Combined with 105.1.
130.	Main Steam Safety valves	Main Steam System	2,M	O	Critical failure mode considered to be stuck open safety valve. Contribution to induced SLB. In calculation of IE frequency, consider frequency of a challenge to open, standby lambda (t) and exposure time, based on the time from last test. Assume order of a year period.	AG130: Aging-induced SLB due to stuck open MS Safety valve caused by aging degradation.
131.	Masonry Wall	131.1 Cooling Water Intake	2,M	O	Combine with 105.2.	Combine with 105.2.
		131.2 Irradiation Fuel Bay		N/A	Out of scope of the study.	Out of scope of the study.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
132.	Metal Clad Switchgear Breakers	Metal Clad Switchgear	2,M	N/A	Considered to be addressed under specific electric systems (Class III, etc.)	Addressed under other categories.
133.	Motor Control Centre (MCC)-600 / 208 V A.C. 125 V D.C.	133.1 Annulus Gas	2,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
		133.2 Boiler Steam and Water				
		133.3 Breathing Air				
		133.4 Common Water				
		133.5 Fuel Transfer System				
		133.6 Powerhouse Ventilation				
		133.7 Service Water				
134.	Motor Operated Valves	134.1 Main Boiler (Main Boiler Feed Pump Discharge)	2,M	O	Combine with 134.4. - Loss of FW	Combine with 134.4. - Loss of FW
		134.2 Boiler Feedwater System		O	Combine with 134.4. - Loss of FW	Combine with 134.4. - Loss of FW
		134.3 HT (HT Pump Discharge & Boiler Inlet Outlet Isolation)		O	Addressed under 61.2.	Addressed under 61.2.
		134.4 Boiler Steam and Water Systems		O	O: single basic event representing aging-induced initiator on the steam side (SLB) and another for the FW side (Loss of FW) (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG134-4(O1): Aging induced SLB due to degradation of MOVs leading to external leakage. AG138-4(O2): Aging induced Loss of FW due to degradation of MOVs (including external leakage).
135.	Motors (4Kv)	135.1 Feedwater and Condensate	2,M	N/A	Considered under specific motor operated equipment groups, where	N/A
		135.2 Main Boiler				

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		135.3 High Pressure Service Water			relevant.	
		135.4 Low Pressure Service Water				
136.	Motors-600 V	Common Water Supply	2,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
137.	Non Return Valves	137.1 Boiler Feedwater System	2,M	O	Address under 138.7.	Address under 138.7.
		137.2 Shield Cooling System		O	As under 138.8.	As under 138.8.
138.	Non-Return or Check Valves	138.1. Fuel Transfer Systems	2,M	O	Relevant for fuel transfer operations. Considered not to be directly related to or have low impact on CD risk. Can be assumed that indications of degradation would be observed during routine fuel transfer operations. Screened out.	Screened out.
		138.2 HPECI Supply & Recirculation		SD	SD is considered to be conservative assumption, since on the supply side of the pumps there would be no pressure transient on demand and any leakage induced by degradation may be observable by the level in the supply tank. Combine this impact with impact under SSC 64.6 (ECI).	Cover under AG64-6: Failure of ECI due to aging induced degradation of check valves.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		138.3 Boiler Steam and Water Systems		O	O: single basic event representing aging-induced initiator on the steam side (SLB) and another for the FW side (Loss of FW) (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG138-3(O1): Aging induced SLB due to degradation of check valves leading to external leakage. AG138-3(O2): Aging induced Loss of FW due to degradation of check valves leading to external leakage
		138.4 Annulus Gas System		SM	Screened out on low risk impact. Assumed that indications of system degradation (e.g. loss of pressure) would be observed during normal operation.	N/A
		138.5 Service Water Systems		O, SD (standby train)	Analogous to 2 (Raw Service Water System). Combine with 2.	Combine with 2 - Raw Service Water System
		138.6 Liquid Zone System		O	Single basic event representing aging-induced initiator - reactor trip, due to aging caused degradation of check valves	AG138-6: Aging induced reactor trip due to loss of power balance caused by degradation of check valves
		138.7 Boiler Feedwater System		O	Combine with 138.3. - Loss of FW	Combine with 138.3. - Loss of FW
		138.8 Shield Cooling System		O	Screened out on low risk impact.	N/A
		138.9 Feedwater and Condensate		O	Combine with 138.3. - Loss of FW	Combine with 138.3. - Loss of FW
139.	Penetrations - Steel Sleeves	Calandria Vault	2,M	O	Combined with 105.1.	Combined with 105.1.
140.	Piping-Piping Components and Supports	140.1 Service Water	2,M	O, SD for standby train.	Analogous to 18.3.	Analogous to 18.3. Basic events 140-1(O) and 140-1(SD).

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		140.2 Shield Cooling System		SM, O	Screen out. Considered to have low significance regarding CD risk.	N/A
		140.3 Main Feedwater System		O	O: single basic event representing aging-induced Loss of FW (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG140-3: Aging induced Loss of FW due to degradation of piping
		140.4 Main Steam System		O	Analogous to 140.3. Aging-induced Steam Line Break.	AG140-4: Aging induced SLB due to degradation of piping.
		140.5 Feedwater and Condensate		O	Risk impact considered to be addressed under 140.3.	Risk impact considered to be addressed under 140.3.
141.	Power Supply	Digital Control Computer	2,M	N/A	Considered to be subject to replacing.	Screened out.
142.	Pressure Relief Valves	Service Water Systems	2,M	SD	Critical failure mode considered to be stuck open. Consider likelihood of a challenge to open upon system actuation on safety signal. Consider standby lambda (t) and exposure time, based on the time from last test. Assume order of a year period. Consider screening out this scenario. Consider CCF, as relevant.	AG142: Failure of Service Water System on demand due to aging-induced degradation of pressure-relief valve(s).
143.	Pumps	143.1 D2O Recovery	2,M	N/A	Considered not to be related to CD risk. (System relevant for normal plant operation.)	N/A
		143.2 HT (HT Pressurizing)		N/A	Screen out on low risk. (Considered that it would result in plant shutdown and prolonged outage.)	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		143.3 HPECI Supply and Recirculation		SD	Address by a single basic event, considering also CCFs. Exposure time: based on STI. Assume 3 months.	AG143-3: Failure of HPECI Supply and Recirculation due to aging-induced degradation of pumps.
		143.4 High Pressure Service Water		N/A	Considered not to be applicable to PLNGS.	N/A
		143.5 Main Feedwater System		O	O: single basic event representing aging-induced Loss of FW (or edit the existing representative BEs). SD is not considered relevant for operating systems. SM is considered to be bounded by O, in this case.	AG143-5: Aging induced Loss of FW due to degradation of pumps.
		143.6 Service Water		O, SD	O: Loss of operating pump (new BE or edit representative BE; depends on the existing PSA model). SD: failure of standby pump. Exposure time based on train cycling. Assume 3 months.	AG143-6(O): Loss of operating Service Water pump, aging-induced. AG143-6(SD): Failure of standby Service Water pump due to aging-induced degradation.
		143.7 Shield Cooling System		O	Screened out on low risk impact.	N/A
144.	Reactivity Control Units	Reactor Regulating System	2,M	O	Reactor trip assumed as enveloping event.	AG144: Reactor trip due to aging caused degradation of Reactivity Control Units.
145.	Seals & Sealants	Calandria Vault (Calandria Vault-Vault Structure Cooling-Shield Tank)	2,M	N/A	Seals and sealants considered to be subject to replacements. Screened out on low risk impact as compared to other failure modes.	N/A
146.	Seismic Monitoring	Post Accident Monitoring	2,M	N/A	Not relevant for the study - out of scope.	Not relevant for the study - out of scope.

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
147.	Stand Alone Motor Starters-600 V	Breathing Air	2,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
148.	Strainer	Boiler Feedwater System	2,M	O	Considered to be of small risk impact as compared to other aging induced degradations in the FW system. Strainer is subject to maintenance / inspection and associated failure modes (e.g. flow blockage) are slow developing. Risk impact considered to be low as compared to, e.g., piping.	Screened out.
149.	Structural Concrete and Steel-Concrete Walls and Slabs; - Structural Steel Beams and Plates	149.1 Calandria Vault Structure	2,M	O	Combined with 105.1.	Combined with 105.1.
		149.2 Intake Structure	2,M	O	Combined with 105.2.	Combined with 105.2.
150.	System Service Transformers (SST)- 230 kV to 4.16 kV	Class IV Distribution System	2,M	O	Loss of offsite power as an enveloping event. Conservative assumption.	AG150: Aging induced LOOP due to degradation of System Service Transformers (230 kV / 4.16 kV)
151.	Transducer	Feedwater and Condensate	2,M	N/A	Electronic modules / equipment considered to be subject to replacing.	Screened out.
152.	Vessels-PV's, Tanks, Drums	152.1 Feedwater and Condensate	2,M	O	Loss of FW as an enveloping event. Conservative assumption.	AG152-1: Aging induced Loss of FW due to degradation of tanks.
		152.2 Shield Cooling System		O	Screened out on low risk impact.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
		152.3 Liquid Zone System		O	Single basic event representing aging-induced initiator - reactor trip, due to aging caused degradation of pressure vessels / tanks	AG152-3: Aging induced reactor trip due to loss of power balance caused by degradation of pressure vessels / tanks in Liquid Zone System.
153.	Vessels-Heat Exchangers	153.1 Annulus Gas	2,M	SM	Screened out on low risk impact. Assumed that indications of system degradation (e.g. loss of pressure) would be observed during normal operation.	N/A
		153.2 Shield Cooling System		O	Screened out on low risk impact.	N/A
154.	Breakers(MCCB)-120/208	Fuel Transfer System	0,M	O	Screened out. See 163.	Screened out.
155.	Cable Penetrations - Various Voltages	Stack Monitoring Screening	0,M	N/A	Considered not to be related to CD risk as modeled in PSA.	N/A
156.	Disconnect Switches	Common Water Supply	0,M	N/A	Either screened out on low risk impact (common non-safety systems) or addressed specifically (e.g. safety service water systems).	N/A
157.	Heaters-600/208/120 Volt A.C.	157.1 Common Water Supply	0,M	N/A	Either screened out on low risk impact (common non-safety systems) or addressed specifically (e.g. safety service water systems).	N/A
		157.2 Feedwater and Condensate System		N/A	Considered not to be related to CD risk. Equipment relevant for normal plant operation. Degradation is considered to produce forced or prolonged normal shutdown.	N/A
		157.3 Stack Monitoring Screening		N/A	Considered not to be related to CD risk	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
					as modeled in PSA.	
158.	Masonry Walls - Interior Shielding Block Walls	Irradiation Fuel bay	0,M	N/A	Possibly related to spent fuel risk. Out of scope.	N/A
159.	Motors-120/208 V	159.1 Fuel Transfer System	0,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
		159.2 Feedwater and Condensate				
		159.3 Powerhouse Ventilation				
160.	Motors-600 V	160.1 Breathing Air	0,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
		160.2 Fuel Transfer System				
		160.3 Powerhouse Ventilation				
161.	Power Transformers - 600 Volts Secondary and less-4.16 kV to 600V; 600Vto 120/208V	Common Water Supply	0,M	N/A	Either screened out on low risk impact (common non-safety systems) or addressed specifically (e.g. safety service water systems).	N/A
162.	Receptacles / Connectors-Various Voltages A.C. and D.C.	162.1 DCC	0,M	N/A	Considered to be addressed under respective systems.	Addressed under other categories.
		162.2 Fuel Transfer System		O	Screened out. See 163.	Screened out.
163.	Resistors-Various Wattages	Fuel Transfer System	0,M	O	Relevant for fuel transfer operations. Considered not to be directly related to or have low impact on CD risk. Can be assumed that indications of degradation would be observed during routine fuel transfer operations. Screened out.	Screened out.
164.	Seals & Sealants - Waterstops, Caulking, Expansion Joints, Tank Insulation	HPECI Storage Tank	0,M	N/A	Seals and sealants considered to be subject to replacements. Screened out on low risk impact as compared to other failure modes.	N/A

#	Components	System/Subsystem	APSA Ranking	Aging Risk Impact	PSA Modeling	Basic event / Failure mode Cases
165.	Motors-120/208 V	165.1 Moderator System	0,M	N/A	Considered under specific motor operated equipment groups, where relevant.	N/A
		165.2 Feedwater Condensate				

The initial SSC characterization from Table 3-1 was used to establish the inventory of required representative basic events (either new ones or existing ones to be edited) for aging-induced impacts. These required basic events were further characterized, as shown in Table 3-2, in the following terms (table's columns):

System / Subsystem	System or subsystem from Table 3-1 to which representative aging-related basic event applies.
Components / Structures	This entry relates to the components from Table 3-1 which are to be represented by the aging-related basic event. (Note that some of those components from Table 3-1 are better described by the term "structure". Those are specifically characterized in terms of: Description: How the component is described in Table 3-1, e.g. "Motor Operated Valve", "Structural Concrete - Concrete Walls and Slabs" etc. Category: Specifically, a SSC category from Table 3-1, as identified by its corresponding number. E.g., category 18.3 specifically relates to the piping in the Raw Service Water system.
Basic Event (BE) Type	To which of the three categories of aging-induced scenarios the considered basic event relates: O, SD or SM. Basic event can only be related to one of the categories. Note that this category determines how the probability (or frequency) associated with basic event is to be established / calculated.
Basic Event (BE) Case	Specifically refers to the required case from Table 3-1. Note, that, several cases from Table 3-1 can be grouped and addressed by a single representative basic event.
BE Description	Description of the basic event, established from the corresponding case from Table 3-1.
Aging Failure Acceleration Case	Identification of aging failure acceleration parameter (*a*, expressed in /hr./yr.) associated with aging failure rate model, which needs to be established. Regarding aging failure rate model, refer to section 2.4.

For example, the first row of the table specifies that aging failure acceleration parameter *a* will have to be established for the SSC category "Bolts - Connections".

AM Effectiveness

Provides available information for establishing the Aging Management (AM) effectiveness input to be incorporated into aging failure rate model. General increase of aging failure rate with time is dependent on this input.

"M" relates to the scheme for AM Effectiveness from Phase 1 report: "3 for fully effective, 2 for partially effective, 1 for not effective, and a 0 is assigned if no information is available." This is primary information.

Additionally, "P" term is given as an indication. It represents a product of two probabilities given, for considered category of SSC, in the TIRGALEX study:

$$P = P_D \, P_{R|D}$$

Here, P_D represents the probability of successful aging detection and $P_{R|D}$ the probability of successful aging mitigation. Together, they are taken as an indication for the AM effectiveness. With "P" term, under the parentheses, given is a designator of SSC category from the TIRGALEX.

Exposure Time

Exposure time necessary to estimate the aging-related failure probability associated with basic event type SD or SM. Usually, based on the STI (for SD type) or AOT (for SM type). Not applicable to a basic event of type O.

Table 3-2: Inventory of required representative aging-related basic events

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Auxiliary Boiler Feedwater and Condensate	Air Operated Valves	31.2;	SD	AG31.2	Failure of AFW due to aging-induced degradation of AOVs.	AOV	M = 1; P(18a) = 0.45	Based on STI.
Auxiliary Boiler Feedwater and Condensate	Motor Operated Valves	61.5;	SD	AG61.5	Failure of AFW due to aging-induced degradation of MOVs.	MOV	M = 2; P(18e) = 0.63	Based on STI for ECI.
Auxiliary Boiler Feedwater and Condensate	Non-Return or Check Valves	64.2;	SD	AG64-2	Failure of AFW due to aging-induced degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	Based on STI.
Auxiliary Boiler Feedwater and Condensate	Pumps	74-6;	SD	AG74-6	Failure of AFW due to aging-induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI.
Boiler Blowoff System	Air Operated Valves	31.7;	O	AG31-7	Transient caused by failure of Boiler Blowoff System due to aging-induced degradation of air operated valves.	AOV	M = 2; P(18a) = 0.45	N/A
Blowoff System	Check Valves	64.12;	O	AG64-12	Transient caused by failure of Boiler Blowoff System due to aging-induced degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Blowoff System	Piping	65.8;	O	AG65-8	Transient caused by failure of Boiler Blowoff System due to aging-induced degradation of piping	Piping	M = 2; P(5) = 0.09	N/A
Boiler Emergency Cooling	Instrument Air Valves	11;	SD	AG11	Failure of Boiler Emergency Cooling due to aging-induced degradation of Instrument Air Valves.	AOV	M = 1; P(18a) = 0.45	Based on STI.
Boiler Emergency Cooling	Check Valves	64.11;	SD	AG64-11	Failure of Boiler Emergency Cooling due to aging-induced degradation of Check Valves.	Check Valve	M = 2; P(18b) = 0.09	Based on STI.
Boiler Emergency Cooling	Piping	65.12;	SD	AG65-12	Failure of Boiler Emergency Cooling due to aging-induced degradation of piping	Piping	M = 2; P(5) = 0.09	Based on STI.
Boiler Emergency Cooling	Tanks	85.1;	SM	AG85-1	Unavailability of Boiler Emergency Cooling tanks due to aging-induced degradation	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for Boiler Emergency Cooling tanks.
Boiler Feedwater System	Concrete Pads Outside RB Support	97;	O	AG97	Aging induced Loss of FW due to degradation of Concrete Pads outside of RB	Other Concrete	M = 1; P(3) = 0.05	N/A
Boiler Feedwater System	Air Operated Valves	108.3;	O	AG108-3	Aging induced Loss of FW due to degradation of AOVs (including external leakage).	AOV	M = 2; P(18a) = 0.45	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Boiler Feedwater System	Cable - 4.16 kV, 600V, 125V, 250V - Power Cables	111.2; 111.8;	O	AG111-2(O2)	Aging induced Loss of FW due to degradation of power cables.	Cables	M = 2; P(10a) = 0.09	N/A
Boiler Feedwater System	Motor Operated Valves	134.4; 134.1; 134.2;	O	AG134-4(O2)	Aging induced Loss of FW due to degradation of MOVs (including external leakage).	MOV	M = 2; P(18e) = 0.63	N/A
Boiler Feedwater System	Check Valves	138.3; 138.7; 137.1; 138.9;	O	AG138-3(O2)	Aging induced Loss of FW due to degradation of check valves leading to external leakage.	Check Valve	M = 2; P(18b) = 0.09	N/A
Boiler Feedwater System	Expansion Joints	99.2;	O	AG99-2	Aging-induced Loss of FW due to degradation of Expansion Joints.	Expansion Joints	M = 1; P(5) = 0.09	N/A
Boiler Feedwater System	Cables	114.10;	O	AG114-10	Aging induced Loss of FW due to degradation of (control) cables.	Cables	M = 2; P(10a) = 0.09	N/A
Boiler Feedwater System	Heat Exchanger	126.2; 126.1;	O	AG126-2	Aging induced Loss of FW due to degradation of HXs	Heat Exchanger	M = 2; P(22) = 0.09	N/A
Boiler Feedwater System	Piping-Piping Components and Supports	140.3; 140.5;	O	AG140-3	Aging induced Loss of FW due to degradation of piping	Piping	M = 2; P(5) = 0.09	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Boiler Feedwater System	Pumps	143.5;	O	AG143-5	Aging induced Loss of FW due to degradation of pumps	Pump	M = 2; P(19a) = 0.63	N/A
Boiler Feedwater System	Vessels-PV's, Tanks, Drums	152.1;	O	AG152-1	Aging induced Loss of FW due to degradation of tanks	Tanks - Atmospheric	M = 2; P(29b) = 0.07	N/A
Boiler Level Control	Air Operated Valves	31.3;	O	AG31-3	Loss of MFW Due to aging induced loss of Boiler level control caused by degradation of AOVs (possible unavailability of Emergency Feedwater due to loss of control)	AOV	M = 2; P(18a) = 0.45	N/A
Boiler Level Control	Motor Operated Valves	61.1;	O	AG61.1	Loss of MFW Due to aging induced loss of Boiler level control caused by degradation of MOVs (possible unavailability of Emergency Feedwater due to loss of control)	MOV	M = 2; P(18e) = 0.63	N/A
Boiler Steam (Main Steam) System	Cable - 4.16 kV, 600V, 125V, 250V - Power Cables	111.2;	O	AG111-2(O1)	Aging induced MSIV closure due to degradation of power cables.	Cables	M = 2; P(10a) = 0.09	N/A
Boiler Steam (Main Steam) System	Motor Operated Valves	134.4;	O	AG134-4(O1)	Aging induced SLB due to degradation of MOVs leading to external leakage.	MOV	M = 2; P(18e) = 0.63	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Boiler Steam (Main Steam) System	Check Valves	138.3;	O	AG138-3(O1)	Aging induced SLB due to degradation of check valves leading to external leakage.	Check Valve	M = 2; P(18b) = 0.09	N/A
Boiler Steam (Main Steam) System	Piping-Piping Components and Supports	140.4;	O	AG140-4	Aging induced SLB due to degradation of piping	Piping	M = 2; P(5) = 0.09	N/A
Boiler Steam (Main Steam) System	Main Steam Safety valves	130;	O	AG130	Aging-induced SLB due to stuck open MS Safety valve caused by aging degradation.	Relief Valve	M = 2; P(18f) = 0.81	Based on the time from last test of pressure relief valve. Assume order of one year period. (To be applied for conditional probability to stick open given a challenge.)
Calandria Vault	Structural Concrete - Concrete Walls and Slabs; Embedded Parts and Supports; Liners - Steel Liners; Penetrations - Steel Sleeves; Structural Concrete and Steel-Concrete Walls and Slabs; - Structural Steel Beams and Plates	105.1; 124; 129; 139; 149.1;	O	AG105-1	Catastrophic structural failure of calandria vault due to aging-induced degradation of concrete or steel elements.	Calandria Vault	M = 1; P(2b) = 0.05; P(3) = 0.05	Assume exposure time of the order of several years.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Class I Power	Air Conditioning Units	30;	SD	AG30(SD1)	Failure of AHUs for Class I Power on demand (safety signal) due to aging-induced degradation	AHU	M = 2; P(24b) = 0.63	Based on STI for response of Class I to safety signal.
Class I Power (250V DC Class I Power System)	Breakers	36.3; 35.3;	O	AG36-3(O)	Aging-induced loss of 250 V DC Class I Power System during normal operation due to degradation of breakers.	CB	M = 2; P(17b) = 0.45	N/A
			SD	AG36-3(SD)	Failure of 250 V DC Class I Power System on demand (safety signal) due to aging-induced degradation of breakers.			Based on STI for response of Class I to safety signal.
Class I Power (250V DC Class I Power System)	Cables	37.4;	O	AG37-4(O)	Aging-induced loss of 250 V DC Class I Power System during normal operation due to degradation of cables.	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-4(SD)	Failure of 250 V DC Class I Power System on demand (safety signal) due to aging-induced degradation of cables.			Based on STI for response of Class I to safety signal.
Class I Power	Class I Batteries	42;	SD	AG42	Failure of Class I Batteries on demand due to aging degradation	Battery	M = 2; P(25) = 0.81	Based on STI for response of Class I to safety signal.
Class I Power (250V DC Class I Power System)	Busses and Disconnect Switches	49;	O	AG49(O1)	Aging-induced loss of 250 V DC Class I Power System during normal operation due to degradation of buses	Bus	M = 2; P(30a,b) = 0.45	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
			SD	AG49(SD1)	Failure of 250 V DC Class I Power System on demand (safety signal) due to aging-induced degradation of buses			Based on STI for response of Class I to safety signal.
Class I Power	Class I 250 VDC Rectifier	39;	O	AG39(O)	Loss of Class I 250 VDC during normal operation due to aging induced degradation of rectifier.	Rectifier	M = 2; P(26c) = 0.45	N/A
			SD	AG39(SD)	Failure of Class I 250 VDC Rectifiers due to aging degradation			Based on STI for response of Class I to safety signal.
Class II Power	Air Conditioning Units	30;	SD	AG30(SD2)	Failure of AHUs for Class II Power on demand (safety signal) due to aging-induced degradation	AHU	M = 2; P(24b) = 0.63	Based on STI for response of Class I to safety signal.
Class II Power (Class II Distribution System)	Breakers	36.2; 35.2;	O	AG36-2(O)	Aging-induced loss of Class II Distribution System during normal operation due to degradation of breakers.	CB	M = 2; P(17b) = 0.45	N/A
			SD	AG36-2(SD)	Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of breakers.			Based on STI for response of Class II to safety signal.
Class II Power (Class II Distribution System)	Cables	37.3;	O	AG37-3(O)	Aging-induced loss of Class II Distribution System during normal operation due to degradation of cables.	Cables	M = 2; P(10a) = 0.09	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
			SD	AG37-3(SD)	Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of cables.			Based on STI for response of Class II to safety signal.
Class II Power	Class II 600 VAC Inverters	41; 59;	O	AG41(O)	Loss of Class II 600 VAC inverters during normal operation due to aging induced degradation.	Inverter	M = 2; P(26b) = 0.45	N/A
			SD	AG41(SD)	Failure of Class II 600 VAC Inverters on demand (safety signal) due to aging degradation			Based on STI for response of Class II to safety signal.
Class II Power	Class II 120 VAC Inverters	43; 59;	O	AG43(O)	Loss of Class II 120 VAC inverters during normal operation due to aging induced degradation.	Inverter	M = 2; P(26b) = 0.45	N/A
			SD	AG43(SD)	Failure of Class II 120 VAC Inverters on demand (safety signal) due to aging degradation			Based on STI for response of Class II to safety signal.
Class II Power (Class II Distribution System)	Dry-type Power Transformers Regulating 9kVA 4.16kV600V	46.2;	O	AG46-2(O)	Aging-induced loss of Class II Distribution System during normal operation due to degradation of power transformers.	Transformer	M = 2; P(27) = 0.63	N/A
			SD	AG46-2(SD)	Failure of Class II Distribution System on demand (safety signal) due to aging-induced degradation of power			Based on STI for response of Class II to safety signal.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
					transformers.			
Class II Power	Busses and Disconnect Switches	49;	O	AG49(O2)	Aging-induced loss of Class II Power System during normal operation due to degradation of buses	Bus	M = 2; P(30a,b) = 0.45	N/A
			SD	AG49(SD2)	Failure of Class II Power System on demand (safety signal) due to aging-induced degradation of buses			Based on STI for response of Class II to safety signal.
Class III Distribution System	Breakers	36.1; 35.1;	O	AG36-1(O)	Aging-induced loss of Class III Distribution System during normal operation due to degradation of breakers.	CB	M = 2; P(17b) = 0.45	N/A
			SD	AG36-1(SD)	Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of breakers.			Based on STI for response of Class III to safety signal.
Class III Distribution System	Cables	37.2;	O	AG37-2(O)	Aging-induced loss of Class III Distribution System during normal operation due to degradation of cables.	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-2(SD)	Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of cables.			Based on STI for response of Class III to safety signal.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	**Category**						
Class III Distribution System	Dry-type Power Transformers Regulating 9kVA 4.16kV600V	46.1;	O	AG46-1O)	Aging-induced loss of Class III Distribution System during normal operation due to degradation of power transformers.	Transformer	M = 2; P(27) = 0.63	N/A
			SD	AG46-1(SD)	Failure of Class III Distribution System on demand (safety signal) due to aging-induced degradation of power transformers.			Based on STI for response of Class III to safety signal.
Class III Distribution System	Busses and Disconnect Switches	49;	O	AG49(O3)	Aging-induced loss of Class III Power System during normal operation due to degradation of buses	Bus	M = 2; P(30a,b) = 0.45	N/A
			SD	AG49(SD3)	Failure of Class III Power System on demand (safety signal) due to aging-induced degradation of buses			Based on STI for response of Class III to safety signal.
Class IV Power	Busses and Disconnect Switches	49;	O	AG49(O4)	Aging-induced loss of Class IV Power System during normal operation due to degradation of buses	Bus	M = 2; P(30a,b) = 0.45	N/A
			SD	AG49(SD4)	Failure of Class IV Power System on demand (safety signal) due to aging-induced degradation of buses			Based on STI for response of Class IV to safety signal.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Class IV Power (Class IV Distribution System)	System Service Transformers (SST)- 230 kV to 4.16 kV	150;	O	AG150(SD)	Aging induced LOOP due to degradation of System Service Transformers (230 kV / 4.16 kV)	Transformer	M = 2; P(27) = 0.63	N/A
Condenser Cooling Water (CCW) System	Cables	114.4;	O	AG114.4	Plant trip due to loss of Condenser Cooling Water caused by aging-induced degradation of cables	Cables	M = 2; P(10a) = 0.09	N/A
Containment	Bearing Plates; Connections - Equipment Support Anchors, Bolts and Welds	1.1; 5.1; 5.2	SD	AG1-1; AG5	Failure of Containment integrity on demand by aging-induced degradation of bearing plates, support anchors, bolts or other connections	Bolts - Connections	M = 1; P(snubbers) =0.81; P(bolts) = 0.45	Between Cont. Leak Tests. Assume order of several years.
Containment	Foundations (Concrete and Steel)	10.1; 10.2	SD	AG10(G1)	Failure of containment integrity due to aging-induced degradation of foundations (concrete and steel) in Containment / RB.	Containment - Foundations	M = 1; P(2b Cont.) =0.05; P(3 Oth. Str.) = 0.05	Conservatively consider remaining life.
Containment	Isolation Valves	12.1; 12.2; 64.8	SD	AG12	Failure of Containment isolation due to aging-induced degradation of Isolation Valves.	Containment Isolation Valves	M = 1; P(MOV) = 0.63; P(AOV) = 0.45; P(Check V.) = 0.09	Based on STI.
Containment	Liners - Steel; Pre-Stressed Steel - Tendons, Cable and Rods; Structural Steel - Structural Steel Beams, Columns, Plates; Pre-Stressed Steel	15.1; 15.2; 22.1; 27.1 ; 27.2; 72.1	SD	AG15; AG22-1	Failure of containment integrity on demand due to aging-induced degradation of various steel elements and structures	Containment - Steel	M = 1; P(2b Cont.) =0.05	Based on the Cont. Leak Test period. Assume order of several years.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Containment	Structural Concrete - Concrete Walls and Slabs; Structural Concrete-Concrete Dome Exterior Walls Pressure Walls Columns Slabs; Masonry Walls - Interior Shielding Block Walls	26.1; 83.1; 91.1	SD	AG26-1	Failure of containment integrity on demand due to aging-induced degradation of various concrete elements and structures	Containment - Concrete	M = 1-2; P(2b Cont.) =0.05	Based on the Cont. Leak Test period. Assume order of several years.
Containment	Penetrations - Openings for Electrical Cable Trays, Manways, Piping, Equipment, Airlocks	17.1; 17.2; 32	SD	AG17	Loss of containment integrity on demand due to aging-induced degradation of penetrations.	Containment - Penetrations	M = 1; P(10b) = 0.18	Based on the Cont. Leak Test period. Assume order of several years.
Containment	Cables	37.8	SD	AG37-8	Failure of containment isolation due to aging induced degradation of cables	Cables	M = 1; P(10a) = 0.09	Based on STI for containment isolation.
Cooling Water Intake and Discharge	Structural Concrete - Concrete Walls and Slabs; Masonry Wall; Foundations, Concrete - Pile Caps	105.2; 131.1; 100.1; 149.2	O	AG105-2	Loss of Raw Service Water caused by aging-induced degradation of structural concrete	Other Concrete	M = 2; P(3) = 0.05	N/A
Dousing System	Heat Exchanger	55.6;	SD	AG55-6	Failure of Dousing System due to aging induced degradation of HXs.	Heat Exchanger	M = 2; P(22) = 0.09	Based on STI for Dousing System.
Dousing System	Piping	65.1;	SM	AG65-1	Unavailability of Dousing System due to aging induced degradation of piping.	Piping	M = 1; P(5) = 0.09	Based on AOT for Dousing System.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Dousing System	Tank	85.4;	SM	AG85-4	Unavailability of Dousing System Tank due to aging induced degradation	Tanks - Atmospheric	M = 1; P(29b) = 0.07	Based on AOT for Dousing System.
Emergency Coolant Injection	Air Operated Valves	31.4; 31.8;	SD	AG31-4	Failure of ECI on demand due to aging-induced degradation of AOVs.	AOV	M = 2; P(18a) = 0.45	Based on STI for ECI.
Emergency Coolant Injection	Cables	37.1;	SD	AG37-1	Failure of ECI on demand due to aging-induced degradation of cables.	Cables	M = 2; P(10a) = 0.09	Based on STI for ECI.
Emergency Coolant Injection	Motor Operated Valves	61.4;	SD	AG61-4	Failure of ECI on demand due to aging-induced degradation of MOVs.	MOV	M = 2; P(18e) = 0.63	Based on STI for ECI.
Emergency Coolant Injection	Check Valves	64.6; 138.2	SD	AG64-6	Failure of ECI on demand due to aging-induced degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	Based on STI for ECI.
Emergency Coolant Injection	Pumps	74.4;	SD	AG74-4	Failure of ECI on demand due to aging-induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI for ECI.
Emergency Coolant Injection	Tanks	85.5;	SM	AG85-5	Unavailability of ECI Tank due to aging induced degradation	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for ECI.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Emergency Coolant Injection (HP ECI Storage Tank)	Tank	106;	SM	AG106	Unavailability of HPECI Storage Tank due to aging induced degradation	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for HP ECI.
Emergency Coolant Injection (HP ECI Storage Tank)	Connections - Equipment Support Anchors, Bolts and Welds; Foundations, Concrete - Pile Caps; Penetrations-Piping Conduit; Structural Concrete - Concrete Walls and Slabs	98; 100.2; 101; 105.3;	SM	AG98	Aging-induced unavailability of HPECI Storage Tank due to degradation of different concrete or steel elements (other than tank vessel).	Bolts - Connections	M = 1; P(2b) = 0.05; P(3) = 0.05; P(31) = 0.45;	Based on AOT for HP ECI.
Emergency Coolant Injection (HPECI Supply and Recirculation)	Cable - 4.16 kV, 600V, 125V, 250V - Power Cables	111.5;	SD	AG111-5	Failure of HP ECI Supply and Recirculation on demand due to aging-induced degradation of power cables.	Cables	M = 2; P(10a) = 0.09	Based on STI for HP ECI.
Emergency Coolant Injection (HPECI Supply and Recirculation)	Pumps	143.3;	SD	AG143-3	Failure of HP ECI on demand due to aging-induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI for ECI.
Emergency Core Cooling and Recovery	Heat Exchanger	55.7; 55.1;	SD	AG55-7	Failure of ECC due to aging induced degradation of HXs.	Heat Exchanger	M = 2; P(22) = 0.09	Based on STI for ECC.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Emergency Core Cooling and Recovery	Piping	65.2; 24.1;	SD	AG65-2	Failure of ECC due to aging induced degradation of piping.	Piping	M = 2; P(5) = 0.09	Based on STI for ECC.
Emergency Core Cooling and Recovery	Pumps	74.2;	SD	AG74-2	Failure of ECC / Recovery on demand due to aging-induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI for ECI.
Emergency Core Cooling and Recovery	Tanks	85.6;	SM	AG85-6	Unavailability of ECC and Recovery due to aging induced degradation of tank.	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for ECC / Recovery.
Emergency Power Supply	Tanks	28.1; 85.7	SM	AG28-1	Unavailability of Emergency Power Supply Tank due to aging induced degradation	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for Emergency Power Supply.
Emergency Power Supply	Battery-125 V	33;	SD	AG33	Failure of 125 VDC Batteries in EPS due to aging degradation	Battery	M = 2; P(25) = 0.81	Based on STI for EPS..
Emergency Power Supply	Cables	37.12	SD	AG37-12	Failure of Emergency Power Supply due to aging induced degradation of cables.	Cables	M = 2; P(10a) = 0.09	Based on STI for EPS.
Emergency Power Supply	Emergency Power Generators	48; 54.1;	SD	AG48	Failure of Emergency Power Supply due to aging induced degradation of Emergency Diesel Generators.	EDG	M = 2; P(11) = 0.27	Based on STI for EPS.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Emergency Power Supply	Piping	65.5	SD	AG65-5	Failure of Emergency Power Supply due to loss of cooling to EDGs caused by aging induced degradation of piping	Piping	M = 2; P(5) = 0.09	Based on STI for EPS.
Emergency Power Supply	Pumps	74.5;	SD	AG74-5	Failure of Emergency Power Supply due to loss of cooling to EDGs caused by aging induced degradation of pumps	Pump	M = 2; P(19a) = 0.63	Based on STI for EPS.
Emergency Power Supply	Solenoid Valves	80.3;	SD	AG80-3	Failure of Emergency Power Supply due to loss of EDG auxiliaries caused by aging induced degradation of solenoid valves.	Solenoid Valve	M = 2; P(18a) = 0.45	Based on STI for EPS.
Emergency Water Supply	Foundations (Concrete and Steel)	10.6; 10.7; 52;	SD	AG10(G2)	Failure of EWS due to aging-induced degradation of foundations (concrete and steel).	Other Foundations	M = 1; P(2b Cont.) =0.05; P(3 Oth. Str.) = 0.05	Conservatively consider remaining life.
Emergency Water Supply	Piping	18.4; 24.2;	SD	AG18-4	Failure of EWS due to aging-induced degradation of piping	Piping	M = 1; P(5) = 0.09	Based on STI for EWS.
Emergency Water Supply	Tanks	28.2;	SM	AG28-2	Unavailability of Emergency Water Supply Tank due to aging induced degradation	Tanks - Atmospheric	M = 1; P(29b) = 0.07	Based on AOT for Emergency Water Supply.
Emergency Water Supply	Cables	37.11;	SD	AG37-11	Failure of Emergency Water Supply due to aging induced degradation of cables.	Cables	M = 2; P(10a) = 0.09	Based on STI for EWS.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Emergency Water Supply	Motor Operated Valves	61.3;	SD	AG61-3	Failure of Emergency Water Supply on demand due to aging-induced degradation of MOVs.	MOV	M = 2; P(18e) = 0.63	Based on STI for EWS.
Emergency Water Supply	Check Valves	64.10;	SD	AG64-10	Failure of Emergency Water Supply on demand due to aging-induced degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	Based on STI for EWS.
Emergency Water Supply	Power Transformers	69;	SD	AG69	Failure of Emergency Water Supply on demand due to aging-induced degradation of power transformers.	Transformer	M = 2; P(27) = 0.63	Based on STI for EWS.
Emergency Water Supply	Pumps	74.7;	SD	AG74-7	Failure of Emergency Water Supply due to aging induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI for EWS.
Emergency Water Supply	Structural Concrete	83-4; 83-5; 92	SD	AG83-4	Failure of Emergency Water Supply due to aging induced degradation of structural concrete	Other Concrete	M = 2; P(3) = 0.05	Based on STI for EWS.
Emergency Water Supply	Connections - Anchors, Bolts and Welds	90;	SD	AG90	Failure of Emergency Water Supply due to aging induced degradation of Connections - Anchors, Bolts and Welds	Bolts - Connections	M = 0; P(snubbers) =0.81; P(bolts) = 0.45	Based on STI for EWS.
HVAC / Chilled Water System	Pumps (Chilled Water)	74.8;	SD	AG74-8	Failure of HVAC due to aging-induced degradation of Chilled Water System pumps	Pump	M = 2; P(19a) = 0.63	Based on STI for HVAC / Chilled Water.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Instrument Air	Air Operated Valves	31-10;	O	AG31-10(O)	Aging induced transient during normal operation due to degradation of air operated valves in Instrument Air system. (Plant trip)	AOV	M = 2; P(18a) = 0.45	N/A
			SD	AG31-10(SD)	AG31-10(SD): Failure of Instrument Air on demand due to aging induced degradation of air operated valves.			Based on STI or maintenance practices / compressor cycling practices.
Instrument Air	Cables	37.13;	O	AG37-13(O)	Aging induced transient during normal operation due to degradation of cables in Instrument Air system. (Plant trip)	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-13(SD)	AG31-10(SD): Failure of Instrument Air on demand due to aging induced degradation of cables.			Based on STI or maintenance practices / compressor cycling practices.
Instrument Air	Check valves	64.3;	O	AG64-3(O)	Aging induced transient during normal operation due to degradation of check valves in Instrument Air system. (Plant trip)	Check Valve	M = 2; P(18b) = 0.09	N/A
			SD	AG64-3(SD)	AG31-10(SD): Failure of Instrument Air on demand due to aging induced degradation of check valves.			Based on STI or maintenance practices / compressor cycling practices.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Liquid Zone System	Air Operated Valves	108.1;	O	AG108-1	Aging induced reactor trip due to loss of power balance caused by degradation of AOVs	AOV	M = 2; P(18a) = 0.45	N/A
Liquid Zone System	Cables	114.8;	O	AG114-8	Aging induced reactor trip due to loss of power balance caused by degradation of cables in Liquid Zone System.	Cables	M = 2; P(10a) = 0.09	N/A
Liquid Zone System	Check Valves	138.6;	O	AG138-6	Aging induced reactor trip due to loss of power balance caused by degradation of check valves	Check Valve	M = 2; P(18b) = 0.09	N/A
Liquid Zone System	Vessels-PV's, Tanks, Drums	152.3;	O	AG152-3	Aging induced reactor trip due to loss of power balance caused by degradation of pressure vessels / tanks in Liquid Zone System.	Tanks - High Pressure	M = 2; P(29b) = 0.07	N/A
Primary Heat Transport	Air Operated Valves	31.5;	O	AG31-5	Aging induced external LOCA due to degradation of AOVs in PHT	AOV	M = 2; P(18a) = 0.45	N/A
Primary Heat Transport	Cables	37.14;	O	AG37-14	Aging induced reactor trip due to degradation of cabling in PHT system.	Cables	M = 2; P(10a) = 0.09	N/A
Primary Heat Transport	Feeders	51;	O	AG51	Aging-induced ex-core LOCA due to degradation of PHT feeders.	PHT Feeders	M = 2; P(4c) = 0.18	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Primary Heat Transport	Fuel Channels	53;	O	AG53	Aging-induced in-core LOCA due to degradation of fuel channels.	PHT Fuel Channels	M = 2; P(1) = 0.09; P(4c) = 0.18	N/A
Primary Heat Transport	Pressure Tubes	71;	O	AG71	Aging-induced in-core LOCA due to degradation of pressure tubes.	PHT Pressure Tubes	M = 2; P(1) = 0.09; P(4c) = 0.18	N/A
Primary Heat Transport	Motor Operated Valves	61.2; 134.3;	O	AG61-2	Aging induced external LOCA due to degradation of MOVs in PHT	MOV	M = 2; P(18e) = 0.63	N/A
Primary Heat Transport	Check Valves	64.5; 64.9;	O	AG64-5	Aging induced external LOCA due to degradation of check valves in PHT system.	Check Valve	M = 2; P(18b) = 0.09	N/A
Primary Heat Transport	Piping	65.4; 65.10; 66.1	O	AG65-4	Aging induced external LOCA due to degradation of piping in PHT system.	Piping	M = 2; P(5) = 0.09	N/A
Primary Heat Transport	Pressure Relief Valves	70.1;	O	AG70-1	Aging-induced external LOCA due to stuck open pressure relief valve caused by aging degradation.	Relief Valve	M = 2; P(18f) = 0.81	Based on the time from last test of pressure relief valve. Assume order of one year period. (To be applied for conditional probability to stick open given a challenge.)

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Primary Heat Transport	Pumps	74.3;	O	AG74-3	Plant trip due to aging-induced failure of PHT pumps.	Pump	M = 2; P(19a) = 0.63	N/A
Primary Heat Transport	Steam Generators	82;	O	AG82(O1)	Aging-induced degradation of SG shell side (mapped to MSLB)	SG Shell Side	M = 2; P(6b) not provided.	N/A
Primary Heat Transport	Steam Generators	82;	O	AG82(O2)	Aging-induced SGTR	SG Tube Side	M = 2; P(6a) = 0.25	N/A
Raw Service Water	Check valves	2;	O	AG2(O)	Loss of Raw Service Water due to aging-induced degradation of check valves	Check Valve	M = 1; P(18b) = 0.09	N/A
			SD	AG2(SD)	Failure of standby Raw Service Water train on demand due to aging-induced degradation of check valves			Based on train cycling (operating - standby).
Raw Service Water	Expansion Joints	8;	O	AG8(O)	Loss of Raw Service Water due to aging-induced degradation of expansion joints	Expansion Joints	M = 1; P(5) = 0.09	N/A
			SD	AG8(SD)	Failure of standby Raw Service Water train on demand due to aging-induced degradation of expansion joints			Based on train cycling (operating - standby).

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Raw Service Water	Motor Operated Valves	16;	O	AG16(O)	Loss of Raw Service Water due to aging-induced degradation of MOVs	MOV	M = 1; P(18e) = 0.63	N/A
			SD	AG16(SD)	Failure of standby Raw Service Water train on demand due to aging-induced degradation of MOVs			Based on train cycling (operating - standby).
Raw Service Water	Piping	18.3;	O	AG18-3(O)	Loss of Raw Service Water due to aging-induced degradation of piping	Piping	M = 1; P(5) = 0.09	N/A
			SD	AG18-3(SD)	Failure of standby Raw Service Water train on demand due to aging-induced degradation of piping			Based on train cycling (operating - standby).
Raw Service Water	Pumps	23;	O	AG23(O)	Loss of Raw Service Water operating train due to aging-induced degradation of pumps (Note: probability can be applied to account for the failure of other train's pump to map it to the total loss of the system, in order to simplify.)	Pump	M = 1; P(19a) = 0.63	N/A
			SD	AG23(SD)	Failure of standby Raw Service Water train on demand due to aging-induced degradation of pumps			Based on train cycling (operating - standby).

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Reactor Building	Structural Concrete - Concrete Walls and Slabs; Structural Concrete-Concrete Dome Exterior Walls Pressure Walls Columns Slabs; Masonry Walls - Interior Shielding Block Walls	26.2; 83.2; 91.2	SD	AG26-2	Failure of RB integrity on demand due to aging-induced degradation of various concrete elements and structures	Containment - Concrete	M = 1; P(2b Cont.) =0.05	Based on the Cont. Leak Test period. Assume order of several years.
Reactor Regulating System	Power Cables	111.7;	O	AG111-7	Aging induced reactor trip due to degradation of reactor regulating system power cables	Cables	M = 2; P(10a) = 0.09	N/A
Reactor Regulating System	Cables	114.9;	O	AG114-9	Aging induced reactor trip due to degradation of reactor regulating system (control) cables	Cables	M = 2; P(10a) = 0.09	N/A
Reactor Regulating System	Reactivity Control Units	144;	O	AG144	Reactor trip due to aging caused degradation of Reactivity Control Units.	Reactivity Control Units	M = 2; P(9) = 0.45 - 0.81	N/A
Recirculated Cooling Water	Flex Hoses	9;	O	AG9(O)	Loss of Recirculated Cooling Water due to aging-induced degradation of flex hoses	Expansion Joints	M = 1; P(5) = 0.09	N/A
			SD	AG9(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of flex hoses			Based on train cycling (operating - standby).

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	**Category**						
Recirculated Cooling Water	Pressure Regulating Valves	21;	O	AG21(O)	Loss of Recirculated Cooling Water train due to aging-induced degradation of Pressure Regulating Valves	AOV	M = 1; P(18a) = 0.45	N/A
			SD	AG21(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of Pressure Regulating Valves.			Based on train cycling (operating - standby).
Recirculated Cooling Water	Air Operated Valves	31.11;	O	AG31-11(O)	Loss of Recirculated Cooling Water train due to aging-induced degradation of AOVs	AOV	M = 2; P(18a) = 0.45	N/A
			SD	AG31-11(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of AOVs.			Based on train cycling (operating - standby).
Recirculated Cooling Water	Cables	37.16;	O	AG37-16(O)	Loss of Recirculated Cooling Water due to aging-induced degradation of cables	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-16(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of cables			Based on train cycling (operating - standby).

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Recirculated Cooling Water	Heat Exchanger	55.4;	O	AG55-4(O)	Loss of Recirculated Cooling Water due to aging-induced degradation of heat exchanger	Heat Exchanger	M = 2; P(22) = 0.09	N/A
			SD	AG55-4(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of heat exchanger			Based on train cycling (operating - standby).
Recirculated Cooling Water	Piping	65.7; 66.2;	O	AG65-7(O)	Loss of Recirculated Cooling Water due to aging-induced degradation of piping	Piping	M = 2; P(5) = 0.09	N/A
			SD	AG65-7(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of piping			Based on train cycling (operating - standby).
Recirculated Cooling Water	Pressure Relief Valves	70.6;	SD	AG70-6	Failure of Recirculated Cooling Water on demand due to aging-induced degradation of pressure-relief valve(s).	Relief Valve	M = 2; P(18f) = 0.81	Based on the time from last test of pressure relief valve. Assume order of one year period.
Recirculated Cooling Water	Pumps	74.12;	O	AG74-12(O)	Loss of Recirculated Cooling Water operating train due to aging-induced degradation of pumps (Note: probability can be applied to account for the failure of other train's pump to map it to the total loss of the system, in order to simplify.)	Pump	M = 2; P(19a) = 0.63	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
			SD	AG74-12(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of pumps			Based on train cycling (operating - standby).
Recirculated Cooling Water	Solenoid Valves	80.5;	O	AG80-5(O)	Loss of Recirculated Cooling Water train due to aging-induced degradation of solenoid valves	AOV	M = 2; P(18a) = 0.45	N/A
			SD	AG80-5(SD)	Failure of standby Recirculated Cooling Water train on demand due to aging-induced degradation of solenoid valves			Based on train cycling (operating - standby).
Safety System Programmable Digital Comparator Computers SDS1, SDS2	Cable Connectors	112;	O	AG112	Plant trip due to aging-induced degradation of cable connectors for SDS1/2 computers	Cable Connectors	M = 2; P(10b) = 0.18	N/A
Safety System Programmable Digital Comparator Computers SDS1, SDS2	Cooling Fans	116;	O	AG116	Plant trip due to aging-induced loss of Colling Fans for SDS1/2 computers	AHU	M = 2; P(24b) = 0.63	N/A
Service Water Systems	Air Operated Valves	108.2;	O	AG108-2(O)	Loss of Service Water due to aging-induced degradation of AOVs	AOV	M = 2; P(18a) = 0.45	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
			SD	AG108-2(SD)	Failure of standby Service Water train on demand due to aging-induced degradation of AOVs			Based on train cycling (operating - standby).
Service Water Systems	Cables	114.2;	O	AG114-2(O)	Loss of Service Water due to aging-induced degradation of cables	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG114-2(SD)	Failure of standby Service Water train on demand due to aging-induced degradation of cables			Based on train cycling (operating - standby).
Service Water Systems	Non-Return or Check Valves	138-5;	O	AG138-5(O)	Loss of Service Water due to aging-induced degradation of check valves	Check Valve	M = 2; P(18b) = 0.09	N/A
			SD	AG138-5(SD)	Failure of standby Service Water train on demand due to aging-induced degradation of check valves			Based on train cycling (operating - standby).
Service Water Systems	Piping-Piping Components and Supports	140.1;	O	AG140-1(O)	Loss of Service Water due to aging-induced degradation of piping	Piping	M = 2; P(5) = 0.09	N/A
			SD	AG140-1(SD)	Failure of standby Service Water train on demand due to aging-induced degradation of piping			Based on train cycling (operating - standby).

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Service Water Systems	Pressure Relief Valves	142;	SD	AG142	Failure of Service Water System on demand due to aging-induced degradation of pressure-relief valve(s).	Relief Valve	M = 2; P(18f) = 0.81	Based on the time from last test of pressure relief valve. Assume order of a year period.
Service Water Systems	Pumps	143.6;	O	AG143-6(O)	Loss of Service Water operating train due to aging-induced degradation of pumps (Note: probability can be applied to account for the failure of other train's pump to map it to the total loss of the system, in order to simplify.)	Pump	M = 2; P(19a) = 0.63	N/A
			SD	AG43-6(SD)	Failure of standby Service Water train on demand due to aging-induced degradation of pumps			Based on train cycling (operating - standby).
Shutdown Cooling System	Air Operated Valves	31.6;	O	AG31-6	Aging induced loss of shutdown cooling caused by degradation of AOVs.	AOV	M = 2; P(18a) = 0.45	N/A
Shutdown Cooling System	Cables	37.6;	O	AG37-6	Aging induced loss of shutdown cooling caused by degradation of cables.	Cables	M = 2; P(10a) = 0.09	N/A
Shutdown Cooling System	Depressurization Valves	45;	O	AG45	Aging induced loss of shutdown cooling caused by degradation of depressurization valves.	Relief Valve	M = 2; P(18f) = 0.81	N/A
Shutdown Cooling System	Heat Exchanger	55.5;	O	AG55-5	Aging induced loss of shutdown cooling caused by degradation of heat	Heat Exchanger	M = 2; P(22) = 0.09	N/A

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
					exchangers.			
Shutdown Cooling System	Non-Return or Check Valves	64.7;	O	AG64-7	Aging induced loss of shutdown cooling caused by degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	N/A
Shutdown Cooling System	Piping	65.9;	O	AG65-9	Aging induced loss of shutdown cooling caused by degradation of piping.	Piping	M = 2; P(5) = 0.09	N/A
Shutdown Cooling System	Pumps	74.14;	O	AG74-14	Aging induced loss of shutdown cooling caused by degradation of pumps.	Pump	M = 2; P(19a) = 0.63	N/A
Shutdown Cooling System	Solenoid Valves	80.2;	O	AG80-2	Aging induced loss of shutdown cooling caused by degradation of solenoid valves.	Solenoid Valve	M = 2; P(18a) = 0.45	N/A
Shutdown System 1 (SDS1)	Cables	37.10;	O	AG37-10(O)	Aging-induced reactor trip caused by degradation of cabling in SDS1.	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-10(SD)	Failure of SDS1 on demand (reactor trip signal) due to aging-induced degradation of cables.			Based on STI for SDS1.
Shutdown System 1 (SDS1)	Reactivity Control; Receptacles / Connectors-Various Voltages A.C. and D.C.; Shut-off Units	75; 58; 76; 79;	SD	AG75	Failure of SDS1 on demand due to aging induced degradation of different equipment - residual risk	SDS1	M = 2; P(9, CRDM) = 0.45-0.81; P(10b) = 0.18	Based on STI for SDS1.

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Shutdown System 2 (SDS2)	Cables	37.7;	O	AG37-7(O)	Aging-induced reactor trip caused by degradation of cabling in SDS2.	Cables	M = 2; P(10a) = 0.09	N/A
			SD	AG37-7(SD)	Failure of SDS2 on demand (reactor trip signal) due to aging-induced degradation of cables.			Based on STI for SDS2.
Shutdown System 2 (SDS2)	Check Valves	64.4;	SD	AG64-4	Failure of Shutdown System 2 due to aging induced degradation of check valves.	Check Valve	M = 2; P(18b) = 0.09	Based on STI for SDS2.
Shutdown System 2 (SDS2)	Piping	65.3;	SD	AG65-3	Failure of Shutdown System 2 due to aging induced degradation of piping	Piping	M = 2; P(5) = 0.09	Based on STI for SDS2.
Shutdown System 2 (SDS2)	Pressure Relief Valves	70.2;	SM	AG70-2	Shutdown System 2 unavailable due to aging-induced degradation of pressure-relief valve(s).	Relief Valve	M = 2; P(18f) = 0.81	Based on AOT for SDS2..
Shutdown System 2 (SDS2)	Pumps	74.13;	SD	AG74-13	Failure of Shutdown System 2 due to aging induced degradation of pumps.	Pump	M = 2; P(19a) = 0.63	Based on STI for SDS2.
Shutdown System 2 (SDS2) (Liquid Injection Shutdown System)	Tank	28.3; 85.10; 85.11;	SM	AG28-3	Unavailability of Liquid Injection Shutdown System due to aging induced degradation of Tank	Tanks - High Pressure	M = 1; P(29b) = 0.07	Exposure time based on AOT..

System / Subsystem	Components / Structures		BE Type	BE Case	BE Description	Aging Failure Acceleration Case	AM Effectiveness	Exposure Time
	Description	Category						
Standby Generators	Piping	18.2	SD	AG18-2	Failure of Standby Generator on demand due to aging-induced degradation of piping.	Piping	M = 2; P(5) = 0.09	Based on STI for Standby Generator.
Standby Generators	Cables	37.5	SD	AG37-5	Failure of Standby Generator on demand due to aging induced degradation of cables.	Cables	M = 2; P(10a) = 0.09	Based on STI for Standby Generator.
Standby Generators	Emergency Power Generators	54.2	SD	AG54-2	Failure of Standby Generators due to aging induced degradation.	EDG	M = 2; P(11) = 0.27	Based on STI for Standby Generator.
Standby Generators	Tanks	85.9	SM	AG85-9	Unavailability of Standby Generator Tank due to aging induced degradation	Tanks - Atmospheric	M = 2; P(29b) = 0.07	Based on AOT for Emergency Power Supply.

4. ESTABLISHING AGING FAILURE RATES

Based on Table 3-2, the aging failure rates need to be established for the following SSCs:

1. AHU (Air Handling Unit)
2. AOV (Air Operated Valve)
3. Battery
4. Bolts - Connections
5. Bus
6. Cable Connectors
7. Cables
8. Calandria Vault
9. CB (Circuit Breaker)
10. Check Valve
11. Containment - Concrete
12. Containment - Foundations
13. Containment - Penetrations
14. Containment - Steel
15. Containment Isolation Valves
16. EDG (Emergency Diesel Generator)
17. Expansion Joints
18. Heat Exchanger
19. Inverter
20. MOV (Motor Operated Valve)
21. Other Concrete
22. Other Foundations
23. PHT Feeders
24. PHT Fuel Channels
25. PHT Pressure Tubes
26. Piping
27. Pump
28. Reactivity Control Units
29. Rectifier

30. Relief Valve
31. SDS1 (Shutdown System 1)
32. SG Shell Side
33. SG Tube Side
34. Solenoid Valve
35. Tanks - Atmospheric
36. Tanks - High Pressure
37. Transformer

Aging failure rates for these SSCs were established, in accordance with the model described in section 2.4, through the evaluations of available data sources, as described in Appendix 10.2. Data sources considered include generic data reflecting PWR, BWR and VVER plants, CANDU data (Phase 1 study) and plant specific data (failure rates from the referential PSA model). Specifically, the references considered include:

- NUREG/CR-5248 , (PNL-6701), Prioritization of TIRGALEX-Recommended Components for Further Aging Research, 1988
- NUREG/CR-5378 , (EGG-2567), Aging Data Analysis and Risk Assessment - Development and Demonstration Study, 1990
- NUREG/CR-6928, (INL/EXT-06-11119), Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants, Idaho National Laboratory - U.S. Nuclear Regulatory Commission, February 2007
- EUR 24643 EN, S. Poghosyan, A. Malkhasyan, A. Rodionov, M. Nitoi: Analysis of data related to ageing of VVER-440 NPP components, DG JRC Institute for Energy, 2010
- EUR 23930 EN, A.Rodionov : A Case Study on Incorporation of Ageing Effects into the PSA Model. EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2009
- Incorporating Ageing Effects into PSA Applications – Phase I, Volumes 1 through 18, Martec Technical Report #TR-07-63 (Prepared for: Canadian Nuclear Safety Commission), Rev. 1, February 2008
- Point Lepreau Generating Station Probabilistic Safety Assessment, Level 1 and 2 Internal Events, 0087-03611-0001-PSA-A-00

Aging failure rates for the above SSCs are established through several phases:

1. Consideration of the available generic data sources reflecting, mostly, the experience of PWR, BWR and VVER plants in order to establish the "generic" aging acceleration rates and average failure rates for the relevant SSCs. These "generic" values were established by evaluation of the data and information from the documents including NUREG/CR-5248, NUREG/CR-5378, NUREG/CR-6928, EUR 24643 EN, EUR 23930 EN and others. Those evaluations are presented in sections 10.2.2 through 10.2.6 of Appendix 10.2. The established "generic" average failure rates and aging acceleration rates are presented in section 10.2.7 of the same appendix.

2. Consideration of the CANDU failure trending data from Phase 1 report in order to obtain an indication of corresponding average failure rates and acceleration rates which would be more specific to CANDU plants. The evaluation of data from Phase 1 report is presented in section 10.2.8 of appendix 10.2. The "generic" aging acceleration rates were modified, where available and applicable, through comparison with CANDU rates, into the final aging acceleration rates, as described in section 10.2.10 of the same appendix.

3. The last phase of establishing the aging failure rates is done through the PSA model: for all relevant SSC categories which are modelled in the baseline PSA model with their specific average failure rates, the final acceleration rates from section 10.2.10 (appendix 10.2) are "updated" with those plant specific failure rates, as discussed in section 10.2.1 (appendix 10.2), in order to obtain "pseudo plant specific" acceleration rates. To obtain some insight on how plant specific average failure rates compare with generic failure rates, a high level comparison was made in section 10.2.9 (appendix 10.2).

The resulting aging acceleration rates for the SSCs listed above are summarized in Table 4-1. The SSCs can, according to the above discussion, be divided into two groups:

- Those which are represented in the baseline PSA model, with their specific failure rates. To those, the corresponding relative acceleration rate (%/yr.) from Table 4-1 will be applied in order to obtain a "pseudo plant specific" acceleration. The aging impact for those SSCs will be propagated through the existing basic events in the PSA model, i.e. projected increase in the failure rate (due to aging) will be added to the current failure rate value.
- Those which are not represented in the baseline PSA model, such as concrete structures, cabling, piping for some of the systems etc. No plant specific failure rates are available in the PSA model. New basic events will be created in the PSA model to represent corresponding aging failures. To those SSCs, the absolute aging acceleration rates (/hr./yr.) provided in Table 4-1 apply. They will be the bases for calculations of corresponding failure probabilities.

Table 4-1: Summary of aging acceleration rates for the relevant SSCs

#	SSC	Conf.	Acceleration Rate(/hr./yr.) (Note 1)	Relative Acceleration Rate (%/yr.) (Note 1)
1	AHU	O		15% (Note 2)
		SD		15% (Note 2)
2	AOV	O		10%
		SD		10%
3	Battery	SD		15% (Note 2)
4	Bolts - Connections	SM	1.0E-09 (Function level)	
		SD	1.0E-09 (Function level)	
5	Bus	O		11%

#	SSC	Conf.	Acceleration Rate(/hr./yr.) (Note 1)	Relative Acceleration Rate (%/yr.) (Note 1)
		SD		11%
6	Cable Connectors	O	4.9E-09	
7	Cables	O	2.4E-09	
		SD	2.4E-09	
8	Calandria Vault	O	1.0E-11	
9	CB	O		10%
		SD		10%
10	Check Valve	O		10%
		SD		10%
11	Containment - Concrete	SD	1.0E-13	
12	Containment - Foundations	SD	1.0E-13	
13	Containment - Penetrations	SD	1.0E-10 (Function level)	
14	Containment - Steel	SD	1.0E-13	
15	Containment Isolation Valves	SD		N/A
16	EDG	SD	1E-06	
17	Expansion Joints	O	3.0E-08 (System level)	
		SD	3.0E-08 (System level)	
18	Heat Exchanger	O		1%
		SD		1%
19	Inverter	O		5%
		SD		5%
20	MOV	O		15% (Note 2)
		SD		15% (Note 2)
21	Other Concrete	O	1.0E-13 (Function level)	
		SD	1.0E-13 (Function level)	
22	Other Foundations	SD	1.0E-13 (Function level)	
23	PHT Feeders	O		1%
24	PHT Fuel Channels	O		

#	SSC	Conf.	Acceleration Rate(/hr./yr.) (Note 1)	Relative Acceleration Rate (%/yr.) (Note 1)
25	PHT Pressure Tubes	O		1%
26a	Piping - PHT	O		1%
26b	Piping - other	O		3%
		SD		3%
27	Pump	O		10%
		SD		10%
28	Reactivity Control Units	O	6E-07 (Function level)	
29	Rectifier	O		3%
		SD		3%
30	Relief Valve	O		7%
		SD		7%
31	SDS1	SD	1E-10	
32	SG Shell Side	O	1E-12	
33	SG Tube Side	O		4%
34	Solenoid Valve	SD		15% (Note 2)
35	Tanks - Atmospheric	O		15% (Note 2)
		SM		15% (Note 2)
36	Tanks - High Pressure	O		1%
37	Transformer	O		1%
		SD		1%

Notes for Table 4-1:

1. Taken from the corresponding column of Table 10-20, Appendix 10.2, except where specifically noted otherwise.

2. In the cases where relative acceleration rates, as presented in Table 10-20, were higher than 15 %/yr., they were cut down to 15 %/yr. This is based on the assumption that corrective actions would be taken based on the observed trends. Those cases are: 1 AHU; 3 Battery; 20 MOV; 34 Solenoid Valve; and 35 Tanks. This should be seen in the following way. If there is an increase in a failure rate larger than 15%/yr., it would make the overall failure rate higher by some 50% in, roughly, three years from now and by 100% or so in some six years from now. It is believed that any operating plant would have monitoring programs (such as “system health programs” as a part of maintenance or aging management programs) capable of recognizing this kind of

increase. For active components, such as valves, the indication would be based on numbers of reported failed tests or problems. For passive components, such as tanks, the indication would be based on the inspection findings. One can expect that an adverse trend such as the above discussed would be recognized at active components in a shorter time period (due to regular testing), as compared to passive components. But, on the other hand, failure rates of passive components are much lower which would compensate for a longer "detection" time period.

5. CONSIDERATION OF AGING MANAGEMENT EFFECTIVENESS

The SSCs are assumed to be subject to regular periodical activities aimed at aging management (AM), i.e. reducing the impact of aging. Those activities include overhauls, equipment "servicing", "refurbishing", inspections (followed by corrective actions, as necessary), replacements of parts or whole components etc.

In terms of reliability modelling, the impact of those activities is to reduce (slow down), or completely eliminate, the increase of failure rate with time, as caused by aging.

This issue has been considered in many references from the literature. Two principles are very often used in describing the influence which maintenance has on equipment failure rate (e.g. [26], [27]):

- reduction in the rate of equipment degradation (e.g. [22]);
- reduction in equipment age (e.g. [23]).

In both cases the final effect is that adequate equipment maintenance reduces the increase of failure rate with time.

To account, quantitatively, for the impact of AM activities on the time-dependent failure rates, the proportional age reduction (PAR) model was selected for this study. According to this principle, each overhaul, or application of particular AM activity in general, reduces the actual equipment age by the amount proportional to the actual age at the time of overhaul / AM activity being performed ([25]). Reference [25] discusses the difference between the term "minimal repair" actions and "major overhauls" and uses the mentioned PAR assumption to incorporate the impact of the latter on the time dependent failure rate. The "minimal repair" is described as a repair action which returns the component to the conditions it was in just before the failure occurrence. (In other words, it repairs the failed component, but component's failure rate remains the same as it was just prior to the failure.) Under such conditions, the reliability of the component would decrease with operating time until it would reach unacceptable values. On the other hand, reference [25] points that, in many situations, before the failures become more and more frequent certain maintenance action is performed in order to improve the component conditions and thus reduce the probability of failure occurrence in the subsequent time interval. (The mentioned reference uses the expression "corrective maintenance", but we avoid using this expression as we believe it may be misleading under this context. Actually, in the given context, the term "preventive maintenance" may be more applicable.) Such a maintenance action is, according to [25], often referred to as "major overhaul". When the major overhaul is effective, the conditions of the component are improved by some degree. Or, in other words, the failure rate has been reduced to the value lower than the one just before the overhaul. (For the purposes of the present study, we will extend the term “major overhaul” to already introduced term “AM activity”. One of the reasons is to include, beside the overhauls on active equipment, also the inspection activities on passive components or structures which may be followed by replacement actions (e.g. replacing a segment of piping on the basis of inspection results) or other corrective or compensatory or improvement measures.)

According to [25], a reliability model which intends to describe correctly the failure / repair process has to be able to model the effect of major overhauls (or, in the case of the present study, more broad AM activities). The PAR model, which can be used for this purpose, introduces the improvement factor ρ as a measure of improvement introduced into the component by the overhaul (or AM) actions. In the present study, this factor will be referred to as the “age improvement” factor. Under the mentioned PAR model, it is assumed that each major overhaul (AM activity) reduces proportionally the age of considered component by a fraction of the epoch of the overhaul (AM activity).

More specifically, it is assumed that immediately following the application of an AM activity the SSC’s age is reduced proportionally to the actual time spent in operation up to the point in time when the AM activity was applied. The factor of proportion is before mentioned “age improvement” factor ρ, where $0 \le \rho \le 1$.

The age of SSC, as a function of calendar time, can be written as:

$$t_{ag}(t) = t - \rho x_i \ ; \ x_i < t < x_{i+1} \qquad \text{Eq. 5-1}$$

In the above expression, x_i is the time point at which the latest AM activity was applied (e.g. the time of latest pump’s overhaul) and x_{i+1} is the time point of the next scheduled AM activity. The average time period between x_i and x_{i+1} is in this document referred to as “aging management activity time period” and is designated as T_{AM}.

Low AM effectiveness means values of ρ considerably smaller than 1. Effective AM means values of ρ close to 1. The impact of improvement factor ρ on SSC’s age is illustrated by Figure 5-1. (In the figure it is assumed that time between two AM activities is 10 years.) In the case of $\rho = 1$, the SSC would, at the time immediately following the AM activity be restored to the status it had at $t = 0$.

With respect to Eq. 2-4, the time-dependent expression for SSC’s failure rate becomes:

$$\lambda\left[t_{ag}(t)\right] = \lambda_0 + \lambda_{ag}\left[t_{ag}(t)\right] = \lambda_0 + a\left(t - \rho x_i\right) \ ; \ x_i < t < x_{i+1} \qquad \text{Eq. 5-2}$$

Figure 5-2 illustrates an increase, due to aging, in a failure rate for an SSC with age shown in Figure 5-1, assuming aging acceleration rate $a = 1.70E\text{-}08$ */hr/yr*.

The above time-dependent failure rate model, which incorporates the aging management effectiveness, is the basis for establishing the aging-related failure rates and probabilities in the PSA model for the SSCs identified in section 4.

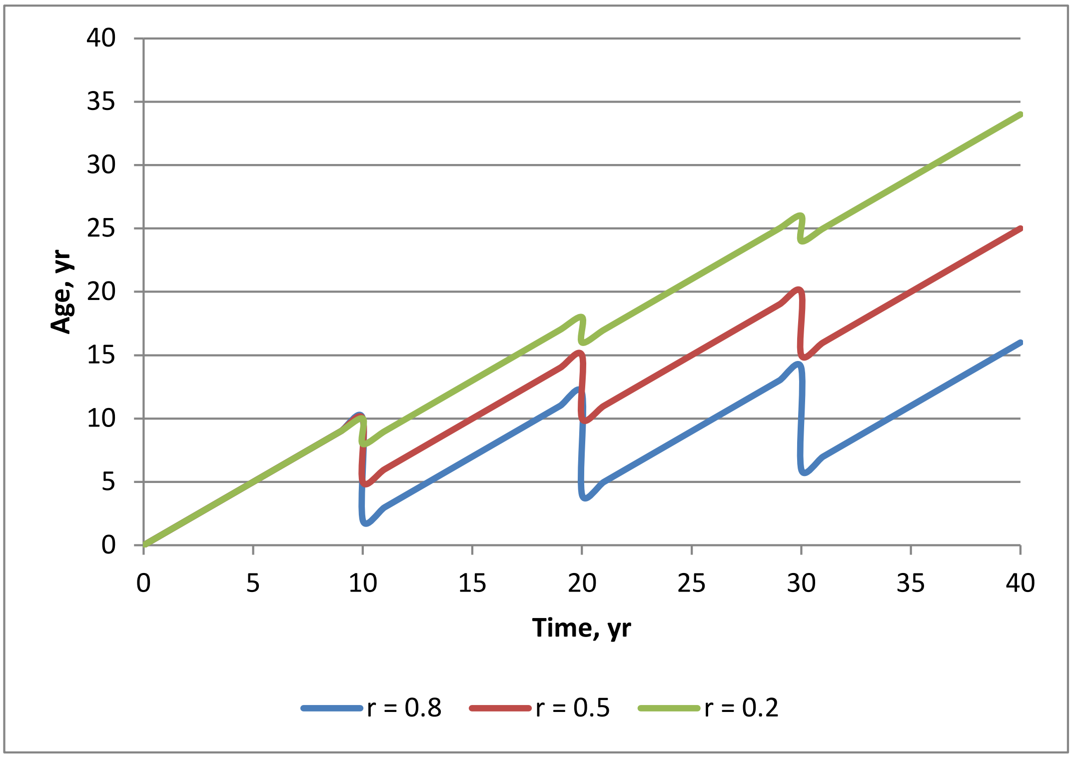


Figure 5-1: SSC's Age with Different Age Improvement Factors - Illustration

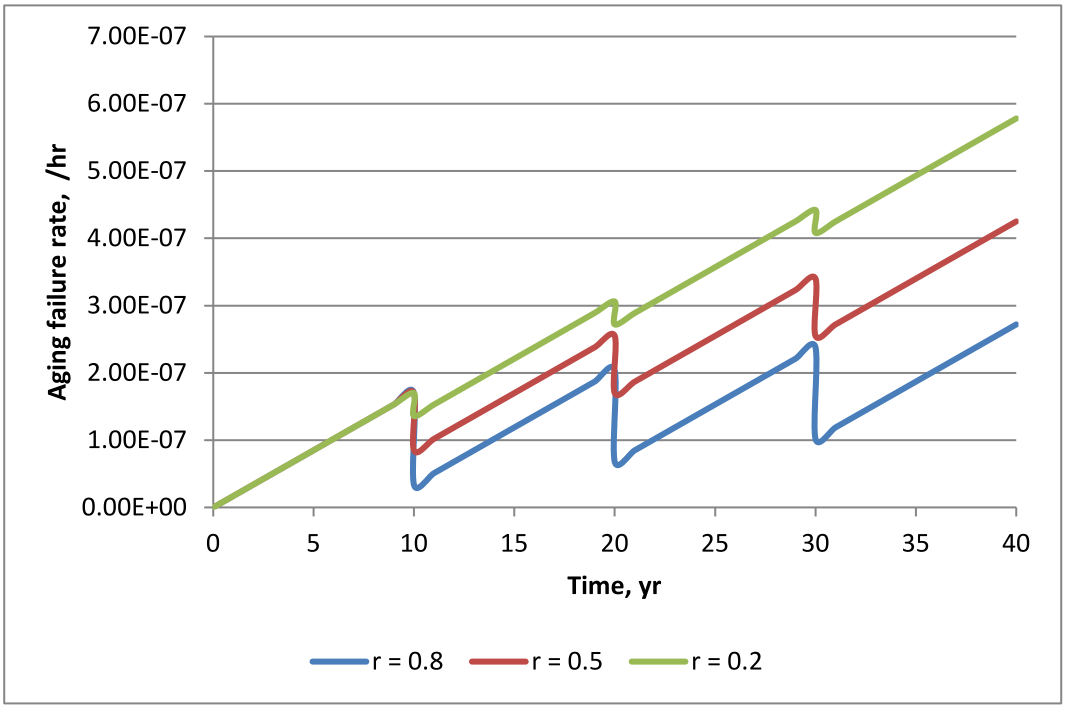


Figure 5-2: SSC's Failure Rate Increase with Different Age Improvement Factors – Illustration

6. PSA MODELLING AND CALCULATIONS

6.1 Input for Aging PSA Model

As described earlier, the identified 37 categories of SSCs in section 4 were, for the purpose of PSA modelling, divided into two groups:

- Those which are represented in the baseline PSA model, with their specific failure rates.
- Those which are not represented in the baseline PSA model (e.g. concrete structures, cabling, piping for some of the systems etc.) and for which no plant specific failure rates are available in the PSA model.

For the first group, the aging impact will be propagated through the existing basic events in the PSA model, by projected increase in the failure rate (due to aging) which will be added to the current failure rate value. The increase in those failure rates is calculated in section 6.1.1.

For the second group, new basic events will be created in the PSA model to represent corresponding aging failures. For those, corresponding probabilities need to be provided. The calculation of those probabilities is described in section 6.1.2.

It is understood that the referential plant started operation in 1983, was shut down at 2008 for „refurbishment"and was restarted in 2012. For the purpose of Aging PSA risk calculations, the zero time (i.e. $t = 0$) was set at restart in 2012.

Here it needs to be stated that there was no point in trying to set the time zero at the beginning of operation (1983) considering that no historical failure data or failure trends were available which would enable establishing time dependent failure rates models from the beginning of operation (except for the very limited data from Phase I report, which were used to the extent possible, section 10.2.8).

For the aging-related risk, a projection for the next 20 years (from time zero) is made. There is no sense in trying to predict the risk for longer periods, considering the uncertainties in projected failure rates / probabilities which depend, among others, on aging management activities and corrective actions which cannot be predicted. In this sense, even selected 20 years period is too long and calculations need to be considered as projections based on the described assumptions, which will need to be verified through the actual data from SSC performance.

Sections 6.1.1 and 6.1.2 provide calculated values of failure rates and probabilities at 5 years periods for the 20 years of projected plant operation.

6.1.1 Increase in the Existing Failure Rates

Basic formula for calculation of "new" time-dependent failure rate to be propagated through the PSA model is given by Eq. 5-2:

$$\lambda(t) = \lambda_0 + a\left(t - \rho x_i\right) \;\; ; \;\; x_i < t < x_{i+1}$$

In this formula the term λ_0 represents, as explained in section 2.4, the initial failure rate as found in the PSA model. The second term, $a(t-\rho x_i)$, represents the projected increase of this initial value in time, due to aging.

Table 6-1 provides the necessary data for calculation of time-dependent increase in failure rates for those SSCs from section 4 / Table 4-1 which are represented in the baseline PSA model through their specific failure rates. All terms are defined within notes under the table, together with reasoning for the values established.

When applied, the above formula produces a “sawteeth” curve increasing in time, like the one shown in Figure 6-1 for the AHU category (Air Handling Units).

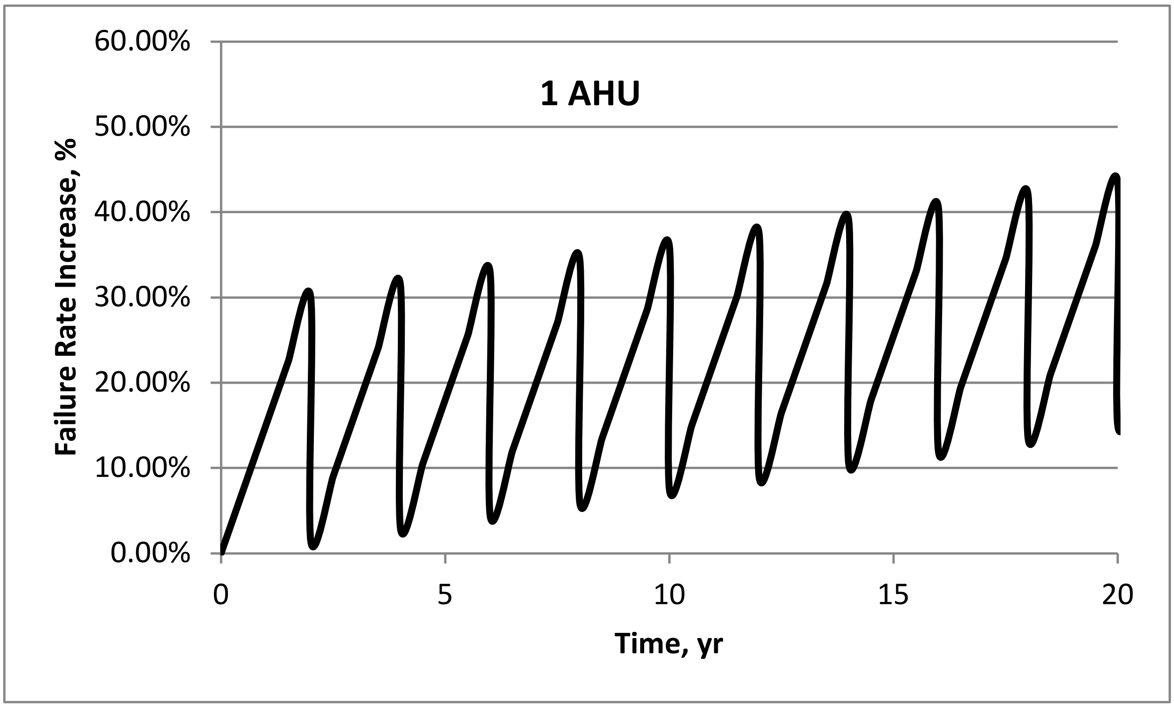


Figure 6-1: Example of Sawteeth Curve - AHU Category

Table 6-1: Summary of data for calculation of increase in existing failure rates in PSA model

# [1]	SSC [1]	Relative Acceleration Rate (%/yr) [2]	Age Improvement Factor (ρ)		Aging Management Activity Period	
			ρ [3]	Remark [4]	T_{AM}, yr. [5]	Remark [6]
1	AHU	15%	0.95	M = 2; P(24b) = 0.63	2	18 months
2	AOV	10%	0.95	M = 2; P(18a) = 0.45	2	18 months
	AOV, RSW	10%	0.9	M = 1; P(18a) = 0.45	2	18 months
3	Battery	15%	0.95	M = 2; P(25) = 0.81	1	6 months
5	Bus	11%	0.95	M = 2; P(30a,b) = 0.45	2	18 months
9	Circuit Breaker	10%	0.95	M = 2; P(17b) = 0.45	2	18 months
10	Check Valve	10%	0.95	M = 2; P(18b) = 0.09	2	18 months
	Check Valve, RSW	10%	0.9	M = 1; P(18b) = 0.09	2	18 months
18	Heat Exchanger	1%	0.95	M = 2; P(22) = 0.09	1	3 months
19	Inverter	5%	0.95	M = 2; P(26b) = 0.45	1	12 months
20	MOV	15%	0.95	M = 2; P(18e) = 0.63	1	3 months
	MOV, RSW	15%	0.9	M = 1; P(18e) = 0.63	1	3 months
23	PHT Feeders (Map to Feeders LOCA)	1%	0.95	M = 2; P(4c) = 0.18	3	36 months (This is based on BWR Small LOCA. (TIRGALEX provides no data for PWR Small LOCA))
25	PHT Pressure Tubes (Map to Pressure Tube LOCA)	1%	0.95	M = 2; P(1) = 0.09; P(4c) = 0.18	10	120 months (Based on PWR/ BWR reactor pressure vessel.)

# [1]	SSC [1]	Relative Acceleration Rate (%/yr) [2]	Age Improvement Factor (ρ)		Aging Management Activity Period	
			ρ [3]	Remark [4]	T_{AM}, yr. [5]	Remark [6]
26b	Piping - other; Blowoff System (Map to SLB).	3%	0.95	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping - other; Boiler Feedwater System (Map to FWLB).	3%	0.95	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping - other; Boiler Steam (Main Steam) System (Map to SLB).	3%	0.95	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping - other; RSW	3%	0.9	M = 1; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
26a	Piping - PHT (Map to ex-core LOCA)	3%	0.95	M = 2; P(4c) = 0.18	3	36 months (This is based on BWR Small LOCA. (TIRGALEX provides no data for PWR LOCA piping))
27	Pump	10%	0.95	M = 2; P(19a) = 0.63	2	18 months
29	Rectifier	3%	0.95	M = 2; P(26c) = 0.45	1	12 months
30	Relief Valve	7%	0.95	M = 2; P(18f) = 0.81	2	18 months
33	SG Tube Side (Map to SGTR)	4%	0.95	M = 2; P(6a) = 0.25	3	36 months
34	Solenoid Valve	15%	0.95	M = 2; P(18a) = 0.45	2	18 months
35, 36	Tank	15% [7]	0.95	M = 2; P(29b) = 0.07	1	12 months
	Tank - Dousing System; EWS; SDS2	15%	0.9	M = 1; P(29b) = 0.07	1	12 months

# [1]	SSC [1]	Relative Acceleration Rate (%/yr) [2]	Age Improvement Factor (ρ)		Aging Management Activity Period	
			ρ [3]	Remark [4]	T_{AM}, yr. [5]	Remark [6]
37	Transformer	1%	0.95	M = 2; P(27) = 0.63	2	18 months

Notes for Table 6-1:

1. Reference number and description of SSC from section 4 (Table 4-1).
2. Relative acceleration rate as in Table 4-1. Note that in relative terms (%), the operating and standby rates are considered to be the same.
3. The values of ρ were assigned on the following basis:
   - For the SSCs with M = 2, ρ = 0.95; (residual aging of 5%);
   - For the SSCs with M = 1, ρ = 0.9; (residual aging of 10%).

   For the explanation of “M” and “P”, refer to Note 4 below. The probability "P" is only provided for information and it should be noted that it does not represent the age improvement factor ρ. Also, the TIRGALEX is a study of older date and inspection / surveillance techniques and practices are nowadays considered to be much more advanced and effective in aging management (e.g. detection probabilities are considered to be larger than in the late 80s / early 90s).

   To obtain some feeling into the sensitivity of the results, rank "2" (for “M”) was mapped to the value of ρ of 0.7 to 0.8 (most of the cases) and rank "1" to 0.4 to 0.6. This was done together with varying the ρ-values for the passive SSCs as described in the Note 3 under Table 6-3. The conclusion is that this could result in an increase to SCDF at power of the order of magnitude at t = 20 years.
4. Terms “M” and “P” as defined in section 3. Values as established in Table 3-2. The term “P” is only provided for information.
5. Average aging management activity period, T_{AM}, as defined in section 5. Considered to be an average for different aging mechanisms and failure modes. It should be considered that each overhaul / inspection may not address all relevant aging mechanisms / failure modes. Also, this average considers the impact of surveillance testing in the sense that for the SSCs which are more frequently subject to the ST the effective AM activity interval would be shortened. This is due to the assumption that in the case of problems indicated by ST, the immediate repair (to restore the component to the status it had prior to the failure occurrence) would be followed by a more detailed inspection and

corrective measures, e.g. at the next outage. Similar for a piping inspection: large finding at one segment would induce detailed inspection at others and thus, the effective average interval would be reduced.

6. Provided for information: indication of aging management activity period from the TIRGALEX study.

7. Larger value taken considering pressurized and atmospheric pressure tanks.

Several considerations apply for developing the sets of values for increase in failure rates for the SSCs from Table 6-1.

- It is assumed, for convenience, that at $t = 0$ the failure rate increase is zero for all SSCs considered (or: $\lambda(0) = \lambda_0$), i.e. that the latest AM activity was completed just prior to $t = 0$. Two points need to be made regarding this. First, the time of the latest / next periodical implementation of AM activities would not significantly impact the projections in longer terms such as 10 or 20 years. Second, since the zero time was selected to be at the startup following the overall plant refurbishment, this appears as a natural assumption to be made.
- As explained earlier (also, in section 2.4) the term λ_0 represents the existing failure rate in the baseline PSA model. It needs to be considered that this existing failure rate was derived as a long-term averaged value (from plant operation before the overall refurbishment) which reflects non-aging as well as aging-related failures, together with previous implementation of AM activities. The "rolling average" of the sawteeth curve from Figure 6-1 should be seen as a continuation of this average failure rate (λ_0) from previous operation. If this "rolling average" is approximated by the line which "cuts" the teeth in half, then the sawteeth curve needs to be translated by the value of the term $\frac{a\,\rho\,T_{AM}}{2}$. (Note that the length of a tooth is $a\,\rho\,T_{AM}$.) If this correction is not applied, then at $t = 0$ there would be a step increase which is not justified (and it is noted, once again, that this correction is necessary due to the fact that the existing average failure rate λ_0 reflects previous aging failures and AM activities). Thus, the final expression for the calculation of time-dependent increase in a failure rate is:

$$\lambda_{ag}(t) = a\,(t - \rho x_i) - \frac{a\,\rho\,T_{AM}}{2} \quad ; \; x_i < t < x_{i+1} \qquad \text{Eq. 6-1}$$

  As an example, the time-dependent failure rate increase calculated by Eq. 6-1 for the same SSC category AHU is shown in Figure 6-2.

  The total time-dependent failure rate is calculated, as before, as $\lambda(t) = \lambda_0 + \lambda_{ag}(t)$.

- As discussed earlier, a projection of aging-related risk is made for the 20 years (starting with time zero). The increase in failure rate is calculated for each SSC from Table 6-1 in five year intervals (i.e. at the time points of 5, 10, 15 and 20 years from time zero). The formula under Eq. 6-1 provides the basis for the calculation. However, to avoid problems and issues with step decreases following the implementation of AM activities (i.e. "teeth"), some shorter-term averaged value needs to be taken at selected time-points, instead of the instantaneous value. Averaged value over one year period was selected, which was approximated by the formula:

$$\lambda_{ag}(t) = \frac{\lambda(t - 0.5yr) + \lambda(t + 0.5yr)}{2} \qquad \text{Eq. 6-2}$$

In the above expression the values of $\lambda(t-0.5yr)$ and $\lambda(t+0.5yr)$ were calculated by applying the formula under Eq. 6-1. Thus, for example, the failure rate increase at $t=5yr$ is approximated by the value $\frac{\lambda(4.5yr)+\lambda(5.5yr)}{2}$.

Failure rate increases for time points of 5, 10, 15 and 20 years from time zero are, for all SSCs from Table 6-1, provided in Table 6-2. It is noted that, since the acceleration a is in Table 6-1 expressed in terms of percentage of λ_0 per year, the failure rate increases in Table 6-2 are presented as percentage of λ_0.

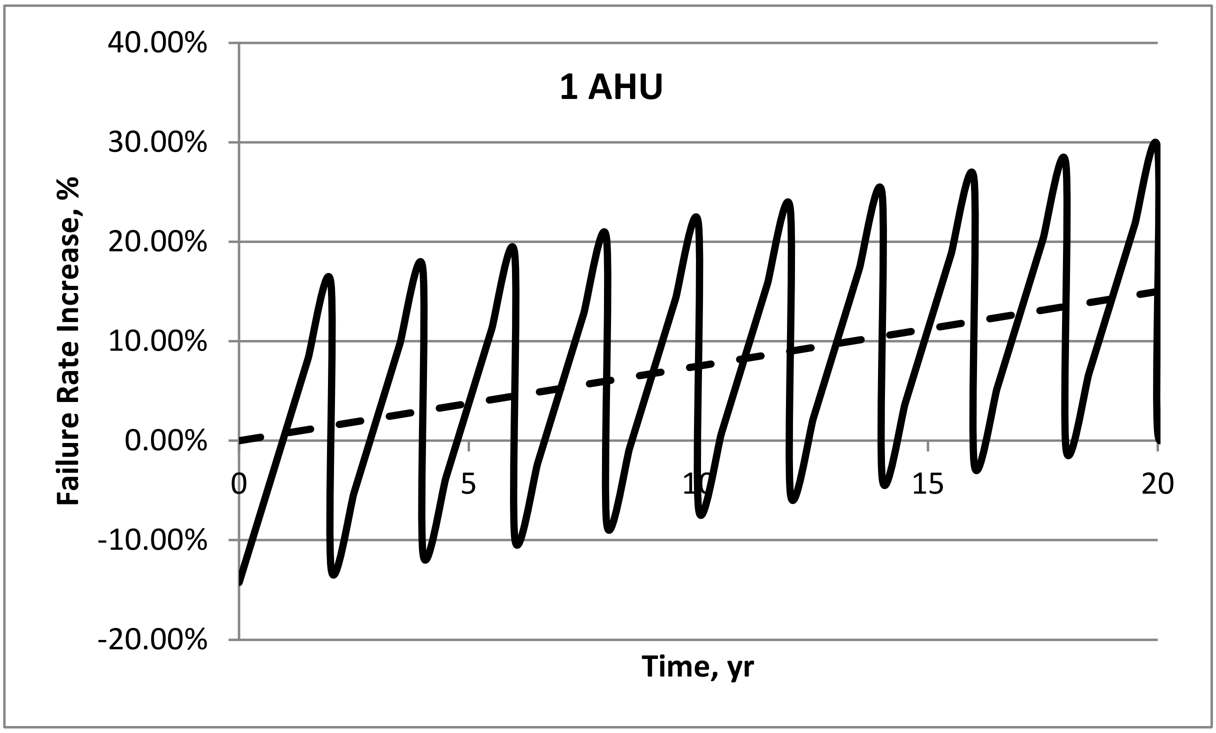


Figure 6-2: Time-dependent Failure Rate Increase for AHU Category

Table 6-2: Failure rate increases at 5, 10, 15 and 20 years from time zero for SSCs represented in baseline PSA

#	SSC	Failure Rate Increase, % of λ_0			
		5 yr	10 yr	15 yr	20 yr
1	AHU	3.8%	7.5%	11.3%	15.0%
2	AOV	2.5%	5.0%	7.5%	10.0%
	AOV, RSW	5.0%	10.0%	15.0%	20.0%
3	Battery	3.8%	7.5%	11.3%	15.0%
5	Bus	2.8%	5.5%	8.3%	11.0%

#	SSC	Failure Rate Increase, % of λ_0			
		5 yr	10 yr	15 yr	20 yr
9	Circuit Breaker	2.5%	5.0%	7.5%	10.0%
10	Check Valve	2.5%	5.0%	7.5%	10.0%
	Check Valve, RSW	5.0%	10.0%	15.0%	20.0%
18	Heat Exchanger	0.3%	0.5%	0.8%	1.0%
19	Inverter	1.3%	2.5%	3.8%	5.0%
20	MOV	3.8%	7.5%	11.3%	15.0%
	MOV, RSW	7.5%	15.0%	22.5%	30.0%
23	PHT Feeders (Map to Feeders LOCA)	0.7%	0.0%	0.8%	1.5%
25	PHT Pressure Tubes (Map to Pressure Tube LOCA)	0.3%	0.5%	0.8%	1.0%
26b	Piping - other; Blowoff System (Map to SLB).	0.8%	1.5%	2.3%	3.0%
	Piping - other; Boiler Feedwater System (Map to FWLB).	0.8%	1.5%	2.3%	3.0%
	Piping - other; Boiler Steam (Main Steam) System (Map to SLB).	0.8%	1.5%	2.3%	3.0%
	Piping - other; RSW	1.5%	3.0%	4.5%	6.0%
26a	Piping - PHT (Map to ex-core LOCA)	2.2%	0.1%	2.3%	4.4%
27	Pump	2.5%	5.0%	7.5%	10.0%
29	Rectifier	0.8%	1.5%	2.3%	3.0%
30	Relief Valve	1.8%	3.5%	5.3%	7.0%
33	SG Tube Side (Map to SGTR)	2.9%	0.1%	3.0%	5.9%
34	Solenoid Valve	3.8%	7.5%	11.3%	15.0%
35, 36	Tank	3.8%	7.5%	11.3%	15.0%
	Tank - Dousing System; EWS; SDS2	7.5%	15.0%	22.5%	30.0%
37	Transformer	0.3%	0.5%	0.8%	1.0%

6.1.2 Probabilities for the New Basic Events

Calculation of probabilities (or frequencies, for the “O”-type events) for the new basic events go, generally, in two main steps:

- Calculation of time-dependent increases in failure rates for the considered SSCs;
- Based on the calculated failure rates: calculation of probabilities / frequencies for the respective (new) basic events.

The increase in failure rates (with respect to $t = 0$) is calculated by the same formula under Eq. 6-1:

$$\lambda_{ag}(t) = a\,(t - \rho x_i) - \frac{a\,\rho\,T_{AM}}{2} \quad ; \; x_i < t < x_{i+1}$$

Table 6-3 provides the necessary data for calculation of time-dependent increase in failure rates for those SSCs from section 4 / Table 4-1 which are not represented in the baseline PSA model. As in the previous case, all terms are defined within notes under the table, together with reasoning for the values established.

Table 6-3: Summary of data for calculation of increase (from time zero) in failure rates for SSCs not presented in baseline PSA model

# (1)	SSC (1)	Mapping to PSA Model	Acceleration Rate (/hr./yr.) (2)	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ (3)	Remark (4)	T_{AM}, yr. (5)	Remark (6)
4	Bolts - Connections, SD, Containment	Fails the Containment integrity.	1.0E-09	0.5	M = 1; P(2b) = 0.05; P(3) = 0.05; (P(31) = 0.45)	5	60 months (Indicated 60 months in TIRGALEX relates to Containment (2b.).)
	Bolts - Connections, SM, Emergency Coolant Injection (HP ECI Storage Tank)	HP ECI Storage Tank unavailable when demanded.	1.0E-09	0.5	M = 1; P(31) = 0.45;	2	18 months (Indicated 18 months in TIRGALEX assumes inspection on disassembled, safety related, bolted components (31.).)
	Bolts - Connections, SD, Emergency Water Supply	Failure of EWS on demand.	1.0E-09	0.5	M = 0; P(31) = 0.45;	2	18 months (Same note as above.)
6	Cable Connectors, O, Dig. Comp. SDS1/2	Initiator: Plant trip. (Fail-safe mode assumed. Plant trip assumed as an enveloping event.)	4.9E-09	0.75	M = 2; P(10b) = 0.18	5	60 months
7	Cables, O, Boiler FW	Initiator: Loss of FW / Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Boiler Steam (MS)	Initiator: Plant Trip (closure of MSIV assumed).	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Class I Power (250V DC Class I Power System)	Initiator: Loss of Class I Power	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Class I Power (250V DC Class I Power	Failure of Class I Power on demand (in the case of safety	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months

# [1]	SSC [1]	Mapping to PSA Model	Acceleration Rate (/hr./yr.) [2]	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ [3]	Remark [4]	T_{AM}, yr. [5]	Remark [6]
	System)	signal actuation).					
	Cables, O, Class II Power (Class II Distribution System)	Initiator: Loss of Class II Power	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Class II Power (Class II Distribution System)	Failure of Class II Power on demand (in the case of safety signal actuation).	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Class III Distribution System	Not applicable. Class III is a standby system.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Class III Distribution System	Failure of Class III Power on demand (in the case of safety signal actuation).	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Condenser Cooling Water (CCW) System	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Containment	Fails the Containment integrity.	2.4E-09	0.5	M = 1; P(10a) = 0.09	5	60 months
	Cables, SD, Emergency Core Cooling and Recovery	Fails ECC on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Emergency Power Supply	Fails EPS on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Emergency Water Supply	Fails EWS on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months

# [1]	SSC [1]	Mapping to PSA Model	Acceleration Rate (/hr./yr.) [2]	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ [3]	Remark [4]	T_{AM}, yr. [5]	Remark [6]
	Cables, O, Instrument Air	Initiator: Loss of IA	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Instrument Air	Fails IA on demand	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Liquid Zone System	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Primary Heat Transport	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Reactor Regulating System	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Recirculated Cooling Water	Initiator: Loss of RCW	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Recirculated Cooling Water	Fails RCW on demand (in the case of actuation of safety signal)	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Safety System Programmable Digital Comparator Computers SDS1, SDS2	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Shutdown System 1 (SDS1)	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Shutdown System 1 (SDS1)	Fails SDS1 on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, O, Shutdown	Initiator: Plant trip	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months

# (1)	SSC (1)	Mapping to PSA Model	Acceleration Rate (/hr./yr.) (2)	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ (3)	Remark (4)	T_{AM}, yr. (5)	Remark (6)
	System 2 (SDS2)						
	Cables, SD, Shutdown System 2 (SDS2)	Fails SDS2 on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
	Cables, SD, Standby Generators	Fails Standby Generators on demand.	2.4E-09	0.75	M = 2; P(10a) = 0.09	5	60 months
8	Calandria Vault, O	Direct core damage.	1.0E-11	0.5	M = 1; P(2b) = 0.05; P(3) = 0.05	5	60 months
11	Containment - Concrete, SD	Fails the Containment integrity.	1.0E-13	0	M = 1-2; P(2b Cont.) =0.05	5	Based on the CLRT.
12	Containment - Foundations, SD	Fails the Containment integrity.	1.0E-13	0	M = 1; P(2b Cont.) =0.05; P(3 Oth. Str.) = 0.05	N/A	Considered uninspected.
13	Containment - Penetrations, SD	Fails the Containment integrity.	1.0E-10	0.5	M = 1; P(10b) = 0.18	5	Based on the CLRT.
14	Containment - Steel, SD	Fails the Containment integrity.	1.0E-13	0	M = 1; P(2b Cont.) =0.05	5	Based on the CLRT.
16	EDG, Standby Generators, SD	Fails Standby Generators on demand.	1.0E-06	0.75	M = 2; P(11) = 0.27	1	3 months
	EDG, Emergency Power Supply, SD	Fails EPS on demand.	1.0E-06	0.75	M = 2; P(11) = 0.27	1	3 months
17	Expansion joints, O, Boiler Feedwater System	Initiator: Loss of FW / Plant trip	3.0E-08	0.5	M = 1; P(5) = 0.09	5	Based on piping

# (1)	SSC (1)	Mapping to PSA Model	Acceleration Rate (/hr./yr.) (2)	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ (3)	Remark (4)	T_{AM}, yr. (5)	Remark (6)
	Expansion joints, O,Raw Service System	Initiator: Loss of RSW.	3.0E-08	0.5	M = 1; P(5) = 0.09	5	Based on piping
	Expansion joints, SD,Raw Service System	Fails RSW on demand (in the case of actuation of safety signal).	3.0E-08	0.5	M = 1; P(5) = 0.09	5	Based on piping
	Expansion joints, O, Recirculated Cooling Water System	Initiator: Loss of RCW.	3.0E-08	0.5	M = 1; P(5) = 0.09	5	Based on piping
	Expansion joints, SD, Recirculated Cooling Water System	Fails RCW on demand (in the case of actuation of safety signal)	3.0E-08	0.5	M = 1; P(5) = 0.09	5	Based on piping
21	Other Concrete, O, Boiler Feedwater System	Initiator: Loss of FW / Plant trip	1.0E-13	0	M = 1; P(3) = 0.05	5	Visual inspections considered.
	Other Concrete, O, Cooling Water Intake and Discharge	Initiator: Loss of RSW.	1.0E-13	0.75	M = 2; P(3) = 0.05	5	Visual inspections considered.
	Other Concrete, SD, Emergency Water Supply	Fails EWS on demand.	1.0E-13	0.75	M = 2; P(3) = 0.05	5	Visual inspections considered.
22	Other Foundations, SD, Emergency Water Supply	Fails EWS on demand.	1.0E-13	0	M = 1; P(2b Cont.) =0.05; P(3 Oth. Str.) = 0.05	N/A	Considered uninspected.
26b	Piping, SD, Boiler Emergency Cooling	Fails Boiler EFW on demand.	1.0E-08 (7)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SM, Dousing System	Dousing System unavailable	5.0E-09 (8)	0.5	M = 1; P(5) = 0.09	5	18 months for large

# (1)	SSC (1)	Mapping to PSA Model	Acceleration Rate (/hr./yr.) (2)	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ (3)	Remark (4)	T_{AM}, yr. (5)	Remark (6)
		when demanded.					piping, 60 months for small piping
	Piping, SD, Emergency Core Cooling and Recovery	Fails ECC on demand.	3.0E-08 (9)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SD, Emergency Power Supply	Fails EPS on demand.	3.0E-09 (10)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SD, Emergency Water Supply	Fails EWS on demand.	1.0E-08 (11)	0.5	M = 1; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, O, Recirculated Cooling Water	Initiator: Loss of RCW	4.0E-08 (12)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SD, Recirculated Cooling Water	Fails RCW on demand (in the case of actuation of safety signal)	4.0E-08 (12)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, O, Shutdown Cooling System	Initiator: Loss of Shutdown Cooling.	2.0E-08 (13)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SD, Shutdown System 2 (SDS2)	Fails SDS2 on demand.	5.0E-09 (14)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for small piping
	Piping, SD, Standby Generators	Fails Standby Generators on demand.	3.0E-09 (15)	0.75	M = 2; P(5) = 0.09	5	18 months for large piping, 60 months for

# (1)	SSC (1)	Mapping to PSA Model	Acceleration Rate (/hr./yr.) (2)	Age Improvement Factor (ρ)		Aging Management Activity Period	
				ρ (3)	Remark (4)	T_{AM}, yr. (5)	Remark (6)
							small piping
28	Reactivity Control Units, O	Initiator: Plant trip	6.0E-07	0.75	M = 2; P(9) = 0.45 - 0.81	2	18 months
31	Shutdown System 1 (SDS1), SD	Fails SDS1 on demand.	1.0E-10	0.75	M = 2; P(9, CRDM) = 0.45-0.81; P(10b) = 0.18	2	18 months
32	SG Shell Side, O	Maps to major SLB initiator.	1.0E-12	0.75	M = 2; P(6b) not provided.	10	Assumed. Based on ISI intervals.

Notes for Table 6-3:

1. Reference number and description of SSC from section 4 (Table 4-1).
2. (Absolute) Acceleration rate as in Table 4-1.
3. As compared to the active equipment (i.e. Table 6-1, base case failure rates represented in the PSA model), different ranges of age improvement factor (ρ) were applied to the passive SSCs not modelled in the base case PSA, such as piping, cables or concrete structures. Generally, lower ρ values were applied, since relatively higher ρ values for active equipment, which is subject to a regular maintenance and surveillance, reflects, also, replacements of the wearied out parts, which may not be applicable to passive SSCs.

   Thus, the values of ρ were assigned on the following basis:

   - For the SSCs with M = 2, ρ = 0.75; (residual aging of 25%);
   - For the SSCs with M = 1, ρ = 0.5; (residual aging of 50%);
   - Exceptions to the above are foundations and concrete and steel structures # 11, 12, 14 (Containment), 21 Boiler Feed Water and 22 EWS for which ρ conservatively assumed = 0.

For the explanation of “M” and “P”, refer to Note 4 below. The same remark regarding “P” applies as in the Note 3 under Table 6-1.

To obtain some feeling into the sensitivity of the results, rank "2" (for “M”) was mapped to the value of ρ of 0.4 to 0.5 and rank "1" was mapped to the range of 0.2 to 0.3 of ρ. This was done together with varying the ρ-values for the active SSCs as described in the Note 3 under Table 6-1. The conclusion is that this could result in an increase to SCDF at power of the order of magnitude at t = 20 years.

4. Terms “M” and “P” as defined in section 3. Values as established in Table 3-2. The term “P” is only provided for information.
5. Average aging management activity period, T_{AM}, as defined in section 5. Analogous note applies as in the case of Table 6-1. The intervals are considered to be longer than in the case of active equipment from Table 6-1.
6. Provided for information only: indication of aging management activity period from the TIRGALEX study.
7. Based on the generic 1E-11 /ft/hr/yr and assumed 1000 ft for the EFW. (The average AFW footage in PWRs in NUREG/CR-6928 is 624 ft.)
8. Based on the generic 1E-11 /ft/hr/yr and assumed 500 ft for the Dousing System.
9. Based on the generic 1E-11 /ft/hr/yr and assumed 3000 ft for the ECC. (The average HPI/LPI footage in PWRs in NUREG/CR-6928 is, approximately, 3000 ft.)
10. Based on the generic 1E-11 /ft/hr/yr and assumed 300 ft of piping for the EPS.
11. Based on the generic 1E-11 /ft/hr/yr and assumed 1000 ft of piping for the EWS.
12. Based on the generic 1E-11 /ft/hr/yr and assumed 4000 ft of piping for the RCW. (The average CCW footage in PWR/BWR in NUREG/CR-6928 is, appr., 3500 ft.)
13. Based on the generic 1E-11 /ft/hr/yr and assumed 2000 ft for the Shutdown Cooling System. (Assumed similar to PWR LPI (RHR), for which NUREG/CR-6928 provides an estimate of 1875 ft.)
14. Based on the generic 1E-11 /ft/hr/yr and assumed 500 ft of piping for the SDS2.
15. Based on the generic 1E-11 /ft/hr/yr and assumed 300 ft of piping for the Standby Generators.

As an example, the time-dependent failure rate increase calculated by Eq. 6-1 for the SSC category “Cables, SD, Emergency Power Supply” is shown in Figure 6-2.

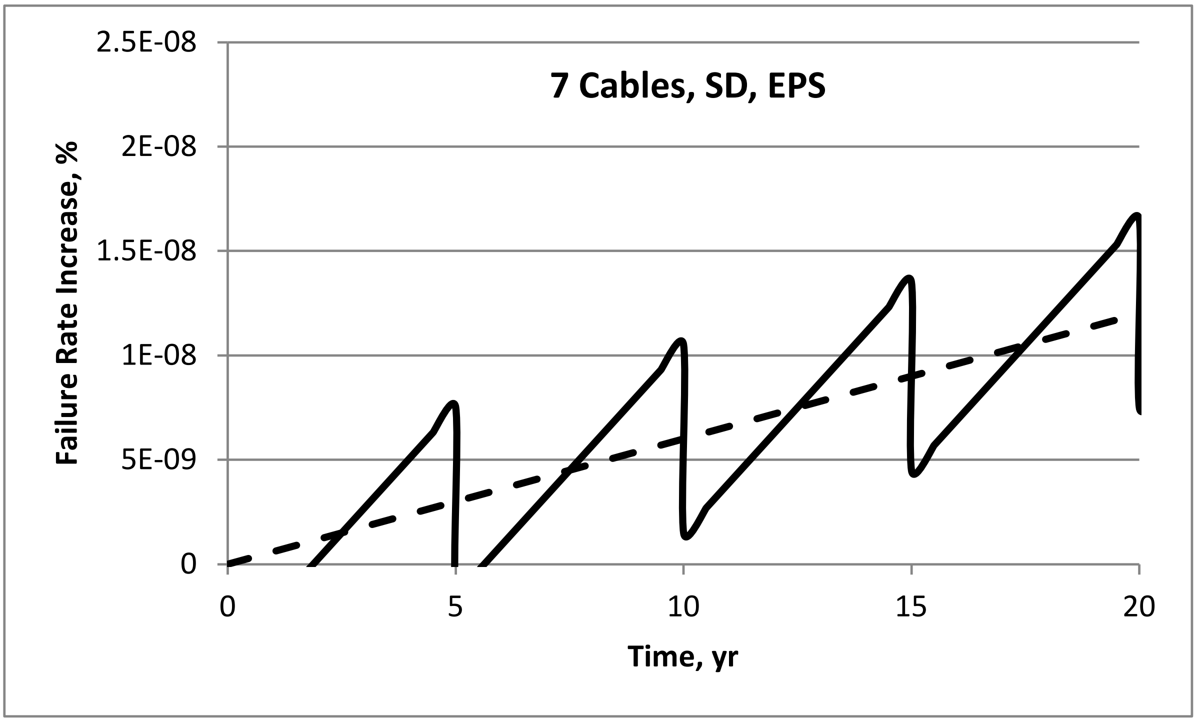


Figure 6-3: Time-dependent failure rate increase for SSC category “Cables, SD, Emergency Power Supply”

Sets of values for increase in failure rates for the SSCs from Table 6-3 were developed in the same manner as in the previous case. For each time point (i.e. 5, 10, 15 and 20 years since $t = 0$) averaged value over one year period was selected, as approximated by the formula under Eq. 6-2, i.e.:

$$\lambda_{ag}(t) = \frac{\lambda(t - 0.5yr) + \lambda(t + 0.5yr)}{2}$$

Failure rate increases for time points of 5, 10, 15 and 20 years from time zero are, for all SSCs from Table 6-3, provided in Table 6-4. Difference with respect to the previous case is that all failure rate increases are now expressed in absolute terms, i.e. per hour.

Table 6-4: Failure rate increases at 5, 10, 15 and 20 years from time zero for SSCs not represented in baseline PSA

#	SSC	Failure Rate Increase, /hr			
		5 yr	10 yr	15 yr	20 yr
4	Bolts - Connections, SD, Containment	2.50E-09	5.00E-09	7.50E-09	1.00E-08
	Bolts - Connections, SM, Emergency Coolant	2.50E-09	5.00E-09	7.50E-09	1.00E-08

#	SSC	Failure Rate Increase, /hr			
		5 yr	10 yr	15 yr	20 yr
	Injection (HP ECI Storage Tank)				
	Bolts - Connections, SD, Emergency Water Supply	2.50E-09	5.00E-09	7.50E-09	1.00E-08
6	Cable Connectors, O, Dig. Comp. SDS1/2	6.13E-09	1.23E-08	1.84E-08	2.45E-08
7	Cables, O, Boiler FW	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Boiler Steam (MS)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Class I Power (250V DC Class I Power System)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Class I Power (250V DC Class I Power System)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Class II Power (Class II Distribution System)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Class II Power (Class II Distribution System)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Class III Distribution System (Not relevant for PSA modelling. Class III is a standby system.)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Class III Distribution System	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Condenser Cooling Water (CCW) System	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Containment	6.00E-09	1.20E-08	1.80E-08	2.40E-08
	Cables, SD, Emergency Core Cooling and Recovery	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Emergency Power Supply	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Emergency Water Supply	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Instrument Air	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Instrument Air	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Liquid Zone System	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Primary Heat Transport	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Reactor Regulating System	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Recirculated Cooling Water	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Recirculated Cooling Water	3.00E-09	6.00E-09	9.00E-09	1.20E-08

#	SSC	Failure Rate Increase, /hr			
		5 yr	10 yr	15 yr	20 yr
	Cables, O, Safety System Programmable Digital Comparator Computers SDS1, SDS2	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Shutdown System 1 (SDS1)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Shutdown System 1 (SDS1)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, O, Shutdown System 2 (SDS2)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Shutdown System 2 (SDS2)	3.00E-09	6.00E-09	9.00E-09	1.20E-08
	Cables, SD, Standby Generators	3.00E-09	6.00E-09	9.00E-09	1.20E-08
8	Calandria Vault, O	2.50E-11	5.00E-11	7.50E-11	1.00E-10
11	Containment - Concrete, SD	5.00E-13	1.00E-12	1.50E-12	2.00E-12
12	Containment - Foundations, SD	5.00E-13	1.00E-12	1.50E-12	2.00E-12
13	Containment - Penetrations, SD	2.50E-10	5.00E-10	7.50E-10	1.00E-09
14	Containment - Steel, SD	5.00E-13	1.00E-12	1.50E-12	2.00E-12
16	EDG, Standby Generators, SD	2.50E-07	5.00E-07	7.50E-07	1.00E-06
	EDG, Emergency Power Supply, SD	2.50E-07	5.00E-07	7.50E-07	1.00E-06
17	Expansion joints, O, Boiler Feedwater System	7.50E-08	1.50E-07	2.25E-07	3.00E-07
	Expansion joints, O,Raw Service System	7.50E-08	1.50E-07	2.25E-07	3.00E-07
	Expansion joints, SD,Raw Service System	7.50E-08	1.50E-07	2.25E-07	3.00E-07
	Expansion joints, O, Recirculated Cooling Water System	7.50E-08	1.50E-07	2.25E-07	3.00E-07
	Expansion joints, SD, Recirculated Cooling Water System	7.50E-08	1.50E-07	2.25E-07	3.00E-07
21	Other Concrete, O, Boiler Feedwater System	5.00E-13	1.00E-12	1.50E-12	2.00E-12
	Other Concrete, O, Cooling Water Intake and Discharge	1.25E-13	2.50E-13	3.75E-13	5.00E-13
	Other Concrete, SD, Emergency Water Supply	1.25E-13	2.50E-13	3.75E-13	5.00E-13
22	Other Foundations, SD, Emergency Water Supply	5.00E-13	1.00E-12	1.50E-12	2.00E-12
26b	Piping, SD, Boiler Emergency Cooling	1.25E-08	2.50E-08	3.75E-08	5.00E-08

#	SSC	Failure Rate Increase, /hr			
		5 yr	10 yr	15 yr	20 yr
	Piping, SM, Dousing System	1.25E-08	2.50E-08	3.75E-08	5.00E-08
	Piping, SD, Emergency Core Cooling and Recovery	3.75E-08	7.50E-08	1.13E-07	1.50E-07
	Piping, SD, Emergency Power Supply	3.75E-09	7.50E-09	1.13E-08	1.50E-08
	Piping, SD, Emergency Water Supply	2.50E-08	5.00E-08	7.50E-08	1.00E-07
	Piping, O, Recirculated Cooling Water	5.00E-08	1.00E-07	1.50E-07	2.00E-07
	Piping, SD, Recirculated Cooling Water	5.00E-08	1.00E-07	1.50E-07	2.00E-07
	Piping, O, Shutdown Cooling System	2.50E-08	5.00E-08	7.50E-08	1.00E-07
	Piping, SD, Shutdown System 2 (SDS2)	6.25E-09	1.25E-08	1.88E-08	2.50E-08
	Piping, SD, Standby Generators	3.75E-09	7.50E-09	1.13E-08	1.50E-08
28	Reactivity Control Units, O	7.50E-07	1.50E-06	2.25E-06	3.00E-06
31	Shutdown System 1 (SDS1), SD	1.25E-10	2.50E-10	3.75E-10	5.00E-10
32	SG Shell Side, O	1.25E-12	2.50E-12	3.75E-12	5.00E-12

With failure rates from Table 6-4, the probabilities (or frequencies, for the “O”-type / initiator events) for the respective new basic events are calculated on the basis of formulas and considerations from Appendix 10.1. General formula for an increase (with respect to $t=0$) in aging related failure probability is:

$$Q_{ag}(t) = \lfloor \lambda_{ag}(t)\; T_{\exp} \rfloor K \qquad \text{Eq. 6-3}$$

In the above expression:

$\lambda_{ag}(t)$ Increase in the corresponding failure rate, as provided in Table 6-4;

$T_{\exp}$ Applicable exposure time, such as (most commonly) one half of the surveillance test period or allowed outage time period; in the case of “O” configuration (initiator type event), the term $T_{\exp}$ does not apply and is, in the above equation, replaced by a dimensionless “1”;

K Conversion factor to obtain a system-level or a function level failure probability.

Additionally, the initial failure probability, Q_0, needs to be added which applies at the time $t=0$. Unlike the previous case, this initial probability does not exist in the model, since the considered SSC is not presented in the baseline PSA model. For the purposes of this study, this initial failure probability at $t=0$ is approximated by the formula:

$$Q_0 = C_R \lfloor \lfloor \lambda(25yr)\ T_{\exp} \rfloor K \rfloor \quad \text{Eq. 6-4}$$

where the term $\lambda(25yr)$ is calculated by the formulas under Eq. 6-1 and Eq. 6-2 by considering $t = 25yr$. This reflects the pre-history of 25 years of operation prior to the plant refurbishment. Note that in the case of "O" configuration (initiating event), Q_0 has the same units as λ, i.e. /hr. The correction factor C_R to accounts for the age improvement brought through the overall plant refurbishment (2008 - 2012). It is assumed $C_R = 0.05$, i.e. 5% of residual aging is considered to apply immediately following a refurbishment, on a general basis.

The total failure probability is then calculated as:

$$Q(t) = Q_0 + \lfloor \lambda_{ag}(t)\ T_{\exp} \rfloor K \quad \text{Eq. 6-5}$$

The above discussed parameters, as assessed for all the SSC categories from **Table 6-4** (i.e. the SSCs not represented in baseline PSA) are presented in **Table 6-5** below. The same table includes the initial failure probability, Q_0, for each SSC, as calculated by the above equation.

Table 6-6 presents the probabilities (or, in the case of "O"-type / initiator events, frequencies) calculated at 5, 10, 15 and 20 years from time zero, for the same SSCs.

Table 6-5: Summary of data for calculation of probabilities (or frequencies) for the SSCs not presented in baseline PSA model

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
4	Bolts - Connections, SD, Containment	21900	One half of the time between CLRTs. CLRT of 5 years assumed.	1.00	Function-level value.	1.37E-05
	Bolts - Connections, SM, Emergency Coolant Injection (HP ECI Storage Tank)	24	Assumed that plant would not operate more than 24 hours with ECC tank OOS.	1.00	Component-level value (ECC tank)	1.50E-08
	Bolts - Connections, SD, Emergency Water Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	System / function -level value.	2.25E-07
6	Cable Connectors, O, Dig. Comp. SDS1/2	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	100.00	Digital system. Assumed there are 100 connectors which can trigger fail-safe mode.	1.53E-07
7	Cables, O, Boiler FW	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	20.00	Failure rate for a single component. Assumed that there are 20 cables which can fail the function. In many cases, multiple failures would, actually, be needed.	1.50E-08
	Cables, O, Boiler Steam (MS)	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	20.00	As above.	1.50E-08
	Cables, O, Class I Power (250V DC Class I Power System)	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	20.00	As above.	1.50E-08

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
	Cables, SD, Class I Power (250V DC Class I Power System)	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Class II Power (Class II Distribution System)	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	20.00	As above.	1.50E-08
	Cables, SD, Class II Power (Class II Distribution System)	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Class III Distribution System (Not relevant for PSA modelling. Standby system.)	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”. (Not relevant for PSA modelling.)	20.00	As above.	1.50E-08
	Cables, SD, Class III Distribution System	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Condenser Cooling Water (CCW) System	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	20.00	As above.	1.50E-08
	Cables, SD, Containment	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	1.08E-05
	Cables, SD, Emergency Core Cooling and Recovery	360	Monthly system surveillance tests assumed. Exposure time is half of the	20.00	As above.	5.40E-06

#	SSC	Exposure Time		Conversion Factor		Q_0 [1]
		T_{exp}, hr	Remark	K	Remark	
			period.			
	Cables, SD, Emergency Power Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, SD, Emergency Water Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Instrument Air	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, SD, Instrument Air	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Liquid Zone System	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, O, Primary Heat Transport	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, O, Reactor Regulating System	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, O, Recirculated Cooling Water	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with	20.00	As above.	1.50E-08

#	SSC	Exposure Time		Conversion Factor		Q_0 [(1)]
		T_{exp}, hr	Remark	K	Remark	
			dimensionless "1".			
	Cables, SD, Recirculated Cooling Water	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Safety System Programmable Digital Comparator Computers SDS1, SDS2	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, O, Shutdown System 1 (SDS1)	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, SD, Shutdown System 1 (SDS1)	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, O, Shutdown System 2 (SDS2)	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	20.00	As above.	1.50E-08
	Cables, SD, Shutdown System 2 (SDS2)	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
	Cables, SD, Standby Generators	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	20.00	As above.	5.40E-06
8	Calandria Vault, O	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with	1.00	Function-level value.	6.25E-12

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
			dimensionless “1”.			
11	Containment - Concrete, SD	21900	One half of the time between CLRTs. CLRT of 5 years assumed.	1.00	Function-level value.	2.74E-09
12	Containment - Foundations, SD	Time passed since t = 0	Time passed since t = 0	1.00	Function-level value.	2.74E-08
13	Containment - Penetrations, SD	21900	One half of the time between CLRTs. CLRT of 5 years assumed.	1.00	Function-level value.	1.37E-06
14	Containment - Steel, SD	21900	One half of the time between CLRTs. CLRT of 5 years assumed.	1.00	Function-level value.	2.74E-09
16	EDG, Standby Generators, SD	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	Function-level value. (EDG)	2.25E-05
	EDG, Emergency Power Supply, SD	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	Function-level value. (EDG)	2.25E-05
17	Expansion joints, O, Boiler Feedwater System	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	1.00	System level value. Assumed that any rupture / leak can fail the system / function, regardless of the expansion joint it occurs at. Conservative assumption.	1.88E-08
	Expansion joints, O,Raw Service System	N/A	For “O” configuration / initiator, replace T_{exp} in the equation with dimensionless “1”.	1.00	System level value. Assumed that any rupture / leak can fail the system / function,	1.88E-08

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
					regardless of the expansion joint it occurs at. Conservative assumption.	
	Expansion joints, SD,Raw Service System	360	Standby period of 1 month assumed for standby parts of the system. Exposure time is a half of this period.	1.00	System level value. Assumed that any rupture / leak can fail the system / function, regardless of the expansion joint it occurs at. Conservative assumption.	6.75E-06
	Expansion joints, O, Recirculated Cooling Water System	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	System level value. Assumed that any rupture / leak can fail the system / function, regardless of the expansion joint it occurs at. Conservative assumption.	1.88E-08
	Expansion joints, SD, Recirculated Cooling Water System	360	Standby period of 1 month assumed for standby parts of the system. Exposure time is a half of this period.	1.00	System level value. Assumed that any rupture / leak can fail the system / function, regardless of the expansion joint it occurs at. Conservative assumption.	6.75E-06
21	Other Concrete, O, Boiler Feedwater System	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	Function-level value.	1.25E-13
	Other Concrete, O, Cooling Water Intake and Discharge	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	Function-level value.	3.13E-14

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
	Other Concrete, SD, Emergency Water Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	System level rupture / leak rate. Assumed that any rupture / leak can fail the system / function, regardless of the piping segment it occurs at. Conservative assumption.	1.13E-11
22	Other Foundations, SD, Emergency Water Supply	Time passed since t = 0	Time passed since t = 0	1.00	Function-level value.	2.74E-08
26b	Piping, SD, Boiler Emergency Cooling	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	System level rupture / leak rate. Assumed that any rupture / leak can fail the system / function, regardless of the piping segment it occurs at. Conservative assumption.	1.13E-06
	Piping, SM, Dousing System	24	Assumed that plant would not operate more than 24 hours with Dousing System OOS.	1.00	As above.	7.50E-08
	Piping, SD, Emergency Core Cooling and Recovery	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	As above.	3.38E-06
	Piping, SD, Emergency Power Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	As above.	3.38E-07
	Piping, SD, Emergency Water Supply	360	Monthly system surveillance tests assumed. Exposure time is half of the	1.00	As above.	2.25E-06

#	SSC	Exposure Time		Conversion Factor		Q_0 [1]
		T_{exp}, hr	Remark	K	Remark	
			period.			
	Piping, O, Recirculated Cooling Water	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	As above.	1.25E-08
	Piping, SD, Recirculated Cooling Water	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	As above.	4.50E-06
	Piping, O, Shutdown Cooling System	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	As above.	6.25E-09
	Piping, SD, Shutdown System 2 (SDS2)	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	As above.	5.63E-07
	Piping, SD, Standby Generators	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	As above.	3.38E-07
28	Reactivity Control Units, O	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with dimensionless "1".	1.00	Function-level value.	1.88E-07
31	Shutdown System 1 (SDS1), SD	360	Monthly system surveillance tests assumed. Exposure time is half of the period.	1.00	Function-level value.	1.13E-08
32	SG Shell Side, O	N/A	For "O" configuration / initiator, replace T_{exp} in the equation with	1.00	Function-level value.	3.13E-13

#	SSC	Exposure Time		Conversion Factor		Q_0 (1)
		T_{exp}, hr	Remark	K	Remark	
			dimensionless "1".			

Notes for Table 6-5:

1. In the case of "O" configuration, Q_0 has the units of λ, i.e. /hr.

Table 6-6: Probabilities (frequencies) at 5, 10, 15 and 20 years from time zero for SSCs not represented in baseline PSA

#	SSC	Probability (Frequency for „O“ configuration – Initiators (1))			
		5 yr	10 yr	15 yr	20 yr
4	Bolts - Connections, SD, Containment	6.84E-05	1.23E-04	1.78E-04	2.33E-04
	Bolts - Connections, SM, Emergency Coolant Injection (HP ECI Storage Tank)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Bolts - Connections, SD, Emergency Water Supply	1.13E-06	2.03E-06	2.93E-06	3.83E-06
6	Cable Connectors, O, Dig. Comp. SDS1/2	7.66E-07	1.38E-06	1.99E-06	2.60E-06
7	Cables, O, Boiler FW	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Boiler Steam (MS)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Class I Power (250V DC Class I Power System)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Class I Power (250V DC Class I Power System)	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Class II Power (Class II Distribution System)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Class II Power (Class II Distribution System)	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Class III Distribution System (Not relevant for PSA modelling. Standby System.)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Class III Distribution System	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Condenser Cooling Water (CCW) System	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Containment	5.40E-05	9.72E-05	1.40E-04	1.84E-04
	Cables, SD, Emergency Core Cooling and Recovery	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, SD, Emergency Power Supply	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, SD, Emergency Water Supply	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Instrument Air	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Instrument Air	2.70E-05	4.86E-05	7.02E-05	9.18E-05

#	SSC	Probability (Frequency for „O“ configuration – Initiators [1])			
		5 yr	10 yr	15 yr	20 yr
	Cables, O, Liquid Zone System	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Primary Heat Transport	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Reactor Regulating System	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Recirculated Cooling Water	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Recirculated Cooling Water	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Safety System Programmable Digital Comparator Computers SDS1, SDS2	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, O, Shutdown System 1 (SDS1)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Shutdown System 1 (SDS1)	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, O, Shutdown System 2 (SDS2)	7.50E-08	1.35E-07	1.95E-07	2.55E-07
	Cables, SD, Shutdown System 2 (SDS2)	2.70E-05	4.86E-05	7.02E-05	9.18E-05
	Cables, SD, Standby Generators	2.70E-05	4.86E-05	7.02E-05	9.18E-05
8	Calandria Vault, O	3.13E-11	5.63E-11	8.13E-11	1.06E-10
11	Containment - Concrete, SD	1.37E-08	2.46E-08	3.56E-08	4.65E-08
12	Containment - Foundations, SD	4.93E-08	1.15E-07	2.24E-07	3.78E-07
13	Containment - Penetrations, SD	6.84E-06	1.23E-05	1.78E-05	2.33E-05
14	Containment - Steel, SD	1.37E-08	2.46E-08	3.56E-08	4.65E-08
16	EDG, Standby Generators, SD	1.13E-04	2.03E-04	2.93E-04	3.83E-04
	EDG, Emergency Power Supply, SD	1.13E-04	2.03E-04	2.93E-04	3.83E-04
17	Expansion joints, O, Boiler Feedwater System	9.38E-08	1.69E-07	2.44E-07	3.19E-07
	Expansion joints, O, Raw Service System	9.38E-08	1.69E-07	2.44E-07	3.19E-07
	Expansion joints, SD, Raw Service System	3.38E-05	6.08E-05	8.78E-05	1.15E-04
	Expansion joints, O, Recirculated Cooling Water System	9.38E-08	1.69E-07	2.44E-07	3.19E-07
	Expansion joints, SD, Recirculated Cooling Water System	3.38E-05	6.08E-05	8.78E-05	1.15E-04
21	Other Concrete, O, Boiler Feedwater System	6.25E-13	1.13E-12	1.63E-12	2.13E-12

#	SSC	Probability (Frequency for „O“ configuration – Initiators [1])			
		5 yr	10 yr	15 yr	20 yr
	Other Concrete, O, Cooling Water Intake and Discharge	1.56E-13	2.81E-13	4.06E-13	5.31E-13
	Other Concrete, SD, Emergency Water Supply	5.63E-11	1.01E-10	1.46E-10	1.91E-10
22	Other Foundations, SD, Emergency Water Supply	4.93E-08	1.15E-07	2.24E-07	3.78E-07
26b	Piping, SD, Boiler Emergency Cooling	5.63E-06	1.01E-05	1.46E-05	1.91E-05
	Piping, SM, Dousing System	3.75E-07	6.75E-07	9.75E-07	1.28E-06
	Piping, SD, Emergency Core Cooling and Recovery	1.69E-05	3.04E-05	4.39E-05	5.74E-05
	Piping, SD, Emergency Power Supply	1.69E-06	3.04E-06	4.39E-06	5.74E-06
	Piping, SD, Emergency Water Supply	1.13E-05	2.03E-05	2.93E-05	3.83E-05
	Piping, O, Recirculated Cooling Water	6.25E-08	1.13E-07	1.63E-07	2.13E-07
	Piping, SD, Recirculated Cooling Water	2.25E-05	4.05E-05	5.85E-05	7.65E-05
	Piping, O, Shutdown Cooling System	3.13E-08	5.63E-08	8.13E-08	1.06E-07
	Piping, SD, Shutdown System 2 (SDS2)	2.81E-06	5.06E-06	7.31E-06	9.56E-06
	Piping, SD, Standby Generators	1.69E-06	3.04E-06	4.39E-06	5.74E-06
28	Reactivity Control Units, O	9.38E-07	1.69E-06	2.44E-06	3.19E-06
31	Shutdown System 1 (SDS1), SD	5.63E-08	1.01E-07	1.46E-07	1.91E-07
32	SG Shell Side, O	1.56E-12	2.81E-12	4.06E-12	5.31E-12

Notes for Table 6-6:

1. In the case of “O” configuration, Q_0 has the units of λ, i.e. /hr.

6.2 PSA Modelling

The development of the Aging PSA models consists of the following tasks:

- Development of top logic for modelling of the risk metrics SCDF and LRF for both at power and shut-down operation;
- Identification of the PSA elements affected by aging and adjusting the failure rate, frequency or probability values according to description presented in 6.1;

- Determination of new PSA elements and incorporation into the top logic models;
- Generation of the minimal cut sets (MSCs) for each of the risk metrics and quantification of the results;
- Development of new quantification procedure.

6.2.1 Development of Top Logic for Modelling of the Risk Metrics SCDF and LRF

The development of the top logic for the modelling of the risk metrics SCDF and LRF was necessary to create a model for easier and fast re-quantification of the results.

The original PSA model in its form does not allow easy re-quantification to support risk-informed activities, as the quantification procedure is rather complicated and time consuming. Therefore, a decision was made to develop new top logic models in order to enable us performing the necessary quantification series needed for this project.

The first step was to regenerate the original PSA model in a different form as it was. It included the development of new CAFTA fault trees collecting the event sequence models from the original CAFTA models in top level "OR" logic for each PDS and EPRC category, and comparison of the quantification results with the original PSA results presented in the appended MS EXCEL worksheets. Also the minimal cut sets were compared. The results showed little difference that can be explained by the correct Boolean solution of the new model and the more reasonable truncation method.

In the second step those PDS and EPRC logics were collected, that, according to the original PSA, could be considered as SCDF and LRF. This was done for both at power and shutdown operation, and the quantification results were again compared with the results of the original quantification. Again, small differences could be observed, but, as mentioned before, those are explainable by different MCS generation and quantification procedure.

In the final step the four models (SCDF at power, SCDF shutdown, LRF at power and LRF shutdown) were integrated in one model named "SCDF-LRF-AP-SD.caf".

Within this new model one can generate the MCSs for the following cases:

- SCDF-AP – Severe core damage frequency at power
- SCDF-SD – Severe core damage frequency at shutdown
- SCDF-ALL - Severe core damage frequency – all operating states
- LRF-AP – Large release frequency at power
- LRF-SD – Large release frequency at shutdown
- LRF-ALL – Large release frequency – all operating states

After incorporating the new basic events discussed in 6.1.2, four MCS models were generated for the purpose of the quantification of the aging risk, namely SCDF-AP, SCDF-SD, LRF-AP and LRF-SD.

The goal was to generate as many MCSs as possible with CAFTA, a truncation probability of 1E-12 was applied. Lower truncation probability caused memory errors during the running of the code.

As a result four sets of MCS were generated and used further in the quantification process. The following number of MCSs was generated for the different cases:

- SCDF_AP: 2.231.091
- SCDF-SD: 374.892
- LRF-AP: 72.327
- LRF-SD: 31.984

6.2.2 Identification of the Affected PSA Elements

Two types of PSA elements that exist in the PL NGS PSA model were affected by aging impact modelling:

- Basic event probabilities, or frequencies,
- Failure rate parameters.

The basic event probabilities or frequencies are assigned directly to the basic event they belong to. The failure rate parameters are individual PSA elements representing the failure rate for a group of similar components, and are assigned to the relevant basic events by coding the parameter ID into the basic event ID (this is a CAFTA feature).

The affected probability type basic events represent plant components or structures, and the aging effect is modelled as a time dependent increase in the failure probability of the component or structure. Failure probabilities for components or structures not presented in the baseline PSA were modeled through newly created probability type basic events which are further described and characterized in section 6.2.3 below.

The frequency type basic events are the initiating events, mainly those representing damage of a pipeline of some system. The change in the initiating event frequency is calculated as described in 6.1.1 and presented in **Table 6-2**. The affected initiating events and the associated initiating event frequency can be found in **Table 6-7**.

The component failure rates are represented by failure rate parameters (they can be found in CAFTA DB "Type Code Data" table). The aging effect causes a time dependent increase, and this increase is calculated as described in 6.1.1 and presented in **Table 6-2**. The affected failure rate parameters and the associated values can be seen in **Table 6-7**.

Table 6-7: Failure rate parameters and values at 10 and 20 Years from time zero for SSCs represented in baseline PSA

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
1	AHU	DAS -LO	4.89E-03	5.24E-03
		DAS -XL	4.89E-03	5.24E-03
2	AOV	VXD CFC	1.46E-02	1.53E-02

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VXD DCS	2.55E-02	2.67E-02
		VXD DFC	2.12E-02	2.22E-02
		VXD DFO	2.12E-02	2.22E-02
		VYC AFC	1.41E-02	1.47E-02
		VYC BFO	3.17E-02	3.32E-02
		VYD ACC	6.47E-04	6.78E-04
		VYD ACS	1.12E-04	1.18E-04
		VYD AFC	1.77E-03	1.86E-03
		VYD AFO	1.13E-03	1.19E-03
		VYD AIL	1.86E-02	1.95E-02
		VYD ALO	9.70E-04	1.02E-03
		VYD AOO	3.23E-04	3.39E-04
		VYD AOS	1.12E-04	1.18E-04
		VYD ASO	1.12E-04	1.18E-04
		VYD AXL	1.46E-03	1.53E-03
		VYD BCC	1.89E-03	1.98E-03
		VYD BCS	1.89E-03	1.98E-03
		VYD BFC	5.47E-03	5.73E-03
		VYD BFO	1.89E-03	1.98E-03
		VYD BOO	1.89E-03	1.98E-03
		VYD BOS	1.89E-03	1.98E-03
		VYD BSO	6.75E-03	7.07E-03
		VYD CCS	7.51E-03	7.87E-03
		VYD CFC	1.08E-02	1.13E-02
		VYD -CS	1.04E-04	1.09E-04
		VAD BCS	7.05E-03	7.38E-03
		VAD BFC	1.02E-02	1.06E-02

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VAD BFO	7.05E-03	7.38E-03
		VBC CFO	1.41E-02	1.47E-02
		VBC CIL	1.41E-02	1.47E-02
		VBC COS	1.41E-02	1.47E-02
		VBC DCC	1.70E-03	1.78E-03
		VBC DCS	1.70E-03	1.78E-03
		VBC DFC	1.70E-03	1.78E-03
		VBC DFO	2.46E-03	2.57E-03
		VBC DIL	1.92E-02	2.01E-02
		VBC DIP	1.70E-03	1.78E-03
		VBC DOO	1.70E-03	1.78E-03
		VBC DOS	1.70E-03	1.78E-03
		VBC DSO	2.46E-03	2.57E-03
		VBC DXL	9.83E-03	1.03E-02
		VBC ECC	1.28E-03	1.34E-03
		VBC ECS	1.42E-03	1.49E-03
		VBC EFC	2.65E-02	2.77E-02
		VBC EFO	1.28E-03	1.34E-03
		VBC EIL	1.88E-02	1.97E-02
		VBC EOO	3.70E-03	3.87E-03
		VBC EOS	1.28E-03	1.34E-03
		VBC ESO	3.14E-02	3.29E-02
		VBD BCS	4.60E-04	4.82E-04
		VBD BFC	4.60E-04	4.82E-04
		VBD DFO	7.06E-03	7.39E-03
		VBD DIL	2.04E-02	2.13E-02
		VBD DOS	7.06E-03	7.39E-03

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VBD DSO	7.06E-03	7.39E-03
		VBD -FC	7.06E-03	7.39E-03
		V-C BCS	3.53E-03	3.70E-03
		VDD BCS	7.07E-03	7.40E-03
		VDD BFC	7.07E-03	7.40E-03
		VDD BFO	1.02E-02	1.07E-02
		VDD BIL	7.06E-03	7.39E-03
		VDD BOS	7.06E-03	7.39E-03
		VDD BSO	2.04E-02	2.13E-02
		VGC CCC	9.22E-03	9.66E-03
		VGC CCS	9.22E-03	9.66E-03
		VGC CFC	1.47E-02	1.54E-02
		VGC CFO	9.22E-03	9.66E-03
		VGC COS	9.22E-03	9.66E-03
		VGC CSO	9.22E-03	9.66E-03
		VGD BCS	7.94E-03	8.32E-03
		VGD BFC	7.94E-03	8.32E-03
		VRC DCC	1.76E-03	1.85E-03
		VRC DFC	2.54E-03	2.66E-03
		VRC DIL	1.02E-02	1.07E-02
		VXC ACC	2.02E-03	2.11E-03
		VXC ACS	2.02E-03	2.11E-03
		VXC AIL	2.91E-03	3.05E-03
		VXC ASO	2.02E-03	2.11E-03
		VXC BCS	7.06E-03	7.39E-03
		VXC BFC	1.02E-02	1.07E-02
		VXC BFO	1.02E-02	1.07E-02

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VXC BIL	1.02E-02	1.07E-02
		VXC BOS	7.06E-03	7.39E-03
		VXC CCS	3.34E-02	3.50E-02
		VXC CFC	3.34E-02	3.50E-02
	AOV, RSW	See Note 1. to this table		
3	Battery	BY- -LO	5.58E-02	5.96E-02
5	Bus	BU- CCN	4.72E-03	4.96E-03
		BU- DCN	1.50E-03	1.58E-03
		BU- ECN	1.21E-03	1.28E-03
		BU- GCN	6.14E-04	6.46E-04
		BU- HCN	8.65E-05	9.10E-05
		BU- ICN	1.67E-03	1.75E-03
		BUC -CN	2.89E-03	3.04E-03
		BUD -CN	2.38E-03	2.51E-03
9	Circuit Breaker	EA- ACF	3.97E-02	4.16E-02
		EA- AFC	6.95E-03	7.28E-03
		EA- AOS	6.95E-03	7.28E-03
		EA- ASC	9.82E-03	1.03E-02
		EC- BFC	9.68E-03	1.01E-02
		EC- BFO	3.29E-02	3.44E-02
		EC- BOS	1.93E-02	2.02E-02
		EC- CFC	3.34E-03	3.50E-03
		EC- CFO	2.06E-02	2.16E-02
		EC- COS	8.46E-03	8.87E-03
		EC- DFC	4.55E-04	4.76E-04
		EC- DFO	9.10E-03	9.54E-03
		EC- DOS	3.64E-03	3.82E-03

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		EC- EOS	2.72E-03	2.85E-03
		EC- GOS	4.82E-03	5.05E-03
		EC- HOS	9.67E-04	1.01E-03
		EC- ZFC	5.65E-03	5.92E-03
		EC- ZOS	6.78E-03	7.11E-03
		ED- AOS	1.66E-03	1.74E-03
		ED- -CC	2.59E-04	2.72E-04
		ED- EOS	1.48E-03	1.55E-03
		ED- -FO	1.11E-03	1.17E-03
		ED- GOS	4.41E-04	4.62E-04
		ED- -OS	2.23E-03	2.33E-03
		EX- -FT	2.76E-02	2.89E-02
		EX- -OC	3.66E-03	3.84E-03
		EXS -FT	1.69E-04	1.77E-04
		EXS -OC	2.24E-05	2.34E-05
10	Check Valve	VC- ACC	4.84E-04	5.07E-04
		VC- AFC	4.84E-04	5.07E-04
		VC- AFO	2.42E-03	2.53E-03
		VC- AIL	1.82E-02	1.90E-02
		VC- AOO	1.68E-04	1.76E-04
		VC- AXL	3.14E-03	3.29E-03
		VC- BFC	1.67E-03	1.75E-03
		VC- BFO	9.66E-03	1.01E-02
		VC- CFC	1.64E-03	1.72E-03
		VC- CXL	7.09E-03	7.43E-03
		VC- EFC	9.20E-06	9.64E-06
		VC- -FC	3.66E-04	3.84E-04

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VC- -FO	2.93E-03	3.07E-03
		VC- -IL	1.72E-02	1.80E-02
		VC- -XL	4.03E-03	4.22E-03
		VCW ACC	3.62E-03	3.80E-03
		VCW AXL	3.62E-03	3.80E-03
		VCW BFC	8.36E-06	8.77E-06
		VCW BXL	1.03E-02	1.08E-02
		VCW CCC	7.81E-03	8.18E-03
		VCW CFC	5.42E-03	5.68E-03
		VCW CFO	7.81E-03	8.18E-03
		VCW DFC	9.13E-06	9.57E-06
		VCW DFO	2.70E-03	2.83E-03
		VCW DXL	8.10E-03	8.48E-03
		VCX DCC	8.19E-05	8.58E-05
		VCX DFC	1.01E-05	1.06E-05
		VCX DFO	8.19E-05	8.58E-05
		VCY AFC	4.47E-04	4.69E-04
		VCY AFO	6.46E-04	6.77E-04
		VCY AIL	1.23E-02	1.29E-02
		VCY AXL	6.46E-04	6.77E-04
	Check Valve, RSW	See Note 1. to this table		
18	Heat Exchanger	H-- -IH	1.94E-01	1.95E-01
		H-- -IL	1.21E-02	1.21E-02
		H-- -LO	5.23E-05	5.25E-05
		H-- -XL	4.87E-02	4.90E-02
		HHS OIH	3.68E-02	3.70E-02

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		HHS OIL	3.68E-02	3.70E-02
		HHS OLO	1.59E-04	1.60E-04
		HHS OXL	3.92E-05	3.94E-05
		HHS RIH	2.77	2.79
		HHS RIL	1.11E-02	1.11E-02
		HHS RLO	1.40E-04	1.40E-04
		H-P -IH	7.99E-04	8.03E-04
		H-P -IL	3.69E-02	3.71E-02
		H-P -LO	1.35E-04	1.35E-04
		H-P -XL	1.85E-01	1.86E-01
		H-U -IH	2.68E-03	2.70E-03
		H-U -IL	1.08E-02	1.08E-02
		H-U -LO	5.96E-05	5.99E-05
		H-U -XL	4.43E-02	4.45E-02
19	Inverter	INV DLO	9.02E-04	9.43E-04
		INV DSP	1.24E-03	1.29E-03
		INV VLO	7.79E-02	8.14E-02
		INV VSP	1.17E-01	1.22E-01
20	MOV	D-M -FC	1.40E-03	1.50E-03
		VBM CCS	1.01E-04	1.08E-04
		VBM CFC	7.14E-04	7.64E-04
		VBM DFC	7.25E-04	7.75E-04
		VBM ECS	1.38E-01	1.47E-01
		VBM EFC	1.38E-01	1.47E-01
		VBM EFO	1.74E-01	1.86E-01
		VBM EOO	1.38E-01	1.47E-01
		VGM CCC	1.23E-03	1.31E-03

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		VGM CCS	1.23E-03	1.31E-03
		VGM CFC	1.23E-03	1.31E-03
		VGM COO	1.23E-03	1.31E-03
		VGM CFO	8.85E-03	9.45E-03
		VGM COS	1.77E-03	1.90E-03
		VGM DCC	6.94E-03	7.43E-03
		VGM DFC	6.94E-03	7.43E-03
		VGM DOO	6.94E-03	7.43E-03
		VGM DCS	4.82E-03	5.15E-03
		VGM DXL	4.82E-03	5.15E-03
		VGM DOS	4.82E-03	5.15E-03
		V-M CCC	1.63E-03	1.75E-03
		V-M COS	1.63E-03	1.75E-03
		VSM DCS	7.21E-03	7.71E-03
		VYM BCS	4.82E-03	5.15E-03
		VYM BFC	4.82E-03	5.15E-03
		VYM BFO	5.56E-02	5.95E-02
	MOV, RSW	See Note 1. to this table		
23	PHT Feeders (Map to Feeders LOCA)	LOHS2.2	1.12E-04	1.13E-04
25	PHT Pressure Tubes (Map to Pressure Tube LOCA)	LOHS1.2	1.02E-03	1.04E-03
26b	Piping - other; Blowoff System (Map to SLB).	Considered in Piping - other; Boiler Steam (Main Steam) System		
	Piping - other; Boiler Feedwater System (Map to FWLB).	LOHS1.2	1.02E-03	1.04E-03
		LOHS1.3	1.02E-04	1.03E-04
		LOHS1.4	2.52E-04	2.55E-04

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		LOHS1.5	7.45E-04	7.56E-04
		LOHS1.6	1.51E-03	1.53E-03
	Piping - other; Boiler Steam (Main Steam) System (Map to SLB).	LOHS4.1	1.01E-03	1.02E-03
		LOHS4.2	4.47E-05	4.55E-05
		LOHS4.3	2.12E-03	2.15E-03
		LOHS5.1	2.30E-02	2.34E-02
	Piping - other; RSW	MI-RSW-12	8.17E-04	8.41E-04
		MI-RSW-24	1.28E-04	1.31E-04
		MNI-RSW-12	8.42E-06	8.66E-06
		MNI-RSW-24	2.11E-05	2.17E-05
		SI-RSW-12	1.61E-03	1.69E-03
		SI-RSW-24	2.55E-04	2.63E-04
		SNI-RSW-12	1.68E-05	1.73E-05
		SNI-RSW-24	4.23E-05	4.36E-05
26a	Piping - PHT (Map to ex-core LOCA)	LOCA2.3	1.0E-04	1.044E-04
27	Pump	P-C ALO	2.98E-02	3.12E-02
		P-C ASZ	2.29E-03	2.40E-03
		P-C AXL	5.28E-02	5.53E-02
		P-C BSZ	1.41E-02	1.47E-02
		P-C CSZ	8.45E-03	8.86E-03
		P-C ESZ	1.41E-02	1.47E-02
		P-C HSZ	1.75E-01	1.84E-01
		PDD -LO	1.71E-02	1.79E-02
		PDD -XL	2.01E-01	2.10E-01
		PDI -LO	4.46E-03	4.68E-03
		PDI -SZ	1.11E-03	1.17E-03

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
		PHC ALO	2.27E-02	2.34E-02
		PHC ASZ	3.19E-03	3.34E-03
		PHC AXL	4.47E-02	4.69E-02
		PHC BLO	1.68E-01	1.76E-01
		PHC CLO	9.20E-03	9.64E-03
		PHC DLO	1.35E-02	1.42E-02
		PHC DSZ	9.40E-03	9.85E-03
		PHC GLO	1.04E-03	1.09E-02
		PHC GSZ	9.40E-03	9.85E-03
29	Rectifier	DIR -OC	1.56E-04	1.59E-04
		DIR -SC	4.70E-05	4.77E-05
30	Relief Valve	VR- -CC	1.89E-03	1.96E-03
		VR- -IL	1.95E-02	2.01E-02
		VR- -SP	4.26E-03	4.41E-03
		VR- -XL	5.21E-03	5.38E-03
		VRG ACC	2.46E-03	2.55E-03
		VRG AFC	3.70E-03	3.82E-03
		VRG AIL	2.03E-02	2.10E-02
		VRG ASP	4.93E-03	5.09E-03
		VRG AXL	5.54E-03	5.72E-03
		VRG -CC	2.46E-03	2.55E-03
		VRG -FC	3.70E-03	3.82E-03
		VRG -IL	2.09E-02	2.16E-02
		VRG -SP	4.92E-03	5.08E-03
		VRG -XL	5.54E-03	5.72E-03
33	SG Tube Side (Map to SGTR)	LOCA4.3	8.43E-04	8.92E-04
		LOCA2.1	8.43E-06	8.92E-06

#	SSC	Parameter/Basic event ID	Value for 10 years (1/year)	Value for 20 years (1/year)
34	Solenoid Valve	V-S -IL	3.92E-03	4.20E-03
		V-S -DE	2.35E-03	2.52E-03
		V-S -DD	6.10E-05	6.52E-05
		V-S -ED	1.73E-03	1.85E-03
		V-S -EE	8.63E-04	9.24E-04
		V-S -SO	1.26E-03	1.34E-03
		V-S -XL	4.09E-03	4.37E-03
35, 36	Tank	TK- -XL	7.07E-03	7.57E-03
		TK- -RU	5.13E-06	5.48E-06
	Tank - Dousing System; EWS; SDS2	See Note 2. to this table		
37	Transformer	XFP ELO	8.27E-04	8.31E-04
		XFP ESC	8.27E-04	8.31E-04
		XFP -LO	3.43E-03	3.44E-03
		XFP -OC	2.37E-03	2.38E-03
		XFP -PP	2.37E-03	2.38E-03
		XFP -SC	3.43E-03	3.44E-03

Notes for **Table 6-7**:

1. The RWS valve failures that could be affected by aging and causing system failure do neither are present in the MCS of the SCDF, nor in the LRF models, therefore the aging model does not have any impact on the PSA results. The aging model for these valves is the same as the aging model of the general cases, regardless the fact that the input calculation in 6.1.1 shows faster degradation.
2. The input calculations in 6.1.1 for these tanks show faster aging than for the general cases. But the MCS generated for the SCDF and LRF calculations do not contain the relevant basic events, therefore it can be stated, that the effect of the faster aging does not have any impact on the PSA results.

6.2.3 Determination and Development of New PSA Elements

In section 6.1.2 the details of the calculation of the aging related failure probabilities for SSCs originally not modelled in the PSA are given. In this section the PSA modelling details are described for each new basic event introduced into the aging PSA model.

There are two groups of new basic events representing the SSC failures originally not modelled in the PSA:

- New initiating events, each linked (in a logical “OR” connection) to one of the existing initiating events of the PSA
- New probability type basic events, each linked to one or more fault tree gates, depending on whether the aging failure causes component or system level unavailability.

The procedure of finding the proper place of the new basic events can be summarized as follows:

- First, the affected component or system was identified (as described in 6.1.2)
- Second, the PSA model was investigated to find which the model of the affected system or component using the computer model and the PSA report.
- Third, the proper fault tree gate(s) was(were) identified where the aging basic event should be linked.
- The basic event was created within CAFTA, the frequency or probability calculated as 6.1.2 described was assigned, and the basic event was linked to the relevant fault tree gate.
- In some initiating event type cases a new “OR” gate was created to link together the original initiating event and the newly created initiating event, and this new OR gate replaced the original initiating event. It is indicated in Table 5-8 column “Fault tree gate(s)”, if a new “OR” gate was introduced.

Table 6-8 below contains the information for each newly modelled case.

Table 6-8: : Basic events, fault tree gates they are linked to and probabilities (frequencies) at 0, 10, and 20 years from time zero for SSCs not represented in baseline PSA

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
4	Bolts - Connections, BE, Containment	Fails the Containment integrity.	***CONT.BOLT***	In New Gate: ***CONT.AGING*** Linked to Gates: ***HE.CI.FAIL.DM.X***, ***HE.CI.FAILURE.DM***	1.37E-05	1.23E-04	2.33E-04
	Bolts - Connections, BE, Emergency Coolant Injection (HP ECI Storage Tank)	HP ECI Storage Tank unavailable when demanded.	***3432TK-TK1----AG***	Linked to Gate: ***TK1.LOW.LEVEL***	1.50E-08	1.35E-07	2.55E-07
			3432TK-TK3----AG	Linked to Gate: ***TK3.LOW.LEVEL***			
	Bolts - Connections, BE, Emergency Water Supply	Failure of EWS on demand.	***BOLTS.AGING.EWS***	Linked to Gates: ***EWS.PIPE.RUPTM^***, ***EWS.HPPIPE.RUP***, ***EWS.PIPE.RUPTMDR***	2.25E-07	2.03E-06	3.83E-06
6	Cable Connectors, IE, Dig.	Initiator: Plant trip. (Fail-safe mode assumed. Plant trip	***GENTA.CABLE1***	In New Gate:	1.53E-07	1.38E-06	2.60E-06

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
	Comp. SDS1/2	assumed as an enveloping event.)		***GENT-AG*** Containing IE: ***GENT***			
7	Cables, IE, Boiler FW	Initiator: Loss of FW / Plant trip	***LOHS1.10CABA***	In New Gate: ***LOHS1-1-AG*** Containing IE: ***LOHS1-1***	1.50E-08	1.35E-07	2.55E-07
	Cables, IE, Boiler Steam (MS)	Initiator: Plant Trip (closure of MSIV assumed).	***GENTA.CABLE2***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, IE, Class I Power (250V DC Class I Power System)	Initiator: Loss of Class I Power	***XEL1.10A.CAB***	In New Gate: ***XEL1-1-AG*** Containing IE: ***XEL1-1***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Class I Power (250V DC Class I Power	Failure of Class I Power on demand (in the case of safety	***CABLE.AGING.BUXA***	Linked to Gates: ***N.PW.C17.BUXA.S,***	5.40E-06	4.86E-05	9.18E-05

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
	System)	signal actuation).		***N.PW.C17.BUXAP,*** ***NO.PW.C17.BUXA,*** ***NO.PW.C17.BUXA1,*** ***NO.PW.C17BUXA2,*** ***NPW.BAT.BUXA.B,*** ***NPW.C17.BUXA.E,*** ***NPW.C17.BUXA.L***			
			CABLE.AGING.BUXB	Linked to Gates: ***N.PW.C19.BUXB.S,*** ***NO.PW.C19.BUXB,*** ***NO.PW.C19.BUXB2,*** ***NPW.BAT.BUXB.B,*** ***NPW.C19.BUXB.E,*** ***NPW.C19.BUXB.P***			
			CABLE.AGING.BUXC	Linked to Gates: ***N.PW.C18.BUXCS,*** ***NO.PW.C18.BUXC,*** ***NO.PW.C18.BUXC1,***			

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
				NO.PW.C18.BUXC2, NPW.C18.BUXC.E, NPW.C18.BUXC.L, NPW.C18.BUXC.P, NPW.CL1.BUXC.B			
			CABLE.AGING.BUYA	Linked to Gates: ***N.PW.C17.BUYA.S, N.PW.C17.BUYAP, NO.PW.C17.BUYA, NO.PW.C17.BUYA1, NO.PW.C17.BUYA2, NPW.C17.BUYA.E, NPW.C17.BUYA.L, NPW.CL1.BUYA.B***			
			CABLE.AGING.BUYB	Linked to Gates: ***N.PW.C19.BUYBS, NO.PW.C19.BUYB, NO.PW.C19.BUYB2,***			

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
				NPW.C19.BUYB.B, ***NPW.C19.BUYB.E,*** ***NPW.C19.BUYB.P***			
			CABLE.AGING.BUYC	Linked to Gates: ***N.PW.C18.BUYCS,*** ***NO.PW.C18.BUYC,*** ***NO.PW.C18.BUYC1,*** ***NO.PW.C18.BUYC2,*** ***NPW.C18.BUYC.B,*** ***NPW.C18.BUYC.E,*** ***NPW.C18.BUYC.L,*** ***NPW.C18.BUYC.P***			
	Cables, IE, Class II Power (Class II Distribution System)	Initiator: Loss of Class II Power	***XEL2.10AC***	Linked to Gate: ***IE-DCC***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Class II Power (Class II Distribution System)	Failure of Class II Power on demand.	***BUTAC.AGING***	Linked to Gate: ***BUTA.PNL.SHORT***	5.40E-06	4.86E-05	9.18E-05

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
			BUTBC.AGING	Linked to Gate: ***BUTB.PNL.SHORT***			
			BUTCC.AGING	Linked to Gate: ***BUTC.PNL.SHORT***			
	Cables, BE, Class III Distribution System	Failure of Class III Power on demand.	***CL3BUE.AGING***	Linked to Gate: ***5322BUE.NO.CL3SB***	5.40E-06	4.86E-05	9.18E-05
			CL3BUF.AGING	Linked to Gate: ***5322BUF.NO.CL3SB***			
	Cables, IE, Condenser Cooling Water (CCW) System	Initiator: Plant trip	***GENTA.CABLE3***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Containment L2 effect	Fails the Containment integrity.	***CONT.CABLE***	In New Gate: ***CONT.AGING*** Linked to Gates:	1.08E-05	9.72E-05	1.84E-04

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
				HE.CI.FAIL.DM.X, ***HE.CI.FAILURE.DM***			
	Cables, BE, Emergency Core Cooling and Recovery	Fails ECC on demand.	***ECC.CABLE***	Linked to Gates: ***ECC-M,*** ***ECC-SL,*** ***ECC-SL2,*** ***ECCMK,*** ***ECCMK-CL3,*** ***ECCMK-IA,*** ***ECCMK-SCA,*** ***ECCMK2,*** ***ECCMK2.T,*** ***L1B.ECC.NO.COOLM***	5.40E-06	4.86E-05	9.18E-05
	Cables, BE, Emergency Power Supply	Fails EPS on demand.	***EPS1A.CABLE***	Linked to Gate: ***NO.PWR.EPS.BUA***	5.40E-06	4.86E-05	9.18E-05
			EPS1B.CABLE	Linked to Gate: ***NO.PWR.EPS.BUB***			

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
	Cables, BE, Emergency Water Supply to EWS.HPPIPE.RUP, EWS.PIPE.RUPTM^, EWS.PIPE.RUPTMDR	Fails EWS on demand.	***EWS.CABLE***	Linked to Gates: ***EWS.HPPIPE.RUP,*** ***EWS.PIPE.RUPTM^,*** ***EWS.PIPE.RUPTMDR***	5.40E-06	4.86E-05	9.18E-05
	Cables, IE, Instrument Air	Initiator: Loss of IA	***XIA1.10A.CAB***	In New Gate: ***XIA1.1-AG*** Containing IE: ***XIA1.1***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Instrument Air	Fails IA on demand	***IA1.CABLE***	Linked to Gate: ***NO.IA.PRV507.S***	5.40E-06	4.86E-05	9.18E-05
			IA2.CABLE	Linked to Gate: ***NO.IA.PRV508.S***			
	Cables, IE, Liquid Zone System	Initiator: Plant trip	***GENTA.CABLE4***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
	Cables, IE, Primary Heat Transport	Initiator: Plant trip	***GENTA.CABLE5***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, IE, Reactor Regulating System	Initiator: Plant trip	***GENTA.CABLE6***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, IE, Recirculated Cooling Water No IE loss of RCW	Initiator: Loss of RCW as Plant Trip	***GENTA.CABLE7***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Recirculated Cooling Water	Fails RCW on demand (in the case of actuation of safety signal)	***RCW1.CABLE***	Linked to Gate: ***7134PM901.FLTM***	5.40E-06	4.86E-05	9.18E-05
			RCW2.CABLE	Linked to Gate: ***7134PM902.FLTM***			

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
			RCW3.CABLE	Linked to Gate: ***7134PM903.FLTM***			
	Cables, IE, Safety System Programmable Digital Comparator Computers SDS1, SDS2	Initiator: Plant trip	***GENTA.CABLE8***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, IE, Shutdown System 1 (SDS1)	Initiator: Plant trip	***GENTA.CABLE9***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07
	Cables, BE, Shutdown System 1 (SDS1)	Fails SDS1 on demand.	***SDS1C.CABLE***	Linked to Gates: (to all 1 to 35) ***SDS1.RT(1-35)***	5.40E-06	4.86E-05	9.18E-05
	Cables, IE, Shutdown System 2 (SDS2)	Initiator: Plant trip	***GENTA.CABLE10***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.50E-08	1.35E-07	2.55E-07

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
	Cables, BE, Shutdown System 2 (SDS2)	Fails SDS2 on demand.	***SDS2C.CABLE***	Linked to Gates: (to all 1 to 35) ***SDS2.RT(1-35)***	5.40E-06	4.86E-05	9.18E-05
	Cables, BE, Standby Generators	Fails Standby Generators on demand.	***SG1.CABLE***	Linked to Gate: ***5211.SG1.FAULT***	5.40E-06	4.86E-05	9.18E-05
			SG2.CABLE	Linked to Gate: ***5211.SG2.FAULT***			
8	Calandria Vault, IE	Direct core damage.	***CALANDRIA.VAULT***	In New Gate: ***SCDF-AP*** Collecting all SCD sequences	6.25E-12	5.63E-11	1.06E-10
11	Containment - Concrete, BE L2 effect	Fails the Containment integrity.	***CONT.CONC***	In New Gate: ***CONT.AGING*** Linked to Gates: ***HE.CI.FAIL.DM.X,*** ***HE.CI.FAILURE.DM***	2.74E-09	2.46E-08	4.65E-08

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
12	Containment - Foundations, BE L2 effect	Fails the Containment integrity.	***CONT.FOUN***	In New Gate: ***CONT.AGING*** Linked to Gates: ***HE.CI.FAIL.DM.X,*** ***HE.CI.FAILURE.DM***	2.74E-08	1.15E-07	3.78E-07
13	Containment - Penetrations, BE L2 effect	Fails the Containment integrity.	***CONT.PENE***	In New Gate: ***CONT.AGING*** Linked to Gates: ***HE.CI.FAIL.DM.X,*** ***HE.CI.FAILURE.DM***	1.37E-06	1.23E-05	2.33E-05
14	Containment - Steel, BE L2 effect	Fails the Containment integrity.	***CONT.STEEL***	In New Gate: ***CONT.AGING*** Linked to Gates: ***HE.CI.FAIL.DM.X,*** ***HE.CI.FAILURE.DM***	2.74E-09	2.46E-08	4.65E-08
16	EDG, Standby Generators, BE	Fails Standby Generators on demand.	***SG1.AGING***	Linked to Gate: ***5211.SG1.FAULT***	2.25E-05	2.03E-04	3.83E-04

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
			SG2.AGING	Linked to Gate: ***5211.SG2.FAULT***			
	EDG, Emergency Power Supply, BE	Fails EPS on demand.	***EPS.AGING***	Linked to Gates: ***1581.POW.EPS, 1582.POW.EPS, 1583.POW.EPS, 1585.PW.FR.EPS, 1586.PW.FR.EPS, 1587.PW.FR.EPS***	2.25E-05	2.03E-04	3.83E-04
17	Expansion joints, IE, Boiler Feedwater System	Initiator: Loss of FW / Plant trip	***LOHS1.10EXJ***	In New Gate: ***LOHS1-1A***	1.88E-08	1.69E-07	3.19E-07
	Expansion joints, IE, Raw Service System	Initiator: Loss of RSW.	***RSW1.10EXJ***	Linked to Gate: ***RSW.IES***	1.88E-08	1.69E-07	3.19E-07
	Expansion joints, BE, Raw Service System	Fails RSW on demand (in the case of actuation of safety signal).	***RSW.EXJ***	Linked to Gates: ***7131PM101.FLTM, 7131PM102.FLTM,***	6.75E-06	6.08E-05	1.15E-04

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
				7131PM103.FLTM, ***7131PM104.FLTM***			
	Expansion joints, IE, Recirculated Cooling Water System No IE loss of RCW	Initiator: Loss of RCW as Plant trip	***GENTA.RCW***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.88E-08	1.69E-07	3.19E-07
	Expansion joints, IE, Recirculated Cooling Water System	Fails RCW on demand (in the case of actuation of safety signal)	***RCW.AGING***	Linked to Gates: ***7134PM901FLTM,*** ***7134PM902.FLTM,*** ***7134PM903.FLTM***	6.75E-06	6.08E-05	1.15E-04
21	Other Concrete, IE, Boiler Feedwater System	Initiator: Loss of FW / Plant trip	***LOHS1.10OCO***	In New Gate: ***LOHS1-1A***	1.25E-13	1.13E-12	2.13E-12
	Other Concrete, IE, Cooling Water Intake and Discharge	Initiator: Loss of RSW.	***RSW1.10OCO***	Linked to Gate: ***RSW.IES***	3.13E-14	2.81E-13	5.31E-13
	Other Concrete, BE, Emergency Water Supply	Fails EWS on demand.	***EWS.OCO***	Linked to Gates: ***EWS.HPPIPE.RUP,***	1.13E-11	1.01E-10	1.91E-10

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
				EWS.PIPE.RUPTM^, ***EWS.PIPE.RUPTMDR***			
22	Other Foundations, SD, Emergency Water Supply	Fails EWS on demand.	***EWS.OFO***	Linked to Gates: ***EWS.HPPIPE.RUP,*** ***EWS.PIPE.RUPTM^,*** ***EWS.PIPE.RUPTMDR***	2.74E-08	1.15E-07	3.78E-07
26b	Piping, BE, Boiler Emergency Cooling	Fails Boiler EFW on demand.	***AFW.AGING***	Linked to Gate: ***LABFW.INIT.CCF***	1.13E-06	1.01E-05	1.91E-05
	Piping, SM, Dousing System	Dousing System unavailable when demanded.	***DOUSING.AGING***	Linked to Gates: ***2DW.LL.WATER.LOS,*** ***5DW.LL.WATER.LOS,*** ***7DW.LL.WATER.LOS,*** ***DW.LL.WATER.LOSS***	7.50E-08	6.75E-07	1.28E-06
	Piping, SD, Emergency Core Cooling and Recovery	Fails ECC on demand.	***ECC.PIPE***	Linked to Gates: ***ECC-M,*** ***ECC-SL,*** ***ECC-SL2,***	3.38E-06	3.04E-05	5.74E-05

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	**10 yr**	**20 yr**
				ECCMK, ***ECCMK-CL3,*** ***ECCMK-IA,*** ***ECCMK-SCA,*** ***ECCMK2,*** ***ECCMK2.T,*** ***L1B.ECC.NO.COOLM***			
	Piping, BE, Emergency Power Supply	Fails EPS on demand.	***EPS.PIPE***	Linked to Gates: ***1581.POW.EPS,*** ***1582.POW.EPS,*** ***1583.POW.EPS,*** ***1585.PW.FR.EPS,*** ***1586.PW.FR.EPS,*** ***1587.PW.FR.EPS***	3.38E-07	3.04E-06	5.74E-06
	Piping, BE, Emergency Water Supply	Fails EWS on demand.	***EWS.PIPE***	Linked to Gates: ***EWS.HPPIPE.RUP,*** ***EWS.PIPE.RUPTM^,*** ***EWS.PIPE.RUPTMDR***	2.25E-06	2.03E-05	3.83E-05

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
	Piping, IE, Recirculated Cooling Water No IE loss of RCW	Initiator: Loss of RCW	***GENTA.RCWP***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.25E-08	1.13E-07	2.13E-07
	Piping, BE, Recirculated Cooling Water	Fails RCW on demand (in the case of actuation of safety signal)	***RCW.PIPE***	Linked to Gates: ***7134PM901.FLTM,*** ***7134PM902.FLTM,*** ***7134PM903.FLTM***	4.50E-06	4.05E-05	7.65E-05
	Piping, IE, Shutdown Cooling System Shutdown initiator	Initiator: Loss of Shutdown Cooling.	***SDLOCA1.1.PIPE***	In New Gate: ***SDLOCA1.1-AG*** Containing IE: ***SDLOCA1.1***	6.25E-09	5.63E-08	1.06E-07
	Piping, BE, Shutdown System 2 (SDS2)	Fails SDS2 on demand.	***SDS2P.PIPE***	Linked to Gates: (to all 1 to 35) ***SDS2.RT(1-35)***	5.63E-07	5.06E-06	9.56E-06
	Piping, BE, Standby Generators	Fails Standby Generators on demand.	***SG1.PIPE***	Linked to Gates: ***5211.SG1.FAULT,***	3.38E-07	3.04E-06	5.74E-06

#	SSC / System	Mapping to PSA Model	New Basic Event	Fault tree gate(s)	IE: (1/year); BE: absolute probabilities		
					0 yr	10 yr	20 yr
				5211.SG2.FAULT			
28	Reactivity Control Units, IE	Initiator: Plant trip	***GENTA.RCU***	In New Gate: ***GENT-AG*** Containing IE: ***GENT***	1.88E-07	1.69E-06	3.19E-06
31	Shutdown System 1 (SDS1), SD	Fails SDS1 on demand.	***SDS1A.AGING***	Linked to Gates: (to all 1 to 35) ***SDS1.RT(1-35)***	1.13E-08	1.01E-07	1.91E-07
32	SG Shell Side, IE	Maps to major SLB initiator.	***SG.SHELL.AG***	In New Gate: ***LOHS4.2-AG*** Containing IE: ***LOHS4.2***	3.13E-13	2.81E-12	5.31E-12

6.2.4 Quantification Procedure

The aging risk model consists of the following computer files:

ASQ_MASTER - aging time 0.RR - Database file for the aging PSA at time point 0

ASQ_MASTER - aging time 10 years.RR - Database file for the aging PSA at time point 10 years

ASQ_MASTER - aging time 20 years.RR - Database file for the aging PSA at time point 20 years

SCDF-AP.CUT - CAFTA Cutset file for SCDF-AP

SCDF-SD.CUT - CAFTA Cutset file for SCDF-SD

LRF-AP.CUT - CAFTA Cutset file for LRF-AP

LRF-SD.CUT - CAFTA Cutset file for LRF-SD

In addition the file

SCDF-LRF-AP-SD.CAF - Fault tree model of SCDF-AP, SCDF-SD, LRF-AP and LRF-SD

is also appended for the purpose of regenerating the minimal cut sets for the different risk metrics, e.g.. with different truncation probability, or modifying/correcting the model for future application. One can use the CAFTA code to do that.

The quantification procedure applied here in this project was the following:

Preconditions:

- Have the above mentioned files in one folder on the computer

Quantification:

1. Make a copy of the corresponding CAFTA Database "ASQ_MASTER - aging time X year.rr" (X is the years) and rename it to "ASQ_MASTER.rr";
2. Start CAFTA
3. Open the corresponding cut set file in CAFTA, e.g. "SCDF-AP.cut";
4. Load the corresponding new probabilities from the database. Go to: / Tools / Load Database Probs. The probabilities are loaded and MCS re-quantification done automatically.
5. For the other risk metrics repeat steps 3. and 4. and read the results.
6. For new time point quantification exit CAFTA and delete "ASQ_MASTER.rr" and repeat steps 1. to 5. as necessary.

With this procedure for all of the calculation cases the same MCS set was used. In case the application requires more precise results, one can try to generate higher number of MCS applying lower cutoff probability, but then the running time of the MCS generation may drastically increase giving no, or very little benefit.

7. AGING RISK QUANTIFICATION AND PRESENTATION OF RESULTS

According to the quantification procedure presented in 6.2.4, the aging risk calculations were performed for the 0 time point (*t = 0*, as defined in section 6.1), 10 years after the 0 time point and 20 years after the 0 time point.

The results of the aging risk quantifications are summarized in Table 7-1 below.

Table 7-1: : SCDF and LRF Results of the Aging Risk Quantification (1/year)

	0 Year	**10 Years**	**20 Years**
SCDF-AP	1.09E-05	1.46E-05	1.85E-05
SDCF-SD	6.92E-06	7.13E-06	7.72E-06
LRF-AP	6.50E-08	8.69E-08	1.11E-07
LRF-SD	8.94E-08	9.03E-08	9.13E-08

It has to be noted that the 0 year results are somewhat higher that the results of the original PSA. It is because the 0 year model includes the new basic events representing the aging of the passive structures as discussed in section 6.1.2, and it caused an increase in the quantification results.

The figures below Figure 6-1 to Figure 6-12 show the contribution of initiating events to the different risk metrics.

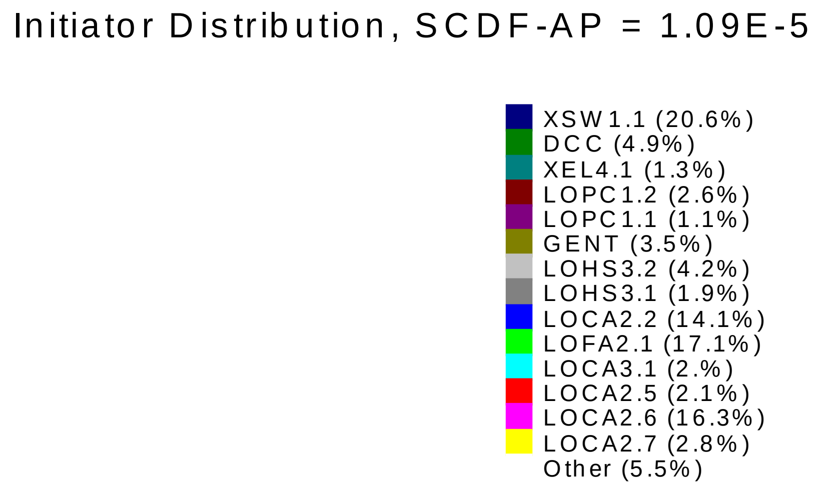


Figure 7-1: Contribution of the Initiating Events to SCDF At Power at Time 0 Years

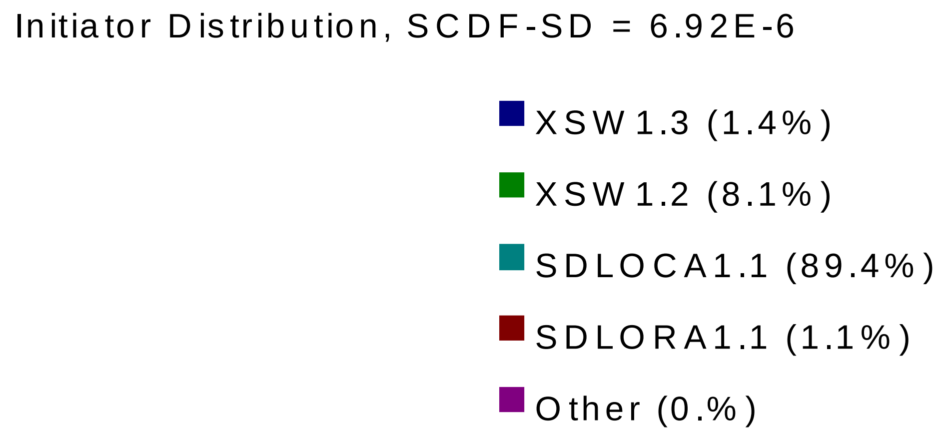


Figure 7-2: Contribution of the Initiating Events to SCDF At Shutdown at Time 0 Years

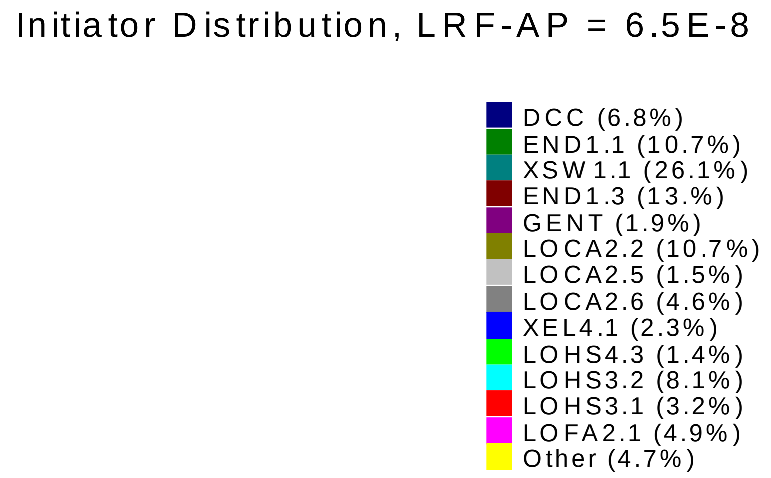


Figure 7-3: Contribution of the Initiating Events to LRF At Power at Time 0 Years

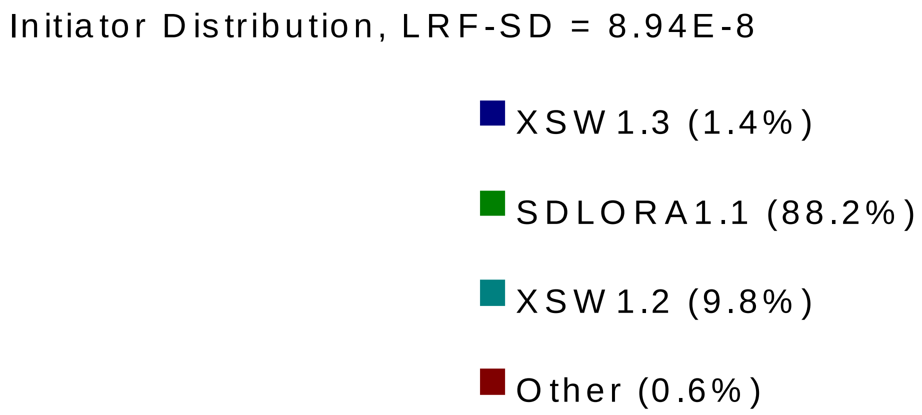


Figure 7-4: Contribution of the Initiating Events to LRF At Shutdown at Time 0 Years

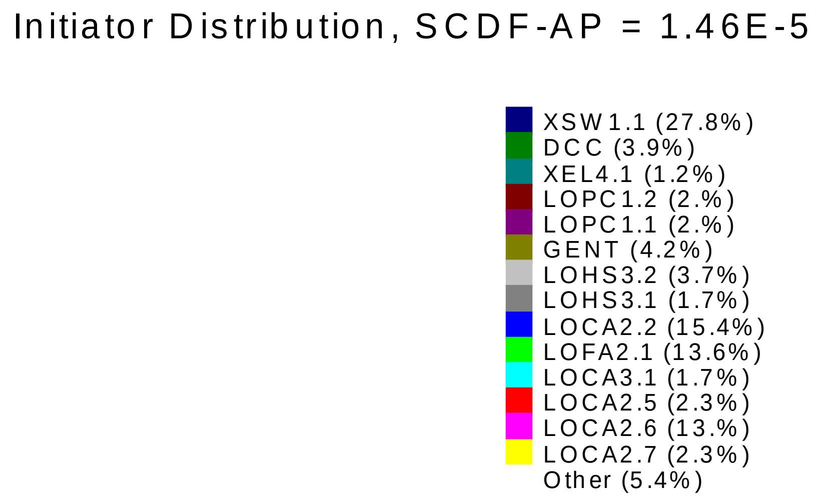


Figure 7-5: Contribution of the Initiating Events to SCDF At Power at Time 10 Years

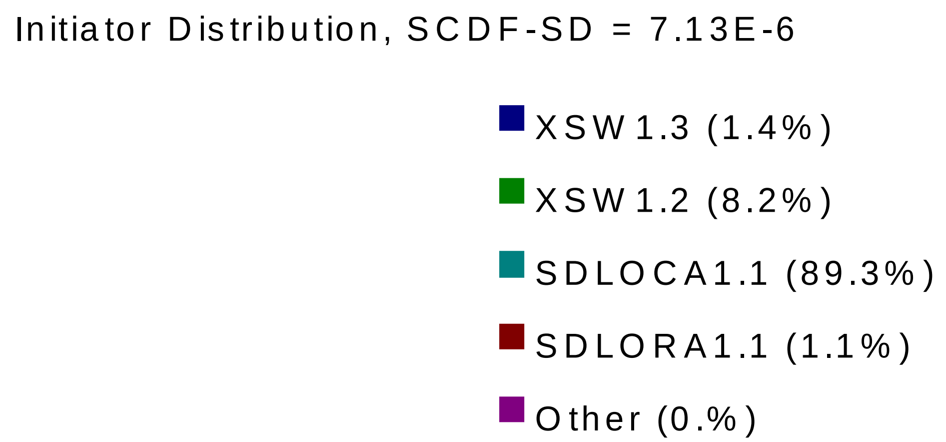


Figure 7-6: Contribution of the Initiating Events to SCDF At Shutdown at Time 10 Years

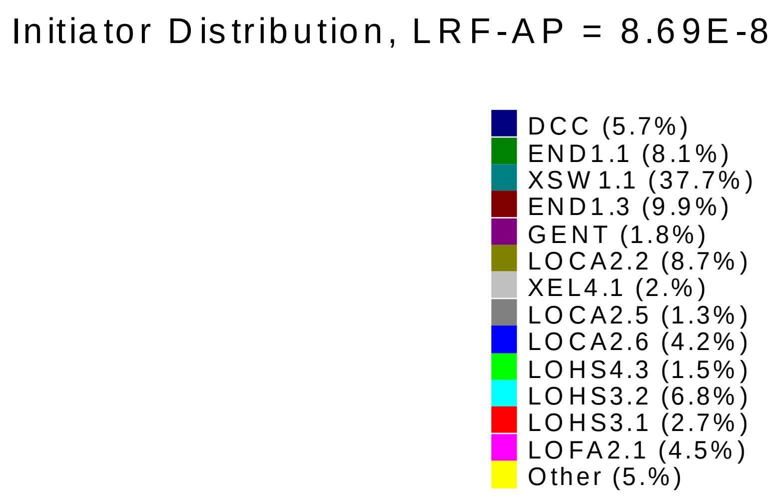


Figure 7-7: Contribution of the Initiating Events to LRF At Power at Time 10 Years

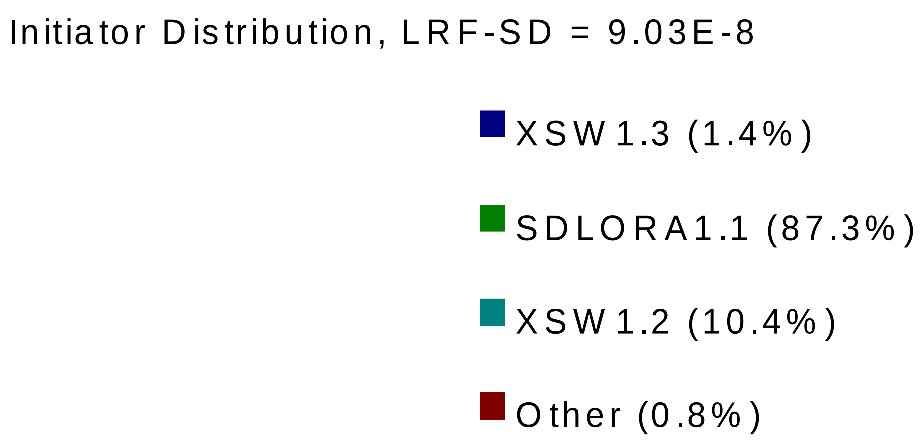


Figure 7-8: Contribution of the Initiating Events to LRF At Power at Time 10 Years

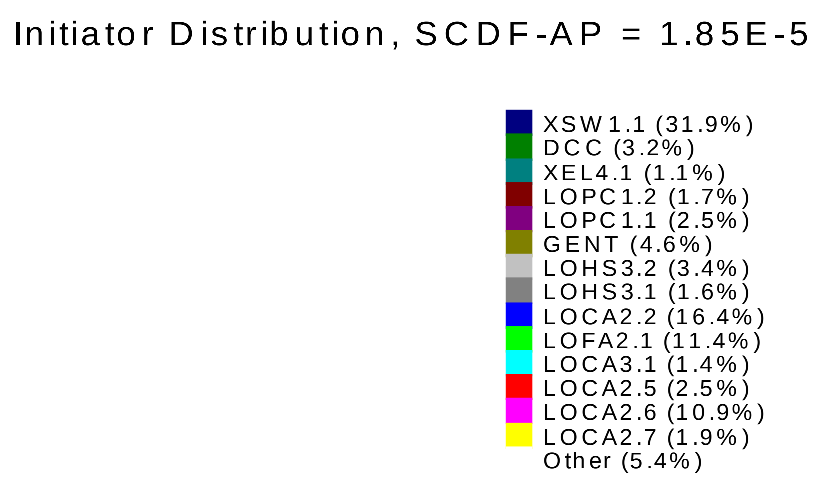


Figure 7-9: Contribution of the Initiating Events to SCDF At Power at Time 20 Years

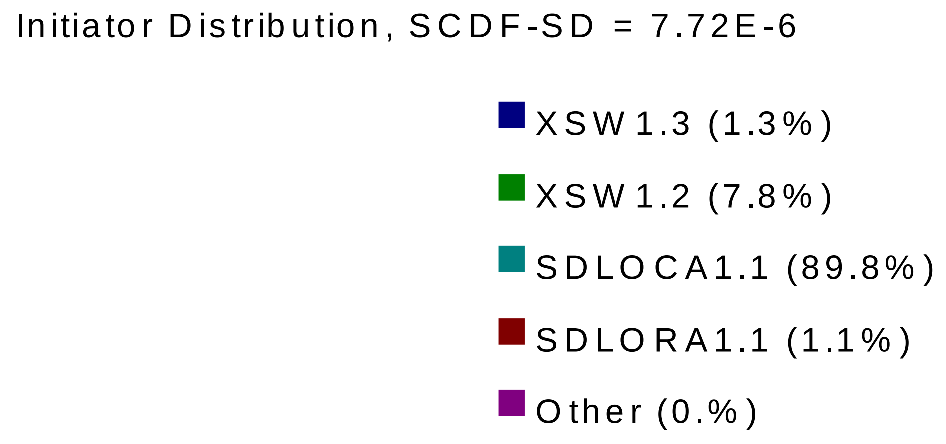


Figure 7-10: Contribution of the Initiating Events to SCDF At Shutdown at Time 20 Years

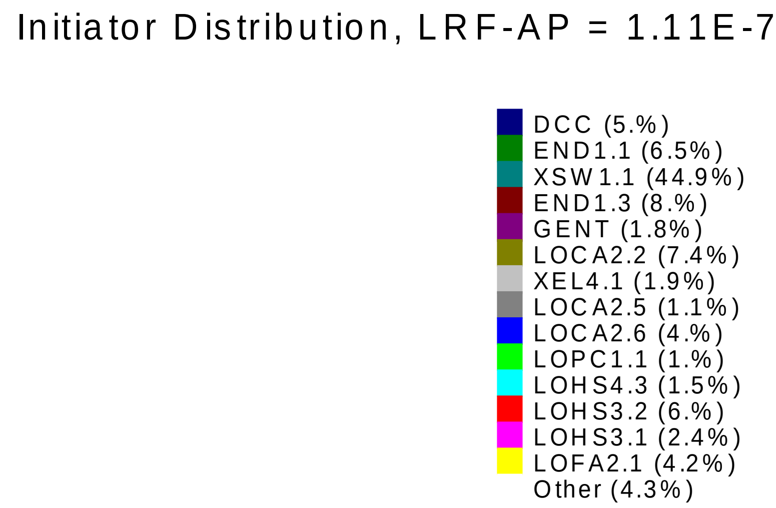


Figure 7-11: Contribution of the Initiating Events to LRF At Power at Time 20 Years

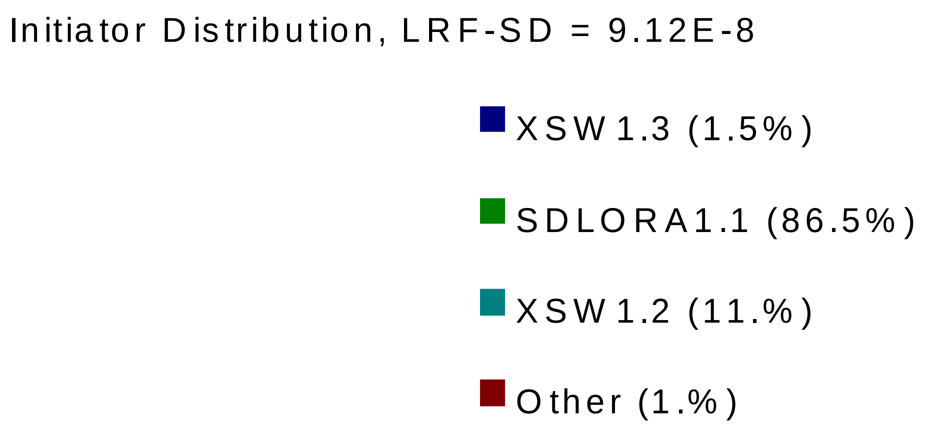


Figure 7-12: Contribution of the Initiating Events to LRF At Power at Time 20 Years

The lists of top minimal cutsets (MCS)for all analysed cases are provided in Appendix 9.4.

One can see in the MCS lists that the most visible change is the increase of the contribution of the initiating event XSW1.1 to SCDF-AP that is the total loss of service water. After 20 years of aging the first cut sets contain this initiating event and the single failures of BUXA, BUXC, BUYA and BUYC buses (Class I) due to cables aging failures.

The increasing importance of initiating event LOFA2.1, that is a single channel blockage, due to the same reason (i.e. cable aging of the same Class I buses) can also be observed in the list of the top MCSs. The LOFA2.1-related group of minimal cutsets with aging failures of the mentioned Class I buses is followed, in the same MCS list, by the analogous group of minimal cutsets related to the initiator LOCA2.6 (Pressure tube and calandria tube rupture).

These impacts do not come as a surprise considering:

- Large RAW (Risk Achievement Worth) of Class I Power (RAW = 526, according to [22]), combined with
- Large CCDP values for the mentioned initiator categories (CCDP(XSW1.1 > 1E-04; CCDP(LOFA2.1) and CCDP(LOCA2.6) > 1E-03, based on the information provided in [4]), which come, apparently, at least partially due to dependence on the Class I Power.

In general it can be stated, that the results show accelerating increase of the core damage risk, and the aging of SSCs will have increasing risk importance. Table 7-2 shows the relative increase in all four risk measures, as calculated according to the described procedure and assumptions.

Table 7-2: : SCDF and LRF Results Expressed as Percentages of Results at *t =0*

	0 Year	**10 Years**	**20 Years**
SCDF-AP	100%	134%	170%
SDCF-SD	100%	103%	112%
LRF-AP	100%	134%	171%
LRF-SD	100%	101%	102%

Total SCDF and LRF (at-power and shutdown modes) results are summarized in Table 7-3. Altogether, the SCDF (at-power and shutdown modes) would increase by 22% at 10 years and by 47% at 20 years, with respect to the same metric at $t = 0$. Analogously, the total LRF (at-power and shutdown modes) would increase by 15% at 10 years and by 31% at 20 years, with respect to the same metric at $t = 0$.

Table 7-3: : Total SCDF and LRF Results (/yr)

	0 Year	**10 Years**	**20 Years**
Total SCDF	1.78E-05	2.17E-05	2.62E-05

Total LRF	1.54E-07	1.77E-07	2.02E-07

Additionally to the above presented quantification, a sensitivity case was run, based on the exponential time dependent model for aging failure rates, as discussed earlier. The purpose of this sensitivity case was to investigate how much would aging risk measures change toward the end of the projected period if the linear time dependent model for the aging failure rates is replaced by the exponential time dependent model. The input aging failure rates and probabilities for the SSCs are described in Appendix 10.3, as well as the results of its quantification. As pointed there, this sensitivity case should be seen as an attempt to provide some insights into possible departures from those results obtained with linear models, rather than an actual "alternative" estimate of aging risk.

As the overall result, the SCDF (at-power and shutdown modes) would, with described exponential failure rate model, increase by 59% at 20 years, with respect to the same metric at $t = 0$. Analogously, the total LRF (at-power and shutdown modes) would, with described exponential failure rate model, increase by 40% at 20 years, with respect to the same metric at $t = 0$.

If compared absolutely to the results at 20 years by the linear model (Table 7-2), the exponential model gives 8% higher SCDF (at-power and shutdown modes) and 6% higher LRF SCDF (at-power and shutdown modes).

7.1 Perspective on Uncertainties and Opportunities for Aging PSA Applications

The above presented results need to be viewed in the light of uncertainties involved in the process of risk modeling and quantification. Generally, these results should be taken as indications and insights rather than as "projections" of risk metrics into the future. Brief discussion and summary of the main sources of uncertainty follows.

The main limitation of the present study was, as pointed earlier, in the lack of relevant time-dependent aging failure rates needed to quantitatively represent the aging impact of SSCs in the PSA model except for very limited examples of failure trends provided in the Phase 1 report. This reflected in two main sources of uncertainty:

- Aging failure acceleration rates (parameter a in the linear failure rate model) had to be established to the largest extent on the basis of available studies for PWR, BWR and VVER plants. (Refer to section 4 and Appendix 10.2.)
- Effectiveness of aging management was accounted for by age improvement factor ρ. (Refer to section 6.1.)

These parameters have major influence on time-dependent failure rates and, hence, on the calculated risk measures, as already pointed in section 6.1.

Beside these two, there may be considerable uncertainty involved in mapping of aging-induced failures of passive SSCs (previously not represented in the PSA model) to the failures of plant systems and functions. In most of the cases, aging failures of SSC categories (e.g. cables associated with particular system) were mapped to a system-level or function-level failure. (Refer to section 6.1.)

For possible future work it can, then, be recommended to:

- Investigate and analyze the data on failures and degradation of relevant SSCs from the pre-refurbishment plant operation in order to identify the trends which could be used to establish realistic time-dependent failure rates. Those aging failure rates can, in the course of Aging PSA applications, later be modified or adjusted to reflect more recent data or trends from the plant's operating history.
- Establish at CNSC an aging monitoring pilot program (as compared to "aging management program" carried out by the licensees) to monitor relevant aging indicators for a selected sample of SSCs important to safety aimed at identifying potential adverse trends. Such information would provide a very valuable feedback to the Aging PSA model to reduce the current uncertainties and also, help to identify the most important SSCs from the aging risk point of view.
- Conduct sensitivity studies on the impact of the effectiveness of actual maintenance and aging management programs/ activities.

It is recommendable to use the Aging PSA model and techniques primarily in a way to identify potential aging risk contributors in the shorter term future operation. For this purpose, operating data and trends (e.g. the indicators mentioned above) from the reasonably recent operating history can be used. (What is "reasonably recent" would depend, e.g. on the history of SSCs modifications or replacements made.) The operating data, such as problems identified in "system health reports" (or absence of those), numbers of failed tests, trending or regression analyses of in-service inspection indications etc., can, also, be used to demonstrate the adequacy of aging management with respect to specific SSCs that may come into focus as a result of Aging PSA application. (With respect to this, it should be noted that this kind of data and trends can be used to demonstrate the zero increase in aging failure rates, or even a decrease, for the relevant SSCs, if applicable.) In short, it can be said that general recommendation regarding the use the Aging PSA would be to foresee the aging risk profile in the reasonably near future and to act accordingly, by making use of operating data and trends from the reasonably recent history. It is believed, from the insights of this study, as much as of available other studies, that real benefit of Aging PSA lies in this kind of applications, rather than in trying to make the long term predictions of risk measures.

8. CONCLUSIONS

This report documents an Ageing PSA case study and its results that was performed for CNSC using a CANDU base-line Level 1 and Level 2 PSA and inputs from Phases 1 and 2 of the CNSC project on Incorporating Aging Effects into PSA Applications. It is believed that this study was among the very first attempts made to incorporate the aging effects into an integrated full scope plant specific PSA model, and to observe its impact on the overall PSA results, by making projections to the future. (One example of a similar but limited work is a study which considered aging impact on the CDF contribution from a large LOCA in a PWR PSA; results obtained indicated an increase of CDF contribution close to 50% at 20 years and of an order of magnitude at 40 years [16].) Thus, the present study should be seen as pushing some boundaries, which also needs to be considered when interpreting and evaluating its results.

8.1 Summary of work

The impact of aging on plant's SSCs was introduced into the referential PSA model through consideration of <u>three configuration categories of aging-induced accident scenarios (section 2.2)</u>:

- "Operating" (O) configuration: Aging produces directly induced PSA initiator
- "Standby – demand" (SD) configuration: Aging produces non-observable impact with latent unavailability
- "Standby – monitored" (SM) configuration: Aging produces observable impact on monitored equipment.

SSCs identified in the Phase 1 report [2] as relevant from the point of aging risk considerations were screened and characterized with respect to the above aging-induced accident scenario categories. This provided the basis for the mapping of aging impacts of relevant SSCs to the PSA model (section 3).

<u>The main limitation of the present study was in the lack of relevant time-dependent aging failure rates</u> needed to quantitatively represent the aging impact of SSCs in the PSA model except for very limited examples of failure trends provided in the Phase 1 report. Therefore, the time-dependent aging failure rates for all the SSCs with aging impact mapped into the PSA model were established within this (Phase 3) study based on the linear time-dependent model (section 2.4).

<u>The key parameter in the linear time dependent aging failure rate model is aging failure acceleration *a* (/hr/yr).</u> The aging failure accelerations for all relevant SSCs were established as follows (section 4):

1) "generic" aging acceleration rates and average failure rates for the relevant SSCs were established mostly from the available operating experience of PWR, BWR and VVER plants
2) Consideration of the CANDU failure trending data, as limited as they were, from Phase 1 report ([2]) in order to obtain an indication of corresponding acceleration rates which would be more specific to CANDU plants. The "generic" aging acceleration rates were modified, where available and considered applicable, through comparison with CANDU rates, into the "final" acceleration rates..
3) "Final" acceleration rates from previous step were "updated" with plant specific average failure rates that were included in the baseline PSA model in order to obtain "pseudo plant specific" acceleration rates. *(To check for consistency among the overall failure rates used in the LWR PSAs and the referential CANDU PSA, a high level comparison was made between CANDU plant specific average failure rates and the generic failure rates for SSCs types such as valves, pumps, buses or, in some cases, piping , and reasonable agreement was confirmed.)*

For PSA modeling of SSC aging, the SSCs were divided into two groups (section 4):

- SSCs already represented in the baseline PSA model, with their specific failure rates; mostly active components such as pumps and valves.

  Their aging impact was propagated through the existing basic events in the PSA model, i.e. projected increase in the failure rate (due to aging) was added to the existing failure rate value; the relative accelerations were established for relevant

SSCs in the range from 1% to 15% per year. The upper limit was put on 15%/yr based on the assumption that corrective actions would be taken based on the observed trends.

- SSCs which were not represented in the baseline PSA model, such as concrete structures, cabling and piping for some of the systems.

  For those SSCs, new basic events were created in the PSA model to represent corresponding aging failures and absolute aging acceleration rates (/hr/yr) were applied to provide for calculations of corresponding failure probabilities.

To account for the impact of aging management activities (e.g. inspection, maintenance, replacement) on the time-dependent SSC failure rates, the proportional age reduction (PAR) model was applied in this study using two additional parameters: "age improvement" factor ($0 \le \rho \le 1$) and "aging management activity time period" and is designated as T_{AM}. Low AM effectiveness means values of ρ considerably smaller than 1; effective AM means values of ρ close to 1. For "AM time period" T_{AM}, the values taken which were considered representative for the of SSC type (section 5).

For the aging risk quantification purposes, zero time point ($t = 0$) was selected at the plant startup following the refurbishment (at 2012) (section 6).

The scheme for AM effectiveness from Phase 1 was utilized ("3 for fully effective, 2 for partially effective, 1 for not effective"). For active SSCs included in the baseline PSA model, 2 was translated to ρ = 0.95 (residual aging of 5%) and 1 was translated to ρ = 0.9 (residual aging of 10%). Relatively high ρ values reflect the point that active SSCs are subject to shorter term preventive AM actions which, if proven ineffective, would produce corrective actions. For passive SSCs not included in the baseline PSA model, considerably lower AM effectiveness were taken: the value of 2 was translated to ρ = 0.75 (residual aging of 25%) and the value of 1 was translated to ρ = 0.5 (residual aging of 50%) (section 6.1).

For the active SSCs, the relative acceleration rates were applied directly to the corresponding parameters in the PSA model - in this way, the aging impact on functional dependencies and interfaces was taken into account through the logic of the PSA model. For the passive SSC, new representative basic events were created, typically at the system or function level, and basic event probabilities were calculated from the absolute aging failure rates established earlier (section 6.2).

8.2 Conclusions

(1) PSA modeling of SSC aging

Risk quantification with linear time dependent failure rate models:

- the total SCDF (at-power and shutdown modes) increased by 22% at 10 years and by 47% at 20 years, with respect to the same metric at $t = 0$.
- the total LRF (at-power and shutdown modes) increased by 15% at 10 years and by 31% at 20 years, with respect to the same metric at $t = 0$.

The largest part of the increases comes from the at-power mode. In the risk profile, the most visible change is an increase of the contribution of the initiating event representing the total loss of service water. At 20 years, the top minimal cut sets contain this initiating event and the failures of BUXA, BUXC, BUYA and BUYC buses (Class I) due to cables aging failures. Increasing importance of initiating event for a single channel blockage due to cable aging failures of the same Class I buses can also be observed in the list of the top MCSs. This is followed, in the same MCS list, by the analogous group of minimal cut sets related to the initiator representing pressure tube and calandria tube rupture.

Sensitivity of the SCDF to the “aging improvement factors” with the linear time dependent failure rate models was investigated using the following ρ-values:

- For active SSCs: 0.7 - 0.8 for partially effective AM, and 0.4 - 0.6 for ineffective AM;
- For passive SSCs: 0.4 - 0.5 for partially effective AM, and 0.2 - 0.3 for ineffective AM

The conclusion reached was that this could result in an increase to SCDF at power of the order of magnitude at t = 20 years. Therefore, the results are very sensitive to changes in the aging improvement factors and aging acceleration rates, i.e. the effectiveness of aging management.

Results of the SCDF sensitivity case based on changes in the exponential time dependent failure rates indicate that at 20 years the exponential model gives 8% higher SCDF (at-power and shutdown modes) and 6% higher LRF SCDF (at-power and shutdown modes) than the linear model. This does not appear to be a significant difference considering the sensitivity of the results to the changes in the parameters affecting the aging failure rate increase with the linear model (aging failure acceleration, age improvement factor).

The above results should be taken as an indication only, rather than a “projection” of the SCDF or LRF into the future as they are conditional on a large number of assumptions stated in this document. Among most notable assumptions are those embedded in the process of establishing the time dependent aging failure rates. *Here, the most important issue is the lack of actual plant data (such as failure or degradation trends) that could be used for establishing plant-specific (or fleet-specific) time dependent failure rates.* The study clearly demonstrated that risk results are sharply sensitive to the aging acceleration rates assumed or aging management effectiveness assumed. Since AM effectiveness (represented in this study by the factor ρ) is a cross-cutting issue, a difference in the top result of an order of magnitude can be easily reached.

(2) Risk importance of aging of cables

The results indicate possible risk importance of aging of cables, although this importance is, also, related to the risk importance of the related system (Class I). It is pointed that this insight should be taken with due caution, considering the uncertainties and possibly conservative assumptions embedded in the derivation of failure probabilities (section 6.1.2). It should be noted that the cable risk values in this report are derived from assumed failure rates because of a lack of actual failure data and thus may be too high. However, the positive effect of an effective AM program was clearly shown.

(3) Risk significance of active SSCs

This study brings up the point that residual aging of active SSCs such as valve or pump operators may be an important contributor to the overall aging risk. Sometimes, a claim is made that active SSCs can be screened out from aging risk assessment on the account that they are subject to regular testing and maintenance. However, there is always a question of a residual aging impact, even with most efficient maintenance strategy. In reliability engineer’s language, there is a question whether an SSC overhaul or refurbishments brings its failure rate to “as good as new” status, or there is some residual aging degradation which can build up. Even in the case of a complete SSC replacement, there are wiring contacts or welds to be made to the rest of the system.

(4) Projecting quantitative risk measures into the longer term future

It should be noted that, in general, it is considered that it is not possible, to make accurate projections of quantitative risk measures into the longer term future. Some authors even do not recommend that aging rates are extended into the future further than three years or so, on account that human interactions are unpredictable (e.g., [7]) unless they are specifically known (planned) and explicitly accounted for in the model. This needs to be taken into account when considering the calculated SCDF or LRF results at, e.g., 20 years from now.

(5) Opportunities for possible future work and APSA application

The present report is first APSA model for CNSC aimed at (a) incorporating the aging effects into an integrated full scope plant specific PSA model, (b) gaining a better understanding of the challenges in modelling aging in PSA, and (c) facilitating progress towards a practical APSA that could be used for quantifying aging impact on NPP safety. Taking into account the lessons learned from this project (Phases 1, 2 and 3), the CNSC may consider the following topics as opportunities for possible future work.

- Investigate and analyze the data on failures and degradation of relevant SSCs from the pre-refurbishment plant operation in order to identify the trends which could be used to establish realistic time-dependent failure rates. Those aging failure rates can, in the course of Aging PSA applications, later be modified or adjusted to reflect more recent data or trends from the plant's operating history.
- Establish at CNSC an aging monitoring pilot program (as compared to "aging management program" carried out by the licensees) to monitor relevant aging indicators for a selected sample of SSCs important to safety aimed at identifying potential adverse trends. Such information would provide a very valuable feedback to the Aging PSA model to reduce the current uncertainties and also, help to identify the most important SSCs from the aging risk point of view.
- Conduct sensitivity studies on the impact of the effectiveness of actual maintenance and aging management programs/ activities.

Regarding possible use of APSA by CNSC or NPP operating organizations, the following applications are proposed for consideration:

- to foresee the aging risk profile (identify significant aging risk contributors) in the reasonably near future by making use of relevant operational data and trends from recent history; avoid making long term predictions of risk measures
- to use the APSA to provide a focus for verification of the adequacy of aging management for specific SSCs that may be pointed as important risk contributors by APSA application by using operational data from "system health reports" such as component degradation or failures, numbers of failed tests, trending or regression analyses of in-service inspection indications, etc.

9. REFERENCES

[1] R322.3 Incorporating Ageing Effects into PSA Applications (RFP No.: 87055-11-0563), Technical and Management Proposal, ENCO-TP-(12)-01, March 2012

[2] Incorporating Ageing Effects into PSA Applications – Phase I, Volumes 1 through 18, Martec Technical Report #TR-07-63 (Prepared for: Canadian Nuclear Safety Commission), Rev. 1, February 2008

[3] Guidelines for Incorporating Aging Effects into Probabilistic Safety Assessment (PSA) Models, Report no.: 35.900.005/R3, Rev. 2, Scandpower Risk Management – Lloyd's Register, 2010

[4] Point Lepreau Generating Station Probabilistic Safety Assessment, Level 1 and 2 Internal Events, 0087-03611-0001-PSA-A-00

[5] NUREG/CR-5248 , (PNL-6701), Prioritization of TIRGALEX-Recommended Components for Further Aging Research, 1988

[6] NUREG/CR-4769, Risk Evaluations of Aging Phenomena: The Linear Aging Reliability Model & Its Extensions, 1987

[7] NUREG/CR-5378 , (EGG-2567), Aging Data Analysis and Risk Assessment - Development and Demonstration Study, 1992

[8] NUREG/CR-5587 , (SAIC-92/1137), Approaches for Age-Dependent Probabilistic Safety Assessments With Emphasis on, Prioritization and Sensitivity Studies, 1992

[9] NUREG/CR-5632, Incorporating Aging Effects into Probabilistic Risk Assessment – A Feasibility Study Utilizing Reliability Physics Models, 2001

[10] NUREG/CR-6928, (INL/EXT-06-11119), Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants, Idaho National Laboratory - U.S. Nuclear Regulatory Commission, February 2007

[11] IAEA-TECDOC-540, Safety Aspects of Nuclear Power Plant Ageing, International Atomic Energy Agency, Vienna, 1990

[12] IAEA Technical Report Series No. 338, Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety, International Atomic Energy Agency, Vienna, 1992

[13] EUR 22483 EN, C.Atwood, O.Cronval, M.Patrik, A. Rodionov: Models and data used for assessing the ageing of systems, structures and components (European Network on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities), DG JRC Institute for Energy, 2007

[14] EUR 23079A EN, Antonov, V.Chepurko, A.Polyakov, A. Rodionov: A Case Study on Investigation of Component Age Dependent Reliability Models (EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2008

[15] EUR 23084 EN, A.Rodionov: Overview of NPPs component reliability data collection with regards to time-dependent reliability analysis applications. EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2007

[16] EUR 23930 EN, A.Rodionov : A Case Study on Incorporation of Ageing Effects into the PSA Model. EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2009

[17] EUR 23954 EN, A.Rodionov, D.Kelly, J.U.Klugel: Guidelines for Analysis of Data Related to Aging of Nuclear Power Plant Components and Systems. EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2009

[18] EUR 23446 EN, M. Nitoi, A. Rodionov: Qualitative approach for selection of Systems Structures and Components to be considered in Ageing PSA. EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities, DG JRC Institute for Energy, 2009

[19] EUR 24503 EN, M. Nitoi, A. Rodionov: Guidelines for Selection of Components, Systems, Structures to be considered in Ageing PSA, DG JRC Institute for Energy, 2010

[20] EUR 24580 EN, J. Holy, M. Nitoi, I. Dinu, L. Burgazzi: Analysis of common cause failures coupling factors and mechanisms from ageing point of view, DG JRC Institute for Energy, 2010

[21] EUR 24643 EN, S. Poghosyan, A. Malkhasyan, A. Rodionov, M. Nitoi: Analysis of data related to ageing of VVER-440 NPP components, DG JRC Institute for Energy, 2010

[22] Point Lepreau Generating Station, Information Report, PSA Insight into Systems Important to Safety and Identification of Risk Related Structures, Systems and Components, IR-01500-16, Rev. 0, 2010

[23] Park, D. H., Jung, G. M., Yum, J. K. "Cost Minimization for Periodic Maintenance Policy of a System Subject to Slow Degradation", Reliability Engineering and System Safety 68, Elsevier Science Ltd., p. 105, 2000.

[24] Levitin, G., Lisnianski, A. "Optimization of Imperfect Preventive Maintenance for Multi-state Systems", Reliability Engineering and System Safety 67, Elsevier Science Ltd., p. 193, 2000.

[25] Pulcini, G. "On the Overhaul Effect for Repairable Mechanical Units: a Bayes Approach", Reliability Engineering and System Safety 70, Elsevier Science Ltd., p. 85, 2000.

[26] Vrbanic, I., Šimić, Z., Šljivac, D., "Prediction of the Time-Dependent Failure Rate for Normally Operating Components Taking into Account the Operational History", Kerntechnik, Independent Journal for Nuclear Engineering, Energy Systems, Radiation and Radiological Protection, Vol. 73 No. 4, Carl Hanser Verlag, September 2008

[27] Šimić, Z., Vrbanić, I., Vuković, I., "Prediction of the Time-Dependent Standby Failure Rates for Periodically Tested Components Taking into Account the Operational History", Kerntechnik, Independent Journal for Nuclear Engineering, Energy Systems, Radiation and Radiological Protection, Vol. 74 No. 5-6, Carl Hanser Verlag, November 2009

10. APPENDICES

10.1 Modelling and Quantifying of Risk from Aging Induced Scenarios

As mentioned earlier, several methods have been described and discussed in the literature (e.g. [5] through [21]) for modelling and quantification of aging risk impact by PSA. They are, also, described in the Phase I report, [2]. Although they differ among themselves to certain extent, they are all based on the same principle:

- Establish and model the likelihood of aging-induced failure;

- Establish and model the direct consequences of aging-induced;
- Combine the likelihood and the direct consequences into the risk from the considered aging-induced failure mode.

Quantitatively, this usually comes to:

- Expressing the aging failure likelihood through some form of time-dependent aging failure rate;
- Expressing the aging failure consequences through a conditional increase in risk metric, such as CCDP and/or CLRP.
- Combining the two into an unconditional increase in risk metric, such as ΔCDF and / or ΔLRF.

In implementing the above principles, some approaches rely on modifying a PSA model in a way to incorporate both the aging failure likelihood as well as its impact / consequence in the model. Aging risk metrics, such as ΔCDF or ΔLRF, are then calculated directly with the PSA model.

Some other approaches rely on modifying a PSA model in a way to calculate risk metrics conditionally on postulated aging impacts. For the same purpose, risk importance measures from PSA model are, sometimes, used directly (i.e. to estimate the conditional risk metrics). These conditional risk metrics (such as CCDPs or CLRPs) are then combined with externally calculated aging failure likelihoods in order to obtain the aging risk estimate.

In either case, an aging risk assessment requires a number of re-quantifications in order to address:

- Different time points in the future, for the risk predictions;
- Different sensitivity cases (e.g. regarding the selected parameters values or selected aging failure rate models).

It needs, however, to be understood that all the mentioned approaches would produce same (or reasonably similar) results, as long as they are applied consistently. Actually, in a broader sense, this is one same approach in which the failure likelihood is combined with failure consequences like in any kind of risk assessment.

We illustrate below, with simplistic examples, the concept where both aging failure likelihood and aging failure consequence are incorporated in a PSA model, to directly quantify the aging risk impact. The illustration is provided for the three aging induced scenarios / impacts considered, i.e. O, SD and SM.

“Operating” (O) Scenario / Configuration

In this case, considered aging impact is on a SSC which is related to a specified initiator category. The impact reflects as an increase in the IE frequency, in a way that aging failure rate (which is a function of time) corresponds to the IE frequency increase, i.e.:

$$\lambda_{ag,SSC}(t) = \Delta f_{IE}(t) \qquad \text{Eq. 10-1}$$

Base Case PSA Model

Relevant part of a base case PSA model is illustrated by Figure 10-1. The initiator IE1 represents a considered IE category. The M1 represents mitigation systems required in response to the IE1 initiator. In the case that, following an occurrence of the IE1, the M1 function fails, core damage is assumed to occur, as indicated by the consequence CD.

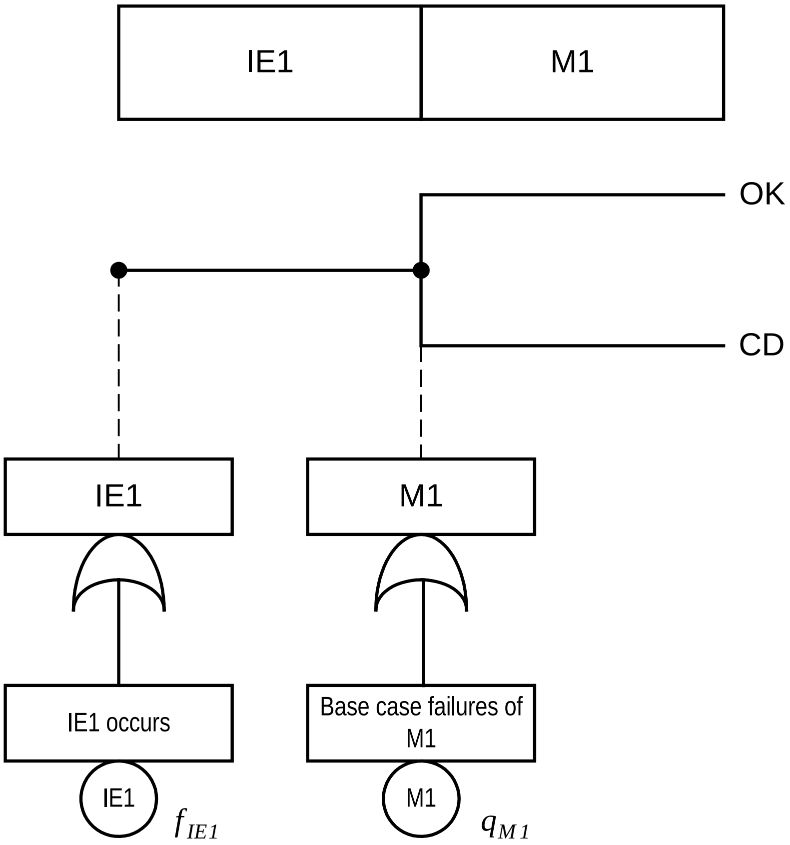


Figure 10-1: Base Case PSA Model for Category O Example

Logical core damage risk equation for this case can be “read out” directly from the logic structure depicted by Figure 10-1:

$$(CD) = (IE1) \times (M1) \qquad \text{Eq. 10-2}$$

Corresponding quantitative risk equation for base case core damage can be written as:

$$f_{CD} = f_{IE1} \times q_{M1} \qquad \text{Eq. 10-3}$$

where

f_{CD} base case frequency of core damage (i.e. CDF);

f_{IE1} base case frequency of IE1 initiator category;

q_{M1} base case probability of failure of M1 function.

Modified PSA Model

In order to incorporate the considered aging impact, the PSA model is modified to reflect the aging induced increase in the IE1 frequency: baseline value f_{IE1} is replaced with $f_{IE1} + \Delta f_{IE1}(t)$. The modified PSA model is shown in Figure 10-2.

(Alternatively, new basic event, e.g. IE1A, could have been logically "OR-ed" to the existing basic event IE1. This new basic event, IE1A, would have been assigned the increase in the IE frequency, $\Delta f_{IE1}(t)$.)

The modified PSA model is, then, run for a "new" CDF. Since the logical event tree structure was not changed, the logical core damage equation remains as given by base case Eq. 10-2:

$$(CD) = (IE1) \times (M1)$$

However, with modified IE frequency the quantitative core damage risk equation becomes:

$$\begin{aligned} f_{CD}(t) &= [f_{IE1} + \Delta f_{IE1}(t)] \times q_{M1} = \\ &= f_{IE1} \times q_{M1} + \Delta f_{IE1}(t) \times q_{M1} \end{aligned} \qquad \text{Eq. 10-4}$$

In order to obtain aging core damage risk contribution, the baseline CDF, given by Eq. 10-3, needs to be subtracted:

$$\Delta f_{CD}(t) = \Delta f_{IE1}(t) \times q_{M1} \qquad \text{Eq. 10-5}$$

Considering that q_{M1} presents the conditional core damage probability (CCDP) for considered initiator IE1 ($P_{CCD,IE1}$), this is the same risk equation as Eq. 2-1.

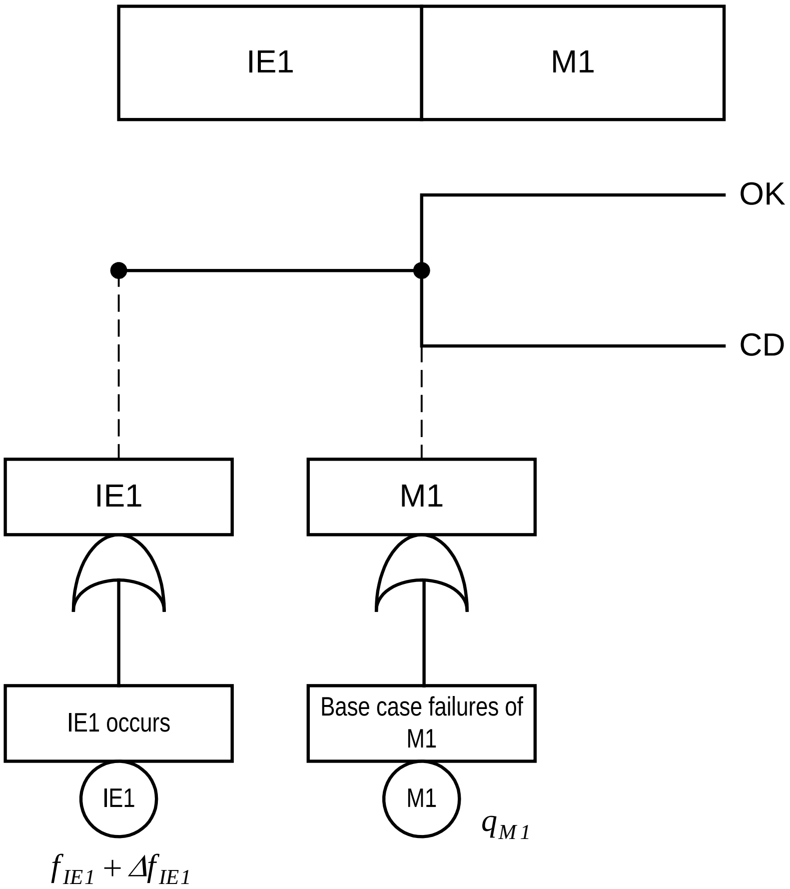


Figure 10-2: Modified PSA Model for Category O Example

<u>"Standby - Demand" (SD) Scenario / Configuration</u>

In this case, considered aging impact is on the SSC related to a specified mitigation function, which is required in the case that any of a number of IEs occurs. Aging impact reflects in an increasing rate of a degraded condition of a SSC which is such that, if not discovered and removed, would prevent a SSC in performing its intended mitigation function when demanded:

$$\lambda_{ag,SSC}(t) = f_{degrad,SSC}(t) \quad \text{Eq. 10-6}$$

Surveillance tests are performed on a SSC with time period T_{ST}. If considered aging-induced degradation is present at the time of test, it would be discovered by the test.

Base Case PSA Model

Relevant part of a base case PSA model is illustrated by Figure 10-3. The IE2 and IE3 represent a group of initiators relevant for the considered mitigation function M2, into which the SSC of concern is involved. Mitigation of any of these initiators requires function M2 and, thus, the SSC of concern. Failure of M2 function following an occurrence of any of these initiators would lead to a core damage, as indicated by the consequence CD in the event trees. Therefore, logical CD risk equation for this case is:

$$(CD) = (IE2) \times (M2) + (IE3) \times (M2) \quad \text{Eq. 10-7}$$

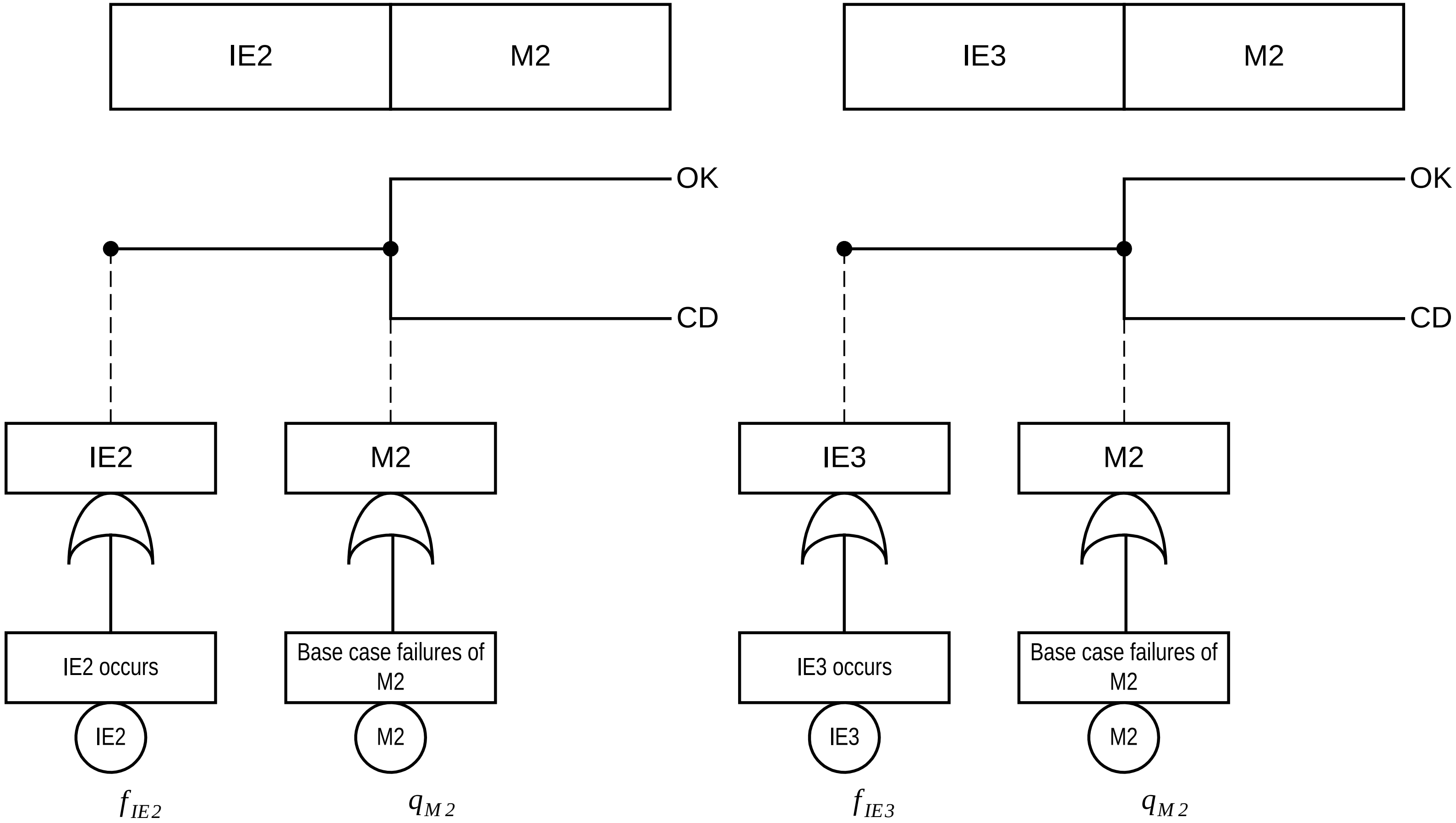


Figure 10-3: Base Case PSA Model for Category SD Example

Corresponding quantitative core damage risk equation is:

$$f_{CD} = f_{IE2} \times q_{M2} + f_{IE3} \times q_{M2} \qquad \text{Eq. 10-8}$$

where

f_{CD}	base case frequency of core damage (i.e. CDF);
f_{IE2}, f_{IE3}	base case frequency of IE2 and IE3 initiator categories;
q_{M2}	base case probability of failure of M2 function.

Modified PSA Model

As pointed, aging impact reflects in an increasing rate of degraded condition of SSCs performing the M2 function such that, if not discovered and removed, it would prevent an SSC to perform the M2 function on demand. The corresponding degradation rate is established on the basis of evaluated SSC aging rate:

$$\lambda_{ag,SSC}(t) = f_{deg\,rad,M2}(t) \qquad \text{Eq. 10-9}$$

The PSA model is modified to incorporate this aging impact, as shown in Figure 10-4.

The degraded condition of M2 caused by aging is modelled as an additional failure mode in the M2 fault tree structure. It is represented by the new basic event named “M2A”, which, basically, represents a failure of M2 function on demand, caused by aging. (Basic event representing the base case failures of M2 was, for convenience, renamed to “M20”.) The “M2A” is a direct input into the top M2 gate, so that its occurrence means a failure of the M2 function.

(Alternatively, the existing basic event representative for M2 failure on demand could have been edited and its assigned probability of failure on demand increased according to the aging contribution.)

The probability of the new basic event, q_{M2A}, is derived from the aging-induced degradation rate $f_{deg\,rad,M2}(t)$ and basic equation for unreliability (unavailability) of non-repairable component:

$$q_{M2A}(\tau) = 1 - exp\left[-\int_0^\tau f_{deg\,rad,M2}(t)dz\right] =$$

$$= 1 - exp\left[-f_{deg\,rad,M2}(t)\int_0^\tau dz\right] = \qquad \text{Eq. 10-10}$$

$$= 1 - exp\left[-f_{deg\,rad,M2}(t)\tau\right] \approx f_{deg\,rad,M2}(t) \times \tau$$

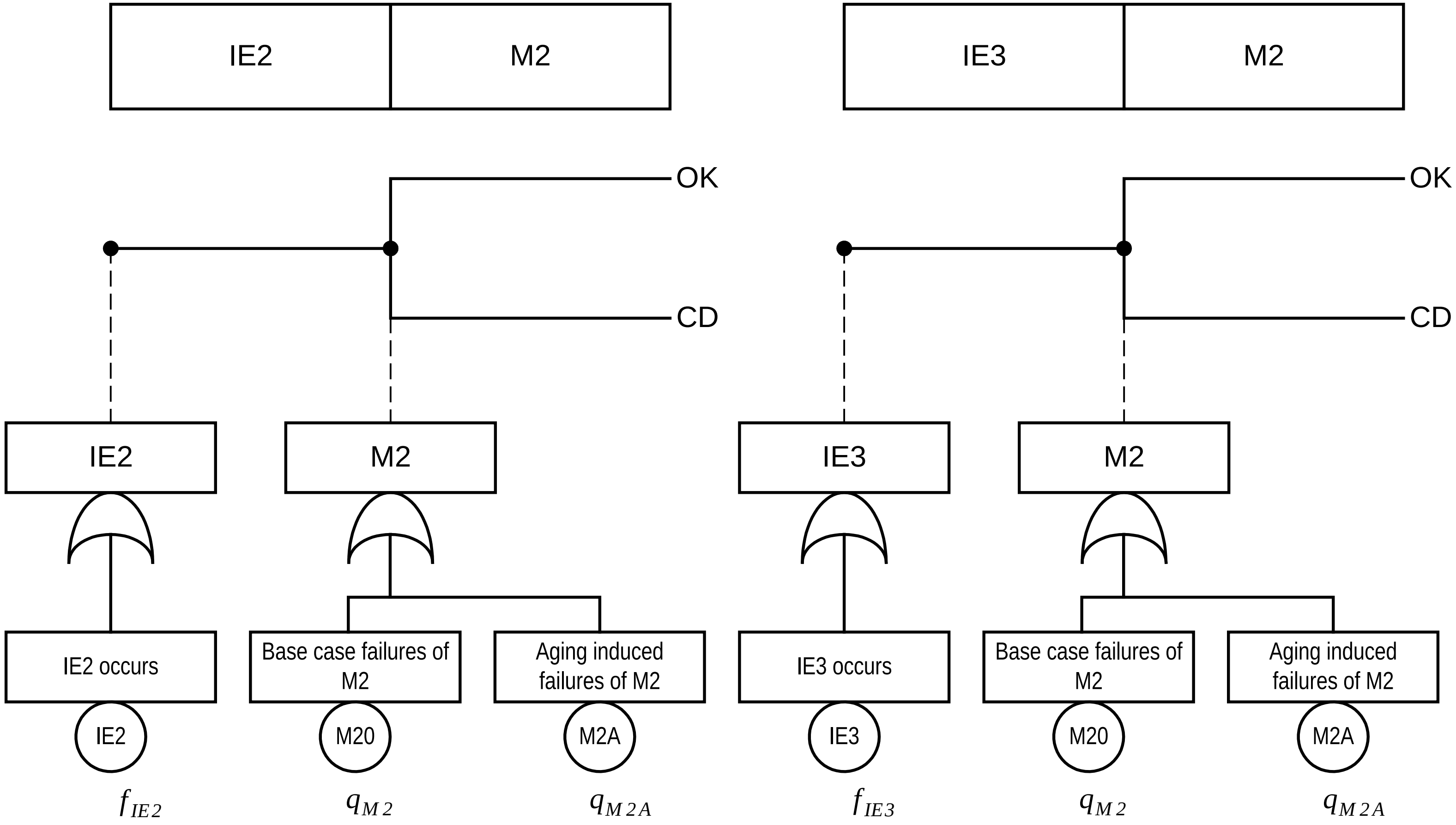


Figure 10-4: Modified PSA Model for Category SD Example

In Eq. 10-12, τ represents the time passed since the last demonstration of operability or availability of the function M2 and t represents the age of SSCs involved in function M2 (or, approximately, the absolute time – time since the SSC was put into operation). Since the degraded condition would be discovered, per the assumption, by the surveillance test, the largest value τ can take would be the time between two consecutive surveillance tests, i.e. T_{ST}. Time period T_{ST} is short in comparison to the time range which is of concern for aging considerations and this is why the aging-induced degradation rate $f_{deg\,rad,M2}(t)$ (although a function of "absolute" time) can be considered constant in the integration performed under Eq. 10-12.

The unavailability of M2, $q_{M2A}(\tau)$, (i.e. the probability that M2 is failed or unavailable due to the aging impact at the time of demand) is proportional (approximately) to the time passed since the last demonstration of availability / operability: longer the time passed, larger the probability. Considering that $0 < \tau < T_{ST}$, the average value of aging-induced M2 unavailability to be assigned to the new basic event "M2A" in the modified PSA model is:

$$
\begin{aligned}
q_{M2A} &= \frac{1}{T_{ST}} \int_0^{T_{ST}} q_{M2A}(\tau) d\tau = \\
&= \frac{1}{T_{ST}} \int_0^{T_{ST}} f_{deg\,rad,M2}(t)\ \tau\, d\tau = \\
&= \frac{f_{deg\,rad,M2}(t)}{T_{ST}} \int_0^{T_{ST}} \tau\, d\tau = \\
&= f_{deg\,rad,M2}(t) \frac{T_{ST}}{2}
\end{aligned}
\qquad \text{Eq. 10-11}
$$

Therefore, the average time during which the function M2 would be exposed to the risk from the aging impact failure is a half of the time between two surveillance tests. This time, when multiplied by the corresponding aging induced degradation rate, is used to provide the probability to be assigned to the basic event M2A in the modified PSA model.

Considering the modifications done to the PSA model, the logical CD risk equation becomes, for this case,:

$$
\begin{aligned}
(CD) &= (IE2)\times(M2)+(IE3)\times(M2) = \\
&= (IE2)\times[(M20)+(M2A)]+(IE3)\times[(M20)+(M2A)]
\end{aligned}
\qquad \text{Eq. 10-12}
$$

Corresponding quantitative core damage risk equation is, taking the rare event approximation:

$$
f_{CD} = f_{IE2}\times(q_{M2}+q_{M2A})+f_{IE3}\times(q_{M2}+q_{M2A}) \qquad \text{Eq. 10-13}
$$

Note that basic event with base case failures, M20, is assigned the same probability q_{M2} as in the base case equation Eq. 10-8.

Substituting the right hand side of Eq. 10-12 for q_{M2A} gives:

$$f_{CD} = f_{IE2} \times q_{M2} + f_{IE3} \times q_{M2} \;+$$

$$+ f_{IE2} \times f_{deg\,rad,M2}(t) \times \frac{T_{ST}}{2} + f_{IE3} \times f_{deg\,rad,M2}(t) \times \frac{T_{ST}}{2} \qquad \text{Eq. 10-14}$$

Similarly to the case with category O above, in order to obtain aging core damage risk contribution (i.e. ΔCDF), the baseline CDF, given by Eq. 10-8, needs to be subtracted from the right hand side of Eq. 10-14. This, upon re-arranging, gives:

$$\Delta f_{CD}(t) = f_{deg\,rad,M2}(t) \times \left(f_{IE2} + f_{IE3}\right) \times \frac{T_{ST}}{2} \qquad \text{Eq. 10-15}$$

Considering that $f_{IE2} + f_{IE3}$ in this simplistic case represents conditional CDF for the plant configuration with unavailable function M2, ($f_{IE2} + f_{IE3} = f_{CCD,config,M2}$) and that $\frac{T_{ST}}{2}$ represents the exposure time, T_{ex}, the above equation can be rewritten as

$$\Delta f_{CD}(t) = f_{deg\,rad,M2}(t) \times f_{CCD,config,M2} \times T_{ex} \qquad \text{Eq. 10-16}$$

which corresponds to the risk equation Eq. 2-2 for the SD configuration.

In the real PSA model, the induced failure probability on demand can relate to a single component, to multiple components or to a whole system. With respect to this, important is consideration of potential for the common cause failures (CCF). We provide a short discussion on these subjects.

Modelling of Failure of a Single Component

From the above discussion, the probability of failure on demand of specific component due to aging impact is estimated as:

$$q(t) = \lambda_{ag}(t) \frac{T_{ST}}{2} \qquad \text{Eq. 10-17}$$

where $\lambda_{ag}(t)$ is aging failure rate, and T_{ST} is time between two surveillance tests. This failure probability is assigned to a basic event in the PSA logical structure, which is representative of considered specific component.

Modelling of System Level Failures

Theoretically, the approach to model the aging-induced failures of a group of components which are subject to CCF potential would be:

- Define a basic event for each component within a group. (Note: It can be logically "OR-ed" to aging-independent representative basic event.)
- Assign the above probability *q(t)* to each basic event.
- Define CCF groups corresponding to the existing CCF groups (i.e. those for the aging-independent basic events), using the existing corresponding CCF parameters (e.g. MGL beta, gamma, etc.). Note: This is the approach which has been used in other aging PSA applications (e.g. [16]).
- (Alternatively: each existing basic event in the CCF group can be edited and its probability increased by aging contribution. The existing CCF group definition would remain as is.)

The above procedure is not feasible within the scope of the current project due to very large number of components. Moreover, some of the components (especially passive) may not be represented / modelled in the referential PSA, due to the assumed low (aging-independent) failure probabilities. The following approximation will be used to address the CCF potential in the case of aging impact / scenario from the SD category:

- For CCF probability estimation, use beta-model (for redundancy levels 2 and larger), with β parameter estimated on the basis of generic values for considered component's type.
- Estimate number of components of considered type (e.g. MOVs) which are "in series", for a single train. This number is, for convenience, referred to, as *n*.
- Define system-level basic event for aging-induced failures of redundant trains.
- Assign to this representative basic event the probability:

$$q^{(S)}(t) = \beta[n\, q(t)] \qquad \text{Eq. 10-18}$$

where *q(t)* is component level probability defined by Eq. 10-17.

The above procedure is used for each type of components, within a system, considered to be subject to aging (i.e. each component type is represented by a system-level basic event at each system where relevant.)

Note: Consideration of CCF potential is specific to the SD category of scenario / configuration. Namely, the failure of multiple components is, in such a scenario, caused by a shock (e.g. pressure transient) imposed on all degraded components by a demand.

In the case of categories O and SM, increased failure rate due to aging is also considered for all components of the same type and function. However, the components / elements are considered to fail independently (even with increased rate / probability), as long as there is no simultaneous demand / shock applied to them.

This is consistent with CCF models which are, usually, applied in the PSAs, such as beta-model, MGL or alpha-model. Each of them specifically considers demand-type failures.

Modelling of a Single Component / Element Failing Whole System's Function

If a single component or element (such as a segment of piping) functionally fails the system as a whole, it can be represented in the system's logical model (fault tree) as follows:

- Define a system-level representative single basic event;
- Assign to this basic event probability *q(t)* (Eq. 10-17). In the case there are more such components, assign the probability *[m q(t)]* where *m* is a number of components / elements of this type, each failing the system as a whole.

<u>"Standby - Monitored" (SM) Scenario / Configuration</u>

PSA modelling of SM scenario corresponds to the modelling of SD scenario, illustrated above. The difference is in the exposure time which, in this case, usually corresponds to the AOT. However, this only reflects in the basic event probability, and not in the logical model.

The probability to be assigned to aging-related basic event representing a failure / unavailability of monitored SSC can be derived from the following considerations. The aging risk impact comes from the concern that certain initiator, IE, may occur during the time considered SSC is unavailable due to the aging induced degradation. Assuming that immediately upon observing the failed status of monitored SSC the LCO would be entered, this out-of-service time (or exposure time, T_{ex}) can be approximated by the AOT. (After the AOT, the SSC is either repaired or plant goes into a shutdown. Any residual risk coming from this controlled shutdown is not further considered here. As noted earlier, it can, under certain assumptions, be considered small in comparison to the first risk contributor.) Sometimes, the AOT may be extended based on the JCO. In such a case, the extended AOT time should be considered.

Expected frequency of SSC entering the failed status ($_{ffail,SSC(t)}$)due to aging corresponds to the time dependent aging failure rate, i.e.:

$$\lambda_{ag,SSC}(t) = f_{fail,SSC}(t) \qquad \text{Eq. 10-19}$$

The CD risk from this scenario (i.e. initiator IE occurs during the time T_{ex} while considered SSC is out of service due to aging-induced failure) can then be estimated as:

$$\Delta f_{CD,IE}(t) = f_{fail,SSC}(t) \times \left(f_{IE} \times T_{ex}\right) \times P_{CCD,SSC,IE} \qquad \text{Eq. 10-20}$$

where:

$\left(f_{IE} \times T_{ex}\right)$ Probability that IE occurs during the time T_{ex}. (T_{ex} is relatively short time, usually measured in days, and any variation of IE frequency due to, e.g. other aging impacts, can be neglected.)

$P_{CCD,SSC,IE}$ Conditional core damage probability (CCDP) for considered IE, given that SSC is unavailable.

By rearranging and considering that $f_{IE} \times P_{CCD,SSC,IE} = f_{CCD,SSC,IE}$ (i.e. the contribution of IE to the conditional CDF (CCDF) for induced aging-related failure of SSC), the above equation can be rewritten as:

$$\Delta f_{CD,IE}(t) = f_{fail}(t) \times f_{CCD,SSC,IE} \times T_{ex} \qquad \text{Eq. 10-21}$$

which fully corresponds to risk equation Eq. 2-3. (The only difference is that Eq. 10-21 reflects only the contribution from the initiator IE, while Eq. 2-3 represents the overall CDF increase considering all the initiators.)

At the same time, if Eq. 10-20 is rearranged to the form

$$\Delta f_{CD,IE}(t) = f_{IE} \times \left(f_{fail,SSC}(t) \times T_{ex}\right) \times P_{CCD,SSC,IE} \qquad \text{Eq. 10-22}$$

it becomes evident that the term $\left(f_{fail,SSC}(t) \times T_{ex}\right)$ can be interpreted as aging-related failure probability of monitored SSC.

Therefore, as compared to the above discussed case of SD scenario, in the case of PSA modelling of SM scenario, the failure probability to be assigned to the basic event representing the unavailability of considered monitored SSC, caused by aging induced failure, is:

$$q_{SSC}(t) = f_{fail,SSC}(t) \times T_{ex} = \lambda_{ag,SSC}(t) \times T_{ex} \qquad \text{Eq. 10-23}$$

where T_{ex} usually represents the AOT for the SSC.

Combination of O Scenario with SD or SM Scenarios

Risk contribution (in terms of CDF increase) coming from a combination of aging-induced O scenario involving specific initiator IE with aging-induced SD or SM scenario involving failure of specific SSC can, considering the above discussions, be expressed as:

$$\Delta f_{CD,IE}(t) = \Delta f_{IE}(t) \times \left(\lambda_{ag,SSC}(t) \times T_{ex}\right) \times P_{CCD,SSC,IE} \qquad \text{Eq. 10-24}$$

where:

$\Delta f_{IE}(t)$	Aging-related increase in frequency of the initiator IE;
$\left(\lambda_{ag,SSC}(t) \times T_{ex}\right)$	Aging-related probability that SSC will fail on demand (SD scenario) or is unavailable (SM scenario) at the time of IE occurrence. In the case of SD scenario, T_{ex} is, usually, half of the STI associated with SSC and in the case of SM scenario it is, usually, the AOT associated with the SSC.
$P_{CCD,SSC,IE}$	Conditional core damage probability (CCDP) given occurrence of IE and failure / unavailability of SSC.

The overall contribution is obtained by summing over all relevant combinations of IEs and SSCs. If all the representative basic events for O, SD and SM scenarios are incorporated in the PSA model as discussed in previous sections, then all relevant combinations are picked up and reflected in the minimal cutsets.

Similarly, any relevant combination among SD-type failures or between SD and SM failures would be picked up by the minimal cutsets.

10.2 Supporting Data Evaluations for Aging Failure Rates

10.2.1 Introduction

This appendix describes the supporting evaluations of available information and data, which were performed in order to establish the aging failure rates for the SSCs identified in section 4. The main referential documents which provided the bases for the evaluations are, also, specified in the section 4.

The data evaluations were aimed at estimating the aging failure acceleration parameter, a (expressed in the units of /hr/yr), from the linear aging failure rate model described by Eq. 2-4, for the relevant SSCs.

The NUREG/CR-4769, [6], provides an estimate of the aging failure acceleration:

$$a = \frac{f_A}{1 - f_A} \frac{\lambda_0}{T_A}$$ Eq. 10-25

where

f_A Fraction of failures, over considered time period, determined to be caused by aging related stressors;

λ_0 Constant failure rate due to random, non-aging mechanisms;

T_A Average age or time of exposure to the aging mechanism.

The above can be rewritten as:

$$a = f_A \frac{\lambda}{T_A}$$ Eq. 10-26

where λ now represents the total constant failure rate, averaged over the same considered time period.

Similar estimators can, also, be found in NUREG/CR-5248, [5], and IAEA TECDOC-540, [11].

The above estimator can be used to map the aging failure acceleration from a generic or "source" plant, a_S, to a considered "target" plant in order to provide a "pseudo plant specific" aging failure acceleration for the "target" plant, a_T. For this, the assumption will be made that for the components of similar age at the target and source plants the fractions of aging-related failures are similar to each other, i.e. $f_{A,S} \approx f_{A,T}$. In other words, it is assumed that larger (or smaller) total failure rate implies correspondingly larger (or smaller) aging failure rate, which is considered to be a reasonable assumption. Under this assumption:

$$a_T \approx a_S \frac{\lambda_T}{\lambda_S} \qquad \text{Eq. 10-27}$$

where λ_T and λ_S are the total averaged failure rates for the target and source plant.

Therefore, regarding the "generic" data from sources such as NUREG/CR-5248 (TIRGALEX), two "generic" parameters are needed in order to be able to make a "pseudo plant specific" aging failure acceleration *a* for a considered SSC:

- "Generic" aging failure acceleration *a* (/hr/yr), and
- "Generic" total (averaged) failure rate λ (/hr).

10.2.2 Data Available from NUREG/CR-5248 (TIRGALEX)

The data on generic aging failure accelerations and total averaged failure rates which were extracted, for the relevant SSCs, from NUREG/CR-5248 are presented in Table 10-1.

Table 10-1: Data Extracted from NUREG/CR-5248 (TIRGALEX Study)

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate λ (/hr)
1	AHU	O	Not considered.	Not considered.
		SD	Item 24.b. *a* = 2.1E-07 /hr/yr	Item 24. λ = 1E-06 /stdby hr
2	AOV	O	Not considered.	Not considered.
		SD	Item 18.a. *a* = 4E-07 /hr/yr.	Item 18.a. λ = 4E-06 /stdby hr.
3	Battery	SD	Item 25; *a* = 3.4E-07 /hr/yr	Item 25; λ = 1E-06 /stdby hr
4	Bolts - Connections	SM	Use same as for SD.	Use same as for SD.
		SD	Consider: for bolts: *a* = 5.1 E-07 /hr/yr; for snubbers *a* = 5.1E-06 /hr/yr. Note: function level "*a*" value. No specific "*a*" value for bearing plates.	For bolts, based on λ for Small LOCA (BWR) = 1E-03/yr. For snubbers: "similar to bolts". No specific value for bearing plates.
5	Bus	O	Not considered.	Not considered.
		SD	Item 30 a/b; *a* = 1.1E-09 /hr/yr.	Item 30; λ = 1E-08 /stdby hr.

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate λ (/hr)
6	Cable Connectors	O	Note: Standby rate from NUREG: Item 10.b. *a* =2.7E-08 /hr/yr	Note: For standby rate (based on NUREG considerations): Take λ for a transformer (as for cables): 1E-06 /stdby hr.
7	Cables	O	Not considered.	Not considered. Note: Take operating λ for a transformer.
		SD	Item 10.a (Cables). *a* = 2.7E-09 /hr/yr. (Note: "aging factor was treated as nearly the same as for a transformer".)	Take λ for a transformer: 1E-06 /stdby hr.
8	Calandria Vault	O	Establish on the basis of values for concrete and steel structures (e.g. items 2 and 3).	N/A
9	CB	O	Not considered.	Not considered.
		SD	Item 17.b (Circuit breaker); *a* = 1.6E-08 /hr /yr	Item 17.b (circuit breaker). λ = 4E-06 /stdby hr
10	Check Valve	O	Not considered.	Not considered.
		SD	Item 18.b. *a* = 3.8E-09 /hr/yr (Final. Pre-calculated 100 x higher.)	18.b. λ = 3.0E-06 /stdby hr
11	Containment - Concrete	SD	All steel and concrete lumped under item 2.	N/A
12	Containment - Foundations	SD	No specific "*a*" value. Consider item 2 (Containment - others; *a*= 1E-13 /hr/yr) and item 3. (other Category 1 structures). *a* = 1E-13 /hr/yr.	N/A
13	Containment - Penetrations	SD	Item 10 (Penetrations as part of containment); *a* = 2.7E-09 through 2.7E-08 /hr/yr.	N/A
14	Containment - Steel	SD	Item 2.b (Containment other than BWR Mark 1); *a* = 1E-13 /hr/yr. (All steel and concrete lumped under item 2.)	N/A
15	Containment Isolation Valves	SD	Containment isolation valves, typically, are MOVs, AOVs or Check Valves. Largest *a* value is for MOV: 3.6E-06 /hr/yr.	Item 18.e. λ = 4E-06 / stdby hr.
16	EDG	SD	Item 11; *a* = 3.6E-06 /hr/yr	Item 11; λ = 4E-05 /stdby hr

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate λ (/hr)
17	Expansion Joints	O	Same remark as for SD.	N/A
		SD	No specific *a* value for expansion joints. Consider categories: item 4. (RC piping and safe ends), 5. (other safety related piping), 10. (Containment penetrations), 14. recirculation piping safe ends.	N/A
18	Heat Exchanger	O	Not considered.	Not considered.
		SD	Item 22; *a* = 1.4E-08 /hr/yr.	Item 22; λ = 3E-06 /stdby hr.
19	Inverter	O	Not considered.	Not considered.
		SD	Item 26b; *a* = 4.9E-06 /hr/yr	Item 26b; λ = 1E-04 /stdby hr
20	MOV	O	Not considered.	Not considered.
		SD	Item 18.e (MOV); *a* = 3.6E-06 /hr/yr.	Item 18.e. λ = 4E-06 / stdby hr.
21	Other Concrete	O	Same remark as for SD.	N/A
		SD	Establish on the basis of values for concrete and steel structures (e.g. items 2 and 3). Item 3 (Other Concrete Structures); *a* = 1E-13 /hr/yr	N/A
22	Other Foundations	SD	No specific *a* value. Consider item 2 (Containment - others; *a* = 1E-13 /hr/yr) and item 3. (other Category 1 structures). *a* = 1E-13 /hr/yr.	N/A
23	PHT Feeders	O	No. Consider Item 4 (RC piping.)	N/A
24	PHT Fuel Channels	O	No. Consider Item 1 (RPV) and 4 (RC piping.)	N/A
25	PHT Pressure Tubes	O	No. Consider Item 1 (RPV) and 4 (RC piping.)	N/A
26	Piping	O	Items 4 and 5. Primary system: LLOCA = 1E-12 /hr/yr; PWR SLOCA = 3E-11 /hr/yr; BWR SLOCA = 3E-08 /hr/yr; Other systems: Large = 3E-09 /hr/yr; Small = 3E-07 /hr/yr	BWR SLOCA λ = 1E-03 /yr. (Item 4c, App. D). All others derived by applying a factor or an order of magnitude.
		SD	Not considered. Comment.	Not considered.
27	Pump	O	Not considered. Comment.	Not considered.

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate λ (/hr)
		SD	Item 19.a. (Motor Driven Pump). *a* = 2.2E-07 /hr/yr	Item 19.a. (Motor Driven Pump). λ = 4.0E-06 /stdby hr
28	Reactivity Control Units	O	Item 9 (CRDM)	N/A
29	Rectifier	O	Not considered.	Not considered.
		SD	Item 26c; *a* = 8.7E-08 /hr/yr	Item 26c; λ = 3E-06 /stdby hr
30	Relief Valve	O	Not considered.	Not considered.
		SD	Item 18.f. *a* = 6.7E-07 /hr/yr.	Item 18.f. λ = 1E-05 /stdby hr.
31	SDS1	SD	Establish acceleration rate by considering items such as 9 (CRDM), 10 (connectors) and others related to SSC categories included under residual risk from SDS1 aging.	N/A
32	SG Shell Side	O	Item 6b (Shell-side): *a* = 1E-12 /hr/yr	See App. D, Item 6b.
33	SG Tube Side	O	Item 6a (Tube-side): *a* = 5E-06 /hr/yr	See App. D, Item 6a.
34	Solenoid Valve	SD	No specific *a* value. Take from AOV.	Check IREP. If no, take from AOV.
35	Tanks - Atmospheric	O	See note on λ.	Failure rate stated "per standby hr". But can, for this type of SSC, be considered same as operating failure rate.
		SM	Item 29b (Atmospheric pressure tank). *a* = 2.0E-10 /hr/yr.	Item 29. λ = 1E-09 /stdby hr
36	Tanks - High Pressure	O	Item 29c (High pressure tank). *a* = 1.0E-12 /hr/yr. See note on λ.	Item 29. λ = 1E-09 /stdby hr. Note: Failure rate stated "per standby hr. But can be, for this type of SSC, considered same as operating f.r.
37	Transformer	O	Not considered.	Not considered.
		SD	Item 27. *a* = 1.7E-09 /hr/yr	Item 27. λ = 1E-06 /stdby hr

10.2.3 Failure Rates from NUREG/CR-6928

NUREG/CR-6928, published in 2007, provides failure rates for components and initiating events at U.S. commercial nuclear power plants. These failure rates can be used to "update" the generic aging failure accelerations from the NUREG/CR-5248 (TIRGALEX Study) in a manner discussed in previous sections. Aging accelerations "updated" in this manner are considered more representative of the current operating plants, having in mind that the TIRGALEX study used the averaged failure rates which were taken from the old IREP study (Interim Reliability Evaluation Program). Averaged failure rates extracted for the relevant SSCs from the NUREG/CR-6928 are presented in Table 10-2.

Table 10-2: Total averaged failure rates extracted from NUREG/CR-6928

#	SSC	Configuration	Failure Rate (/hr) (1)	Remark
1	AHU	O	1.50E-05	Running / alternating mode (as compared to standby).
		SD	1.11E-06	Standby mode (as compared to running / alternating).
2	AOV	O	3.50E-06	Approximate sum of all time-related failure mode rates.
		SD	1.67E-06	
3	Battery	SD	2.00E-06	
4	Bolts - Connections	SM	N/A	
		SD	Note: SLOCA for BWR = 5.0E-04 /yr	
5	Bus	O	4.00E-07	For bus, no distinction is made between failure rate (FTO mode, Failure to Operate) for operating and standby mode.
		SD	4.00E-07	See above.
6	Cable Connectors	O	N/A	
7	Cables	O	N/A	
		SD	N/A	
8	Calandria Vault	O	N/A	
9	CB	O	1.50E-07	Time-related failure modes (spurious opening)
		SD	3.47E-06	
10	Check Valve	O	7.30E-06	Approximate sum of all time-related failure mode rates.
		SD	7.78E-08	Mean between failure to open and failure to close probability.
11	Containment - Concrete	SD	N/A	
12	Containment - Foundations	SD	N/A	
13	Containment -	SD	N/A	

#	SSC	Configuration	Failure Rate (/hr) (1)	Remark
	Penetrations			
14	Containment - Steel	SD	N/A	
15	Containment Isolation Valves	SD	1.39E-06	Based on MOV.
16	EDG	SD	1.11E-05	Sum of failure rates for failure to start and failure to load and run for 1 hr.
17	Expansion Joints	O	N/A	
		SD	N/A	
18	Heat Exchanger	O	6.00E-07	Approximate sum of time-related failure modes. No demand-related failure modes. No distinction between standby and operating modes.
		SD	6.00E-07	See above remark.
19	Inverter	O	5.00E-06	Failure to operate, the only failure mode. Time-related. No distinction between operating and standby modes.
		SD	5.00E-06	See above remark.
20	MOV	O	3.20E-06	Approximate sum of all time-related failure mode rates.
		SD	1.39E-06	
21	Other Concrete	O	N/A	
		SD	N/A	
22	Other Foundations	SD	N/A	
23	PHT Feeders	O	N/A	
24	PHT Fuel Channels	O	N/A	
25	PHT Pressure Tubes	O	N/A	
26	Piping	O	SLOCA for BWR = 5.0E-04 /yr; for PWR = 6.0E-04 /yr;	For Other Piping, estimates can be made by system.
		SD	N/A	No distinction.
27	Pump	O	5.00E-06	Failure to run for Running / Alternating mode. Note that leakage rates are by an order of magnitude lower.

#	SSC	Configuration	Failure Rate (/hr) (1)	Remark
		SD	2.08E-06	Failure to start for standby mode.
28	Reactivity Control Units	O	N/A	Demand failure probability provided at 1.2E-05 /demand.
29	Rectifier	O	4.00E-06	For battery charger. Running / Alternating mode. No distinction regarding standby mode.
		SD	4.00E-06	See above remark.
30	Relief Valve	O	1.24E-07	Spurious opening.
		SD	6.11E-06	Mean between failure to open and failure to close.
31	SDS1	SD	1.67E-08	Based on Control Rod Drive failure probability per demand.
32	SG Shell Side	O	N/A	(TIRGALEX): "One order of magnitude larger than a small break in large pipe in a PWR".
33	SG Tube Side	O	4E-03 /yr	
34	Solenoid Valve	SD	N/A	
35	Tanks - Atmospheric	O	3.20E-08	Unpressurized. Large + Small Leakage. No distinction between operating and standby modes.
		SM	3.20E-08	See above remark.
36	Tanks - High Pressure	O	4.30E-08	Pressurized. Large + Small Leakage.
37	Transformer	O	9.00E-07	Failure to operate. No distinction between modes.
		SD	9.00E-07	See above remark.

Notes for Table 10-2:

1. Demand failure probabilities converted, where applicable, by applying 720 hrs (consistently with NUREG/Cr-5248).

10.2.4 Data Extracted from EUR 24643

The study EUR 24643 (Analysis of data related to ageing of VVER-440 NPP components) provides, in its Appendix 1, data on numbers of failures and demands / exposure times from 13 VVER plants for the types of components:

- Main Feedwater Pumps;
- Emergency Diesel Generators;

- Circuit Breakers.

Data are shown in the form of number of failures and number of demands / hours of exposure for particular plant in particular year of operation.

Time span (calendar years) considered in the evaluation for the purposes of this study was selected in a way to encompass the largest possible number of plants considered.

10.2.4.1 Summary

Summary of the evaluation of data extracted from the EUR 24643 study is presented by Table 10-3. The details of evaluations for the three categories of components are provided in the corresponding sections below.

Table 10-3: Summary of evaluated data extracted from EUR 24643

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
9	CB	O	N/A	N/A	
		SD	5.7E-07 /hr/yr	3.3E-06 /hr	
16	EDG	SD	Negligible.	Roughly, 4E-05 /hr.	Data point to a negative trend.
27	Pump	O	Negligible.	Roughly, 1E-05 /hr.	Data point to a negative trend. Note: Non-safety, MFW Pumps only. Normally running.
		SD	N/A	N/A	N/A

10.2.4.2 Emergency Diesel Generators

The data extracted from the EUR 24643 study for Emergency Diesel Generators are summarized in Table 10-4.

If implied failure rates from the EUR 24643 study (Table 10-4) are taken to estimate probabilities of failure to perform mission (taking 24 hrs as a mission time, for indication), the obtained failure probabilities are, apparently, too high. The estimates imply mission failure probabilities of, roughly, 20%. It is considered that this is not applicable to Canadian plants. The reason for this is, most likely, underestimated exposure times. If number of demands for starting failures is taken as an indication (i.e. 400 demands on an annual basis), it appears that an average EDG is, at test, left to run for only a bit longer than 1 hour. These appear to be early running failures which will be, for the purpose of this evaluation, re-counted as failures to start (i.e. added to numbers of failures to start, with numbers of demands unchanged – as same demand applies to a start and to continued operation following a start).

Table 10-4: Data extracted from EUR 24643 for emergency diesel generators

Year of Operation	Failure to Start				Failure to Run			
	No. of Failures	No. of Demands	Q, (Note 1) /demand	λ (Note 2), /hr	No. of Failures	No. of Hours	λ (Note 1), /hr	Q (Note 3), /demand
1996	9	400			2	460.14		
1997	8	400			4	460.14		
1998	4	400	1.75E-02	2.43E-05	3	460.14	6.52E-03	1.56E-01
1999	8	400	1.67E-02	2.31E-05	8	460.14	1.09E-02	2.61E-01
2000	7	400	1.58E-02	2.20E-05	2	460.14	9.42E-03	2.26E-01
2001	6	400	1.75E-02	2.43E-05	3	460.14	9.42E-03	2.26E-01
2002	7	400	1.67E-02	2.31E-05	6	460.14	7.97E-03	1.91E-01
2003	6	400	1.58E-02	2.20E-05	2	460.14	7.97E-03	1.91E-01

Notes for Table 10-4:

1. Rolling average for three consecutive years.
2. Assuming 1 month (= 30 x 24 = 720 hrs) as average time between demands.
3. Assuming mission time of 24 hrs.

The evaluation with revised numbers of failure to start is shown in Table 10-5. Estimated failure rates (λ, /hr) show good comparison with corresponding values from NUREG/CR-5248 (4E-05 /hr) and NUREG/CR-6928 (1.1E-05 /hr).

Table 10-5: Data extracted from EUR 24643 for emergency diesel generators – revised numbers of failure to start

Year of Operation	Revised Failures to Start			
	No. of Failures	No. of Demands	Q, (Note 1) /demand	λ (Note 2), /hr
1996	11	400		
1997	12	400		
1998	7	400	2.50E-02	3.47E-05
1999	16	400	2.92E-02	4.05E-05
2000	9	400	2.67E-02	3.70E-05
2001	9	400	2.83E-02	3.94E-05
2002	13	400	2.58E-02	3.59E-05
2003	8	400	2.50E-02	3.47E-05

Notes for Table 10-5:

1. Rolling average for three consecutive years.
2. Assuming 1 month (= 30 x 24 = 720 hrs) as average time between demands.

Failure rate trend for the data from Table 10-5, based on the minimum sum of squares, is shown in Figure 10-5. It shows negative trend implying the negative aging failure acceleration, a, of -3.31E-07 /hr/yr. The result of this trending will be, for the purpose of this evaluation, interpreted as negligible aging failure acceleration due to the effective aging management (at considered group of nuclear power plants).

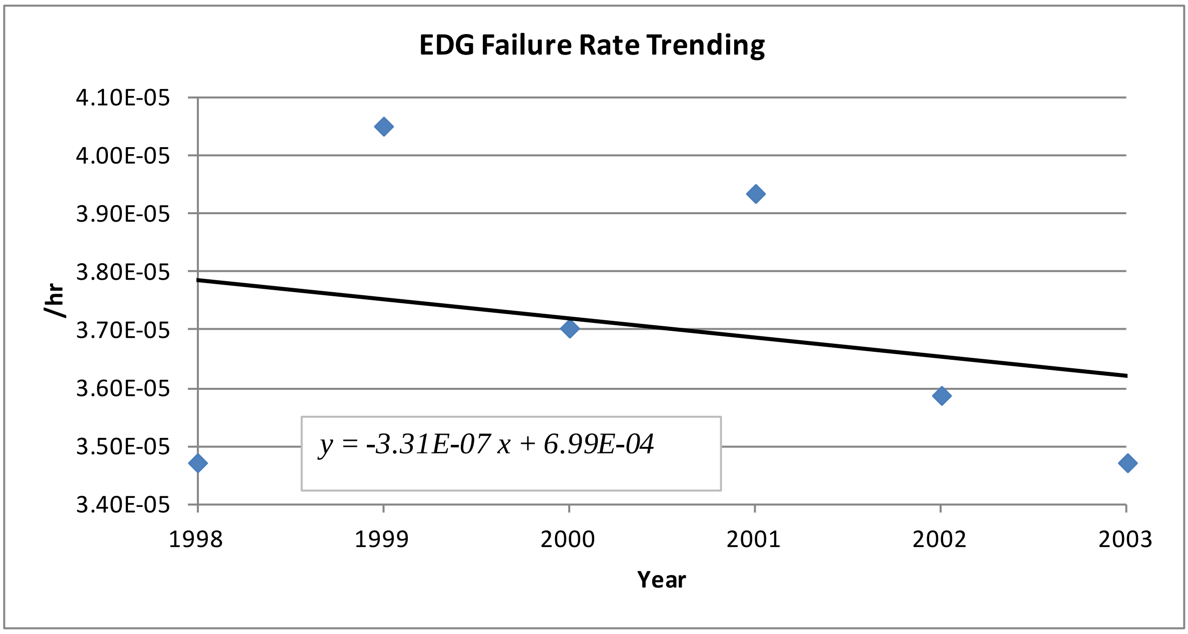


Figure 10-5: Failure rate trend for EDG based on data extracted from the EUR 24643 study

10.2.4.3 MFW Pumps

The data extracted from the EUR 24643 study for MFW Pumps are summarized in Table 10-6. Being normally operating and non-safety pumps, primary risk impact would come from failure to run which would trigger an initiating event.

Table 10-6: Data extracted from EUR 24643 for MFW pumps

Year of Operation	Failures to Run			
	No. of Failures	No. of Hours	λ, (Note 1) /hr	Q (Note 2), /yr
1996	8	329655		
1997	4	329655		
1998	4	329655	1.62E-05	1.29E-01
1999	8	329655	1.62E-05	1.29E-01
2000	1	329655	1.31E-05	1.05E-01
2001	2	329655	1.11E-05	8.90E-02
2002	3	329655	6.07E-06	4.85E-02
2003	3	329655	8.09E-06	6.47E-02

Notes for Table 10-5:

1. Rolling average for three consecutive years.
2. Assuming mission time of 8000 hrs per year. For indication only.

Failure rate trend for the data from Table 10-6 is shown in Figure 10-6. It shows negative trend implying the negative aging failure acceleration, which will be, as before, for the purpose of this evaluation, interpreted as negligible aging failure acceleration due to the effective aging management (at considered group of nuclear power plants).

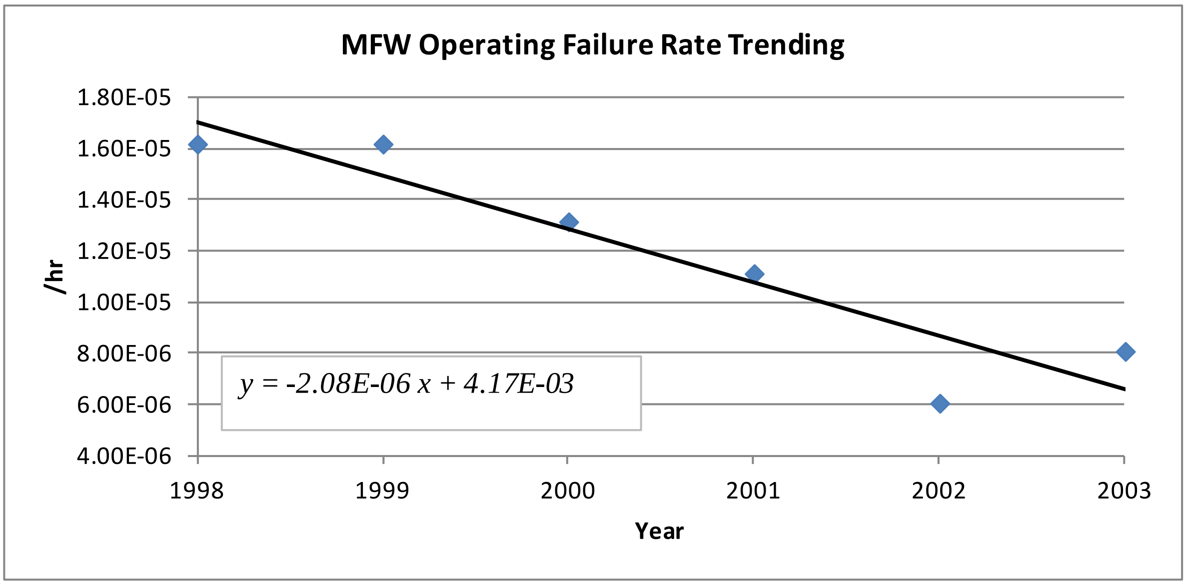


Figure 10-6: Failure rate trend for MFW pumps (failure to run) based on data extracted from the EUR 24643 study

10.2.4.4 Circuit Breakers

Table 10-7 provides summary of the data extracted from the EUR 24643 study for circuit breakers. Estimated failure rates (λ, /hr) show good comparison with corresponding values from NUREG/CR-5248 (4E-06 /hr) and NUREG/CR-6928 (3.5E-06 /hr).

Table 10-7: Data extracted from EUR 24643 for circuit breakers

Year of Operation	Failure to change position		
	No. of Failures	No. of Hours	λ, (Note 1) /hr
1999	12	4949400	
2000	11	4949400	
2001	19	4949400	2.83E-06
2002	19	4949400	3.30E-06
2003	21	4949400	3.97E-06

Notes for Table 10-5:

1. Rolling average for three consecutive years.

Failure rate trend for the data from Table 10-7 is shown in Figure 10-7. It implies the aging failure acceleration rate (5.7E-07 /hr/yr) which is by more than an order of magnitude higher than the one from the NUREG/CR-5248.

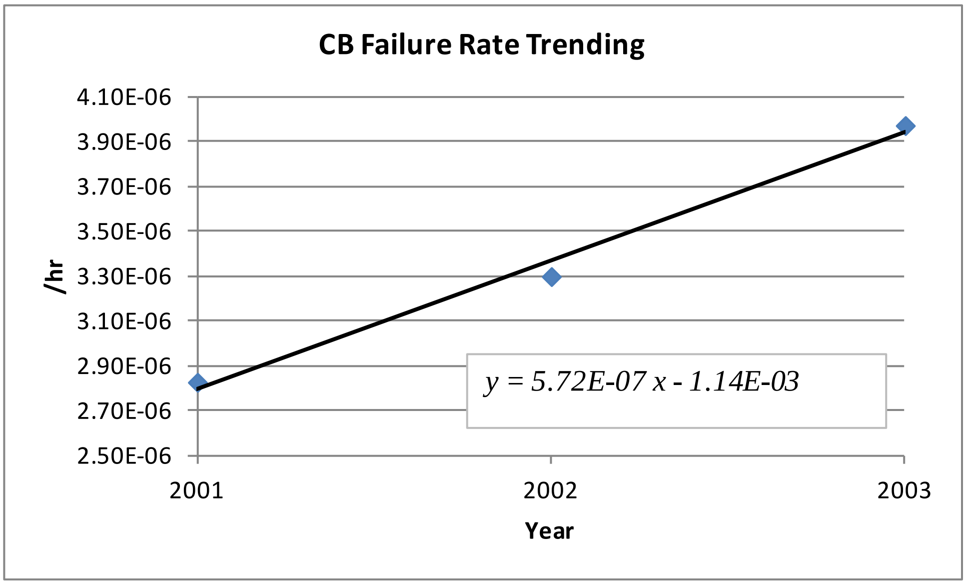


Figure 10-7: Failure rate trend for circuit breakers (failure to change position) based on data extracted from the EUR 24643 study

10.2.5 Data Extracted from EUR 23930

The study EUR 23930 (A Case Study on Incorporation of Ageing Effects into the PSA Model) provides, in its Annex 4, tabulated time-dependent failure rates for selected equipment from nuclear power plants.

10.2.5.1 Summary

Table 10-8 presents the summary of the evaluation of data extracted from the EUR 23930 study. The details of evaluation are provided in the section below.

Table 10-8: Summary of evaluated data extracted from EUR 23930

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
3	Battery	SD	1.6E-07 /hr/yr	2.8E-06 /hr	
10	CB	O	1.2E-08 /hr/yr	3.1E-07 /hr	
		SD	1.3E-06 /hr/yr	2.8E-05 /hr	

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
20	MOV	O	N/A	N/A	
		SD	3.7E-06 /hr/yr	1.1E-04 /hr	Provided only for information. Failure rate considered to have too high value, based on comparison with other sources.
27	Pump	O	7.9E-06 /hr/yr	8.9E-05 /hr	
		SD	4.4E-06 /hr/yr	3.6E-05 /hr	

10.2.5.2 Evaluation

In the EUR 23930 document it is stated that, for the purpose of study undertaken, the set of "virtual" reliability data was prepared on the basis of the results of case studies, available generic data sources and expert opinions. The data include time-dependent reliability models for certain mechanical, electrical and I&C components of Low Pressure Safety Injection (LPSI) and Containment Spray (CSS) Systems.

The data which are in the EUR 23930 document presented for the component types relevant for the present evaluation are summarized in Table 10-9.

It is not clear whether and how aging management measures were incorporated into the increasing failure rates (if any). This can have a large impact on the failure rate predictions in the later decades, especially for the exponential models. For this reason, aging failure acceleration, *a*, is assessed on the basis of increment of lambda between 10^{th} and 20^{th} year (in order to avoid the impact of the later decades).

It should, also, be noted that exponential predictions have very large error factors (EF) for the later decades (e.g. of the order of several hundred (the 3^{rd} decade) or, even, several thousands (the 4^{th} decade)). This, actually, puts into question a usability of those predictions.

Table 10-9: Data extracted from EUR 23930

Component group	Failure rate reference value, /hr (Note 1)	λ(10 yr), /hr	λ(20 yr), /hr	λ(30 yr), /hr	λ(40 yr), /hr	$\frac{\lambda(20yr)-\lambda(10yr)}{10yr}$ (Note 3)	Remark
Electrical Batteries	2.80E-06	2.72E-06	4.30E-06	5.88E-06	7.46E-06	1.58E-07 /hr/yr	
Switchers 380 V (pumps) FF	3.10E-07	3.03E-07	4.18E-07	5.05E-07	5.78E-07	1.15E-08 /hr/yr	Mapped to “O”.
Switchers 380 V (pumps) FD	8.40E-06	6.45E-06	2.32E-05	8.35E-05 (Note 3)	3.00E-04 (Note 3)	1.68E-06 /hr/yr	Mapped to “SD”. Take mean between two values as an indicator, for total averaged failure rate as well as for "*a*".
Switchers 6,6 kV FD	4.80E-05	5.54E-05	6.48E-05	7.10E-05	7.57E-05	9.40E-07 /hr/yr	
Pumps Motors 6.6kV FR	1.90E-06	2.04E-06	2.87E-06	3.50E-06	4.04E-06	N/A	Not considered: pumps motors only. Considered to be included under the pump component boundary.
Pumps Motors 6.6kV FS	1.80E-05	1.57E-05	2.14E-04 (Note 3)	2.94E-03 (Note 3)	4.02E-02 (Note 3)	N/A	Same as above. Additionally: very large EF.
Pumps Motors 6.6kV FS (alternative model)	1.80E-05	1.89E-05	8.20E-05	1.94E-04	3.56E-04	N/A	Not considered: pumps motors only.
LPSI and CSS Pumps FR	8.90E-05	5.91E-05	1.38E-04	2.26E-04	3.21E-04	7.89E-06 /hr/yr	Mapped to “O”, for indication.
CCS Pumps FD	3.60E-05	3.85E-05	8.25E-05	1.77E-04 (Note 3)	3.78E-04 (Note 3)	4.40E-06 /hr/yr	Mapped to “SD”.
CSS MOVs FO	6.80E-04	7.59E-04	1.49E-03	2.21E-03	2.92E-03	7.31E-05 /hr/yr	Not considered. Values considered too high, for both averaged failure rate and aging acceleration. See other sources.

Component group	Failure rate reference value, /hr (Note 1)	λ(10 yr), /hr	λ(20 yr), /hr	λ(30 yr), /hr	λ(40 yr), /hr	$\frac{\lambda(20yr)-\lambda(10yr)}{10yr}$ (Note 3)	Remark
							(Mapped to "SD".)
LPSI MOVs FD	1.10E-04	9.92E-05	1.36E-04	1.86E-04	2.54E-04	3.68E-06 /hr/yr	Only for information. Referential failure rate considered to be too high, as compared to other sources. Mapped to "SD".

Notes for Table 10-9:

General Note: Failure modes. FD interpreted as failure on demand. FS interpreted as failure to start (pumps). FR interpreted as failure to run (pumps). FO interpreted as failure to open or operate (MOV). FF interpreted as time-related operating failure such as spurious opening (circuit breaker).

1. Take as a basis for the total averaged failure rate.
2. Taken as an indication for aging failure acceleration, *a*, /hr/yr.
3. Based on log-linear model with very large error factor. Marked are instances with EF > 20. Some of the pointed values actually have EF values of several hundred or, even, thousands. The EF for prediction increases with time and achieves large values in later decades.

10.2.6 Data Extracted from NUREG/CR-5378

The study NUREG/CR-5378 (Aging Data Analysis and Risk Assessment – Development and Demonstration Study) provides tabulated time-dependent failure rates for selected equipment from Auxiliary Feed water System in a PWR nuclear power plant.

10.2.6.1 Summary

Table 10-10 presents the summary of the evaluation of data extracted from the NUREG/CR-5378 study. The details of evaluation are provided in the section below.

Table 10-10: Summary of evaluated data extracted from NUREG/CR-5378

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
10	Check Valve	O	N/A	N/A	
		SD	Low	N/A	After reinterpretation of failures, constant failure rate was used.
20	MOV	O	Indicates order of magnitude of 1E-06 /hr/yr	Indicates order of magnitude of 1E-05 /hr	
		SD	Indicates order of magnitude of 1E-06 /hr/yr	Indicates order of magnitude of 1E-05 /hr	
27	Pump	O	Low.	N/A	Time-dependency (trend) of failure rates was not confirmed.
		SD	Low.	N/A	

10.2.6.2 Evaluation

Table 10-11 presents the data extracted from NUREG/CR-5378 (Table 7-1, Broadly Defined Failures). It appears that failure rates toward the beginning of component's life (years 1974 and 1973 in the same table, not reproduced here) were based on projections, rather than on the estimated numbers of failures. Because of this, those values involve larger uncertainties (some of those values are even larger than values at later times) and are considered not to be appropriate bases for estimating the acceleration rates. For this reason, the time span 1987 - 1990 was taken as a basis for acceleration estimate.

Additionally, time-dependency (trend) of failure rates was not confirmed for turbine driven and motor driven pumps, for failures to start and failures to run (Table 6-3 in NUREG/CR-5378). This would imply low aging acceleration rate.

Table 10-11: Data extracted from NUREG/CR-5378

Equipment / Failure mode	Configuration	Model	λ, /hr 1987.	λ, /hr 1988.	λ, /hr 1989.	λ, /hr 1990.	$\frac{\lambda(1990)-\lambda(1987)}{3yr}$ (Note 1)	Remark
"AFW-MOV-PG". MOV. Plugging.	Normally, would apply to operating mode. But, considering the system the valves a part of, it is considered to apply to both O and SD.	Exponential	6.09E-05	6.59E-05	7.14E-05	7.76E-05	5.57E-06	
		Weibull	4.90E-05	5.02E-05	5.14E-05	5.25E-05	1.17E-06	
		Linear	5.58E-05	5.84E-05	6.10E-05	6.36E-05	2.60E-06	
"AFW-PMP-STMBD". Pump. Steam binding.	Considered to apply to SD.	Exponential	1.60E-05	2.44E-05	3.99E-05	6.93E-05	1.78E-05	Use only as indication. It appears that, even if attributed to a pump failure, this failure mode relates to the flow paths containing multiple check valves which fail due to steam binding.
		Weibull	1.42E-05	1.84E-05	2.42E-05	3.21E-05	5.97E-06	
		Linear	7.64E-06	8.36E-06	9.08E-06	9.79E-06	7.17E-07	
"AFW-CKV-OO". Check valve. Backflow. (Failure to close.)	Applies to SD.	Exponential	6.55E-05	8.46E-05	1.11E-04	1.46E-04	2.68E-05	Indicated (Note d.) that this failures (backflow) were later reinterpreted as non-failures, based on the discussions with plant personnel. This failure mode was no longer regarded as affected by aging and constant rate was used.
		Weibull	6.29E-05	7.55E-05	9.01E-05	1.07E-04	1.47E-05	
		Linear	4.59E-05	5.02E-05	5.45E-05	5.87E-05	4.27E-06	

Notes for Table 10-14:

General Note: Basis for a total averaged failure rate is considered to be λ values at the beginning of observation interval, i.e. at 1987.

1. Taken as an indication for aging failure acceleration, *a*, /hr/yr.

10.2.7 Averaged Failure Rates and Aging Failure Acceleration Rates Established from Generic Data

Evaluations of generic data sources presented in sections 10.2.2 (NUREG/CR-5248 - TIRGALEX), 10.2.3 (NUREG/CR-6928), 10.2.4 (EUR 24643 study), 10.2.5 (EUR 23930 study) and 10.2.6 (NUREG/CR-5378 study) provided bases for establishing generic averaged failure rates (λ, /hr) and aging failure acceleration rates (*a*, /hr/yr) for the relevant SSCs identified in section 4.

These established generic λ (/hr) and *a* (/hr/yr) values are presented in Table 10-12. The basis is described for each case.

Table 10-12: Averaged failure rates and aging failure acceleration rates established from generic data

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
1	AHU	O	1.5E-05	3.1E-06	Note 1
		SD	1.1E-06	2.3E-07	Note 2
2	AOV	O	3.5E-06	3.5E-07	Note 1
		SD	1.7E-06	1.7E-07	Note 2
3	Battery	SD	2.0E-06	6.8E-07	As under Note 2. EUR 23930 points toward somewhat lower acceleration for battery. However, it generally complies with selected values.
4	Bolts - Connections	SM	N/A	1.0E-09	Same as for SD.
		SD	N/A	1.0E-09	The importance of these elements comes from their failure on demand implying potential failure of containment. Aging acceleration of 5.1E-07 /hr/yr which was assigned in TIRGALEX relates to bolts associated with primary piping (most likely risk-significant event resulting from bolt failure was considered to be Small LOCA) and mechanisms including the erosion from chemicals such as boric acid. Those are not applicable to bolts and anchors considered here, which are part of the containment structure. Therefore, actual acceleration for these elements is considered to be orders of magnitude lower. Applicable, in TIRGALEX context, would be aging

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
					acceleration related to containment (item 2.b) to which very low acceleration rate of 1E-13 /hr/yr was assigned. Indicative acceleration rate of 1E-09 /hr/yr is assigned as some kind of (geometric) mean of these two values. This value is assigned at function level. (Note that both values from TIRGALEX considered above are at function level.)
5	Bus	O	4.0E-07	4.4E-08	Note 1
		SD	4.0E-08	4.4E-09	For bus failure rate in NUREG/CR-6928, no distinction is made between operating and standby mode. During normal plant operation, safety buses are in the operating state considering normal operation and, at the same time, in the standby state considering their safety functions (e.g. supplying ECCS on demand). However, failures during normal operation would reflect immediately as some kind of initiator (or LCO, at least), while latent failure which could reflect at safety function may not be discovered. It is felt that rate of those "standby" / latent failures can be significantly lower, which also reflects in the TIRGALEX standby failure rate. Therefore, value by an order of magnitude lower than NUREG/CR-6928 is taken (4E-08 / hr) and aging acceleration corrected accordingly (as under Note 2).
6	Cable Connectors	O	9.0E-07	4.9E-09	Baseline failure rate same as for the transformer / cable. For acceleration, the reasoning from TIRGALEX taken: one order of magnitude higher than for cables. Divide by factor of 5 to account for functional diversity, as in TIRGALEX (i.e. failure of connector is not necessarily a failure of a function). Overall: $a_{CAB} \times \frac{10}{5} = 2 \times a_{CAB}$

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
7	Cables	O	9.0E-07	2.4E-09	Baseline failure rate taken to be the same as for the transformer. Acceleration estimated by applying the ratio a/λ) from SD case, i.e. as under Note 1. Note: single "component".
		SD	9.0E-07	2.4E-09	Baseline failure rate taken to be the same as for the transformer. Take the acceleration from TIRGALEX and update it by baseline failure rate, i.e. by applying factor $\frac{\lambda_{new}}{\lambda_{TIRG}}$. Note: single "component".
8	Calandria Vault	O	N/A	1.0E-11	TIRGALEX provides 2E-12 /hr/yr for Reactor Pressure Vessel, 1E-13 /hr/yr for Containment and 1E-13 /hr/yr for other concrete structures. Take 1E-11 /hr/yr as some kind of an enveloping value.
9	CB	O	1.5E-07	6.9E-09	Note 1
		SD	3.5E-06	1.6E-07	Baseline failure rates from TIRGALEX, NUREG/CR-6928 and EUR-24643 are very close to each other. Therefore, the value NUREG/CR-6928 taken. Both EUR24643 and EUR23930 point to a relative yearly increase by an order of magnitude higher than TIRGALEX. Therefore, TIRGALEX acceleration increased by an order of magnitude finally taken.
10	Check Valve	O	7.3E-06	7.3E-07	Note 1
		SD	1.0E-07	1.0E-08	As compared to TIRGALEX, NUREG/CR-6928 points to a baseline failure rate by an order of magnitude lower. For the baseline failure rate, the NUREG/CR-6928 is considered the most relevant reference of the sources evaluated. Therefore, the average failure rate is rounded to a value of 1E-07 /hr. Both TIRGALEX And NUREG/CR-5378 point to a low acceleration. Acceleration rate from TIRGALEX is rounded up to 1E-08 /hr/yr.

#	SSC	Conf.	λ (/hr)	a (/hr/yr)	Basis
11	Containment - Concrete	SD	N/A	1.0E-13	All containment concrete and steel structures are in TIRGALEX lumped under acceleration value of 1E-13 /hr/yr (item 2.b). In the present Aging PSA model, the overall structure is divided into classes such as concrete, steel, foundations etc. Assigning 1E-13 /hr/yr to each of them (as compared to all of them) is considered to provide some kind of risk envelope for the containment structures.
12	Containment - Foundations	SD	N/A	1.0E-13	As under #11 (Containment – Concrete).
13	Containment - Penetrations	SD	N/A	1.0E-10	Table 2.2 in TIRGALEX implies that under item 10 considered are also penetrations as part of the containment (e.g. penetrations carrying the cables). However, there is no actual consideration of containment penetrations under item 10 in Appendix D. Considering the number of penetrations, the probability for containment integrity failure modes will be raised by three orders of magnitude and this value taken as an indication at function level. Therefore: 1000 x 1E-13 = 1E-10 /hr/yr.
14	Containment - Steel	SD	N/A	1.0E-13	As under #11 (Containment – Concrete).
15	Containment Isolation Valves	SD	1.4E-06	1.3E-06	Based on MOV. Among the MOV, AOV and Check Valve, the MOV has the highest acceleration rate.
16	EDG	SD	1.1E-05	1.0E-06	TIRGALEX provides for the average failure rate the value of 4E-05 /hr and similar value is roughly indicated by the EUR24643. NUREG/CR-6928 provides similar but somewhat lower value of 1.11E-05 /hr, which is considered to be the most relevant from these sources. Acceleration rate is taken from TIRGALEX and “updated” with NUREG/CR-6928 averaged failure rate.

#	SSC	Conf.	λ (/hr)	a (/hr/yr)	Basis
17	Expansion Joints	O	N/A	3.0E-08	In the absence of any reference, take the same value as for the (other) piping, to be applied at the system level.
		SD	N/A	3.0E-08	As above.
18	Heat Exchanger	O	6.0E-07	2.8E-09	Note 1
		SD	6.0E-07	2.8E-09	NUREG/CR-6928 does not make distinction between standby and operating failure modes for a heat exchanger. For standby failure rate, the same value taken as for operating. Same consideration applies as for piping, #26 - SD. Acceleration rate updated as under Note 2.
19	Inverter	O	5.0E-06	2.5E-07	Note 1
		SD	5.0E-06	2.5E-07	Same considerations as under #18 – SD.
20	MOV	O	3.2E-06	2.9E-06	Note 1
		SD	1.4E-06	1.3E-06	Note 2
21	Other Concrete	O	N/A	1.0E-13	Same as for SD.
		SD	N/A	1.0E-13	All other (than containment) concrete structures are in TIRGALEX lumped under acceleration value of 1E-13 /hr/yr (item 3). Similar considerations as under # 11. Apply at the function level.
22	Other Foundations	SD	N/A	1.0E-13	As under #21 above.
23	PHT Feeders	O	6.3E-08	5.0E-10	Same value will be taken as for Piping – PHT (#26a).
24	PHT Fuel Channels	O	N/A	N/A	Addressed under specific elements.
25	PHT Pressure Tubes	O	6.3E-08	5.0E-10	Same value will be taken as for Piping – PHT (#26a).
26a	Piping - PHT	O	6.3E-08	5.0E-10	In TIRGALEX, the acceleration for (Small) LOCA is in the range 3E-11 (PWR) through 3E-08 (BWR). Although PWR is considered to be more applicable to CANDU PHT piping, value of 1E-09 /hr/yr will be taken as a representative. This value will, further be divided by 2, considering that by this factor

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
					LOCA frequencies in the NUREG/CR-6928 are smaller than in the TIRGALEX. Therefore: 5E-10 /hr/yr is taken as indication. For average failure rate, value of 5E-04 / yr /8000 (operating hr/ yr) = 6.25E-08 /hr is taken, based on NUREG/CR-6928.
26b	Piping - other	O	1E-09 /hr-ft	1E-11 /ft/hr/yr	In TIRGALEX, the acceleration values for other piping are in the range of 3E-09 (large piping) to 3E-07 (small piping) /hr/yr. The value of 3E-08 /hr/yr will be taken for indication, as some kind of geometric mean. This value is considered to be at the system-level. It will be applied to average footage of 3000 ft/system from NUREG/CR-6928, to obtain: 1E-11 /ft/hr/yr. For average failure rate, the value is taken from NUREG/CR-6928: approximately 1E-09 /hr-ft . To obtain average failure rate per hour, this value needs to be multiplied by footage per system. The above estimate would give 1% /yr relative yearly increase for the failure rate. For comparison, older estimates of piping failure rates can be taken from references closer to the time of TIRGALEX study. As an example, one such reference is: S. H. Bush "Statistics of Pressure Vessel and Piping Failures", Journal of Pressure Vessel Technology, Vol. 110, August 1988. This table indicates, for large and intermediate piping, failure rates per year and per foot of 1.3E-05 (Tables 11 and 12). This would give the rate of 1.3E-05 / 8760 = 1.5E-09 /ft/hr, which compares well with the value estimated from NUREG/CR-6928.
		SD	1E-09/hr-ft	1E-11 /ft/hr/yr	For standby piping , use, at the system level, the same failure rate as for operating piping. This is

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
					considered to be a conservative assumption. In a standby mode, piping segments may not be exposed to the same stressors as operating segments. Consequentially, use the same acceleration rate.
27	Pump	O	5.0E-06	3.0E-07	Regarding the average failure rate: EUR24643 indicates, roughly, value two times higher than NUREG/CR-6928, while EUR23930 indicates value higher by more than an order of magnitude. NUREG/CR-6928 value taken. Regarding "*a*": relative yearly increase indications: TIRGALEX: 6%; EUR23930: 9%; EUR24643 and NUREG/CR-5378: app. 0%. Value based on 6%.
		SD	2.0E-06	2.0E-07	Regarding average failure rate: TIRGALEX and NUREG/CR-6928 provide comparable values (NURGE/CR-6928 value is lower by factor of 2), while the value in EUR23930 is higher by an order of magnitude. NUREG/CR-692 value taken. Regarding "*a*": EUR23930 indicates relative yearly increase by a factor of 2 higher than TIRGALEX. NUREG/CR-5378 indicates low acceleration (trend not confirmed). "*a*" based on annual fraction of 10%.
28	Reactivity Control Units	O	N/A	6E-07	Relates to the Reactor Regulating System, as an operating system. This is not considered comparable to the rates provided in TIRGALEX for the CRDM (see under #31 below). In the absence of any data or information, the following assumption will be applied: it is assumed that (without any aging management) toward the end of operating period of 40 years, aging-related failures of Regulating System would contribute with one reactor trip per 5 years of operation. This assumption would provide the acceleration rate of 0.2 (/yr) /

#	SSC	Conf.	λ (/hr)	a (/hr/yr)	Basis
					8000 (operating hrs/yr) / 40 yr = 6E-07 /hr/yr.
29	Rectifier	O	4.0E-06	1.2E-07	Note 1
		SD	4.0E-06	1.2E-07	NUREG/CR-6928 does not make distinction between standby and operating failure modes . Although similar consideration may apply as for bus (#5 - SD), for standby failure rate the same value is taken as for operating (considering also that the value is very close to the TIRGALEX value). Acceleration rate updated as under Note 2.
30	Relief Valve	O	1.2E-07	8.3E-09	Note 1
		SD	6.1E-06	4.1E-07	Note 2
31	SDS1	SD	1.7E-08	1.0E-10	Relates to failure to perform a reactor trip, causing an ATWS type of event. TIRGALEX provides acceleration rate for CRDM (related to ATWS) in the range of 3E-11 /hr/yr (PWR) to 3E-09 /hr/yr (BWR). The PWR case is considered to be closer to CANDU. The acceleration rate at 1E-10 /hr/yr will be taken as indication. For average failure rate, the NUREG/CR-6928 implies the value at 1.7E-08 /hr.
32	SG Shell Side	O	N/A	1.0E-12	Acceleration rate: 1E-12 /hr/yr indicated in TIRGALEX.
33	SG Tube Side	O	5.0E-07	2.0E-08	TIRGALEX assumes very high SGTR rate (item 6.a). "A SG tube leak was estimated to occur every year." Consequentially, acceleration rate is high. In relative terms, the acceleration rate of 5E-06 /hr/yr = 5E-06 x 8000 /yr/yr = 0.04 /yr/yr, represents 4 %/yr, considering assumed (in TIRGALEX) SGTR rate of 1 /yr. This 4% is applied to the SGTR frequency from NUREG/CR-6928 (4E-03 /yr), resulting in indicative SGTR acceleration rate of 2E-08 /hr/yr.
34	Solenoid Valve	SD	5.6E-07	5.6E-08	Based on AOV values. AOV values divided by factor of 3, considering that in the IREP

#	SSC	Conf.	λ (/hr)	*a* (/hr/yr)	Basis
					database (NUREG/CR-2728), which was the reference for average failure rate in TIRGALEX, failure rate for solenoid valve was by the factor of 3 lower than for the AOV.
35	Tanks - Atmospheric	O	3.2E-08	6.4E-09	Note 1
		SM	3.2E-08	6.4E-09	Note 1
36	Tanks - High Pressure	O	4.3E-08	4.3E-11	Note 1
37	Transformer	O	9.0E-07	1.5E-09	Note 1
		SD	9.0E-07	1.5E-09	Analogous to Rectifier – SD (#29).

Notes for Table 10-12:

1. Baseline failure rate from NUREG/CR-6928. Acceleration estimated by applying the ratio a/λ from SD case, i.e.:

$$a_O = \left(\frac{a_{SD}}{\lambda_{SD}}\right)\lambda_O = a_{SD}\left(\frac{\lambda_O}{\lambda_{SD}}\right)$$

   Analogous discussion applies to the one in section 10.2.1.

2. Baseline failure rate from NUREG/CR-6928. Acceleration from TIRGALEX, updated by baseline failure rate from NUREG/CR-6928, i.e. by applying the factor $\lambda_{6928}/\lambda_{TIRG}$:

$$a = a_{TIRG}\left(\frac{\lambda_{N6928}}{\lambda_{TIRG}}\right)$$

10.2.8 CANDU Data (Phase 1 Report)

10.2.8.1 Summary

Table 10-13 provides the summary of evaluation of failure trends data extracted from the Phase 1 report. The details of evaluation are presented in the section 10.2.8.2

Table 10-13: Summary of evaluated data extracted from Phase 1 Report

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
9	CB	O	6.E-07	3.E-06	
		SD	3.E-07	5.E-07	

#	SSC	Config.	Aging acceleration *a* (/hr/yr)	Failure Rate (/hr)	Remark
10	Check Valve	O	9.E-08	1.E-06	
		SD	N/A	N/A	
16	EDG	SD	2.E-05	2.E-04	
19	Inverter	O	0.E+00	5.E-05	
		SD	0.E+00	5.E-05	
20	MOV	O	1.E-06	2.E-06	
		SD	8.E-07	1.E-06	
26b	Piping - others	O	6.E-09	2.E-07	
		SD	6.E-09	2.E-07	
27	Pump	O	N/A	N/A	
		SD	4.E-07	4.E-06	
34	Solenoid Valve	SD	1.E-07	4.E-07	

10.2.8.2 Evaluation

Data from Phase 1 report (Part 2: Ageing Related Data in Canadian NPP and Identification of Trends of Ageing on SSC Failure Rates) which were mapped to the relevant SSCs from section 4 are reproduced in Table 10-14. Added, in the last column, is an identifier for each record, which was used in this evaluation.

Table 10-14: Data extracted from Phase 1 Report

GROUP	DESCRIPTION	Range1	Range 2	Range3	Range4	Number	*Identifier*
3762V-FO	INVERTER - NEW - ALL VOLTAGES - NEW	9	12	14	6	8	*a*
18058-SO	CIRCUIT BREAKER - 4.16 KV, 3000A	1	1	1	2	22	*b*
18069-OP	CIRCUIT BREAKER - 600 V, 600A	0	1	1	2	89	*c*
GR202-RO	CIRCUIT BREAKER - ECI Power Supply CBs	1	1	0	3	20	*d*
6899-EP	BOP VALVES - MANUAL <= 2"	0	1	3	3	244	*e*
B6802AH-CP	VALVES-BOP - BUTTERFLY >=12"<=24"	3	3	3	0	24	*f*
99SG-SF	STDBY GENERATOR - STDBY GENERATOR 7 MW	19	32	33	22	6	*g*
EPG-SF	Combustion Turbine - Emergency Power Generator	5	8	8	10	2	*h*
B6804BA-OP	BOP VALVES - GATE MOTORIZED <=2"	0	0	4	5	56	*i*
GR173-SC	Valve - Motorized - Electric Valve Operator	0	2	2	2	64	*j*
N6804BG-SC	VALVES-NI - GATE ELEC. >6" <=12"	0	0	1	3	32	*k*
NLSM-WP	PIPING-NI - SMALL <= 1"	0	2	3	5	432 (Note 1)	*l*
B4311PA-SF	BOP PUMP - PA CENTRIF. HORIZ.	0	0	0	2	20	*m*
GR197-SF	Pump - NI - LP ECI Pump	2	2	0	0	6	*n*
GR198-SF	Pump - NI - LP ECI LPSW Supply Pump	2	2	1	1	20	*o*
SV-SO	Valve - Solenoid - Composite	1	2	3	3	228	*p*

Notes for Table 10-14:

1. It is understood, from Phase 1 report, that this number needs to be multiplied by the factor of 24.

These data from Phase 1 report are presented in the form of numbers of failures during specified time interval (one year). In order to make use of this kind of data for the purpose of present evaluation, a change (over time) in a number of failures needs to be related to the gaining failure acceleration, a, expressed in /hr/yr. Assuming that failure rate can be averaged over time periods of duration T_S, expected number of failures within the *ith* time period would be:

$$N_i = \lambda_i T_S$$

The above expression normally applies to operating component / failure rate, but can also be considered as an approximation for a periodically tested standby component / failure rate. Namely, assuming that N_D is a number of demands (tests) during the time period T_S, the expected number of failures during the same time period would be:

$$N_i = N_D Q_D$$

Here the term Q_D represents the probability of failure on demand, which can be approximated by:

$$Q_D \approx \lambda_i T_{INT}$$

where T_{INT} represents time interval between two consecutive tests and λ_i represents the standby failure rate, averaged over the time period of duration T_S. The number of failures over the considered time period can, then, be approximated by:

$$N_i \approx N_D (\lambda_i T_{INT}) = \lambda_i (N_D T_{INT}) = \lambda_i T_S$$

Assuming, further, that failure rate follows linear law (which is averaged over time periods with duration T_S, as discussed above) with acceleration constant "a", it can be easily shown that an increase in expected number of failures between two consecutive time periods of duration T_S is:

$$\Delta N \approx a T_S^2$$

From this, acceleration rate can be estimated as:

$$a \approx \frac{\Delta N}{T_S^2} = \Delta n$$

where Δn represents change (increase) in a yearly number of failures, per year. Here, "a" would be expressed in terms of /yr/yr instead of usual /hr/yr.

Thus, Δn can be used to relate the data from Phase 1 presented in Table 10-14 to the aging failure acceleration "a".

Numbers in columns "Range 1" through "Range 4", taken from the Phase 1 report, are understood to be numbers of failures within the population of the components in the considered year and previous two years (altogether - numbers of failures in three years). These numbers of failures were, for trending purposes, normalized (in the Phase 1 report) by the maximum number of failures (among the four values for particular component / failure mode), N_{max}.

Linear trend for normalized numbers of failures was, in the Phase 1 report, expressed in the form:

$F(t) = k\,t + l$

where "*t*" represents calendar time measured in years. Linear trend coefficient *k*, /yr, as calculated in the Phase 1 report for relevant SSCs / failure modes from Table 10-14, presented in Table 10-15.

Table 10-15: Trend coefficient for SSC failures from Phase 1 Report

ID	SSC	Remark	k, /yr
a	19. Inverter	Map to O. For inverter, can, also, be applied to "SD".	-0.05
b	9. CB	Map to SD.	0.15
c	9. CB	Map to O.	0.3
d	9. CB	Failure to re-close. Removed.	0.1667
e	10. Check Valve	Only for information, as data, actually, relate to manual valves. Map to O.	0.3667
f	10. Check Valve	As above. Map to O.	-0.3
g	16. EDG	Map to SD.	0.0303
h	16. EDG	Map to SD.	0.15
i	20. MOV	Map to O.	0.38
j	20. MOV	Map to SD.	0.3
k	20. MOV	Map to SD.	0.3333
l	26. Piping	Map to O. For piping, can also be used for SD.	0.32
m	27. Pump	Map to SD.	0.3
n	27. Pump	Map to SD.	-0.4
o	27. Pump	Map to SD.	-0.2
p	34. Solenoid Valve	Map to SD.	0.2333

From above, the term

$$\frac{k\,N_{max}}{T}, \text{ /yr/yr}$$

where $T = 3$ *years*, represents the change in a yearly number of failures among the population of components per year, Δn_{pop}.

When divided by a number of components in the population, *M*, this term can be used, in accordance with above discussion, as an indication for "*a*", with a notion that "*a*" would be expressed in terms of /yr/yr (as opposed to usual /hr/yr):

$$\frac{k\,N_{max}}{T\,M} = \Delta n \approx a, \text{ /yr/yr}$$

The term

$$\frac{k\,N_{max}}{8000\,T\;M} = \Delta\,n \approx a\,,\ \text{/hr/yr}$$

is comparable to "*a*" expressed in /hr/yr (assuming 8000 hours as relevant exposure time for the equipment during one calendar year). Calculated values for relevant SSCs are presented in Table 10-16. The same table contains, also, the indications for average failure rates.

Table 10-16: Estimates of aging accelerations and average failure rates based on Phase 1 Report

ID	SSC	$\frac{k\ N_{max}}{8000\ T\ M}$ (Note 1), /hr/yr	$\frac{N}{8000\ T\ M}$ (Note 3), /hr	Config.	*a*, /hr/yr (Note 4)	*λ*, /hr (Note 5)
a	19. Inverter	0 (Note 2)	5.21E-05	O (SD)	0.E+00	5.E-05
b	9. CB	5.68E-07	2.84E-06	SD	6.E-07	3.E-06
c	9. CB	2.81E-07	4.68E-07	O	3.E-07	5.E-07
d	9. CB	N/A	N/A	N/A	N/A	N/A
e	10. Check Valve	1.88E-07	2.56E-07	O	9.E-08	1.E-06
f	10. Check Valve	0 (Note 2)	2.60E-06			
g	16. EDG	6.94E-06	1.81E-04	SD	2.E-05	2.E-04
h	16. EDG	3.13E-05	1.56E-04			
i	20. MOV	1.41E-06	1.86E-06	O	1.E-06	2.E-06
j	20. MOV	3.91E-07	6.51E-07	SD	8.E-07	1.E-06
k	20. MOV	1.30E-06	1.95E-06			
l	26. Piping	6.43E-09	2.41E-07	O (SD)	6.E-09	2.E-07
m	27. Pump	1.25E-06	2.08E-06	SD	4.E-07	4.E-06
n	27. Pump	0 (Note 2)	6.94E-06			
o	27. Pump	0 (Note 2)	3.13E-06			
p	34. Solenoid Valve	1.28E-07	3.65E-07	SD	1.E-07	4.E-07

Notes for Table 10-16:

1. Used as an estimator for aging failure acceleration "*a*". Meaning of particular variables as in the equation discussed above.
2. Negative trends of numbers of failures reported in Phase 1 are, in the present evaluation, interpreted as zero aging accelerations.

3. Taken as an indication of average failure rate "λ". $N = \frac{N_{min} + N_{max}}{2}$, where N_{min} represents the smallest number of failures. Meaning of other variables as in the equation discussed above. Used only for information.
4. Based on the estimator from the second column. Rounded. Mean value taken where multiple entries provided.
5. Based on the indication from the third column. Rounded. Mean value taken where multiple entries provided. Only for information.

10.2.9 Failure Rates from the Referential Plant Specific CANDU PSA

Failure rates were extracted from the referential plant specific PSA model, for the relevant SSCs identified in the section 4, and evaluated for the purpose of comparing them to the generic failure rates from section 10.2.7, which were established from the data for PWR and BWR plants. Actual plant specific failure rates from the PSA model will be used to "update" the aging failure accelerations, *a*, /hr/yr, in a manner discussed in section 10.2.1, in order to obtain a "pseudo plant specific" time dependent failure rates.

Table 10-17 provides the summary of failure rates extracted from the referential PSA model. It needs to be recognized that not all of the SSC categories from section 4 are represented in the baseline PSA model, including the SSCs such as different concrete structures, electrical cabling, bolts etc.

In order to map the failure rate parameters from the referential PSA model to the SSC categories represented in the Table 10-12 with generic failure rates, the following general procedure was applied:

1. Where applicable, identify sub-groups (sub-classes) of components, e.g. AOV < 2 inches; AOV 2 to 6 inches, etc.
2. Within a sub-group, map particular failure modes to O or SD (SM) configuration. For this purpose, the failures to change state or position (for active components) are considered to be SD and time-related failures such spurious changing of the position / state or leakage are considered to map to O.
3. Further, divide (group) failure modes according to the principles:
   - alternative failure modes where the representative failure rate is assessed by averaging, as opposed to
   - other failure modes where the representative failure rate can be assessed by summing up.
4. Failure modes related to re-opening / re-closing of valves and other similar failure modes were not considered.

Table 10-17 presents resulting representative failure rates for the sub-groups of SSCs.

Table 10-17: Failure Rates from the referential plant specific PSA Model

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
1. Air Handling Unit / Fan Cooler			
U-TUBE HEAT EXCHANGER INTERNAL LEAKAGE (DIFFUSION)	1.07E-02	O	1.07E-02
U-TUBE HEAT EXCHANGER LOW OUTPUT	5.93E-05	SD	5.93E-05
2. Air Operated Valve			

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
2 TO <6 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE OPEN SPURIOUSLY	1.80E-03	O	1.80E-03
2 TO <6 INCHES PNEUMATIC DIAPHRAGM GLOVE VALVE CLOSES SPURIOUSLY	1.80E-03		
2 TO <6 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE FAILS TO OPEN	5.21E-03	SD	2.29E-02
2 TO <6 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE FAILS TO CLOSE	1.80E-03		
2 TO <6 INCHES PNEUMATIC DIAPHRAGM DIAPHRAGM VALVE SLOW OPERATION	1.94E-02		
2 TO <6 INCHES PNEUMATIC CYLINDER BALL VALVE INTERNAL LEAKAGE	9.69E-03	O	1.64E-02
2 TO <6 INCHES PNEUMATIC CYLINDER BALL VALVE OPEN SPURIOUSLY	6.72E-03		
2 TO 6 INCHES PNEUMATIC DIAPHRAGM BUTTERFLY VALVE FAILS TO OPEN	4.38E-04	SD	4.38E-04
PNEUMATIC DIAPHRAGM BUTTERFLY VALVE CLOSES SPURIOUSLY	4.38E-04	O	4.38E-04
<2 INCHES PNEUMATIC CYLINDER BALL VALVE INTERNAL LEAKAGE	2.77E-03	O	2.77E-03
<2 INCHES PNEUMATIC CYLINDER BALL VALVE SLOW OPERATION	1.92E-03	SD	1.92E-03
<2 INCHES PNEUMATIC DIAPHRAGM GLOVE VALVE OPEN SPURIOUSLY	1.07E-04	O	1.07E-04
<2 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE CLOSES SPURIOUSLY	1.07E-04		
<2 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE FAILS TO CLOSE	1.08E-03	SD	1.08E-03
<2 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE INTERNAL LEAKAGE	1.77E-02	O	1.77E-02
24 INCHES & GREATER PNEUMATIC CYLINDER BUTTERFLY VALVE CLOSES SPURIOUSLY	1.35E-03	O	1.35E-03
24 INCHES & GREATER PNEUMATIC CYLINDER BUTTERFLY VALVE INTERNAL BREAKAGE	2.78E-04	O	9.09E-03
24 INCHES & GREATER PNEUMATIC CYLINDER BUTTERFLY VALVE INTERNAL LEAKAGE	1.79E-02		
24 INCHES & GREATER PNEUMATIC CYLINDER BUTTERFLY VALVE FAILS TO CLOSE	1.22E-03	SD	1.32E-02
24 INCHES & GREATER PNEUMATIC CYLINDER BUTTERFLY VALVE FAILS TO OPEN	2.52E-02		
24 INCHES & GREATER PNEUMATIC CYLINDER	2.99E-02	SD	2.99E-02

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
BUTTERFLY VALVE SLOW OPERATION			
12 TO <24 INCHES PNEUMATIC CYLINDER BUTTERFLY VALVE INTERNAL LEAKAGE 12 TO <24 INCHES PNEUMATIC CYLINDER BUTTERFLY VALVE CLOSES SPURIOUSLY	1.83E-02 1.62E-03	O	1.99E-02
12 TO <24 INCHES PNEUMATIC CYLINDER BUTTERFLY VALVE FAILS TO CLOSE 12 TO <24 INCHES PNEUMATIC CYLINDER BUTTERFLY VALVE SLOW OPERATION 12 TO <24 INCHES PNEUMATIC CYLINDER BUTTERFLY VALVE FAILS TO OPEN	2.34E-03 2.34E-03 1.62E-03	SD	4.32E-03
12 TO 24 INCHES PNEUMATIC DIAPHRAGM BALL VALVE CLOSES SPURIOUSLY	2.43E-02	O	2.43E-02
12 TO 24 INCHES PNEUMATIC DIAPHRAGM BALL VALVE FAILS TO OPEN 63210-TCV6 MAIN MODERATOR VALVE FAILS TO CLOSE	2.02E-02 5.40E-05	SD	1.01E-02
6 TO <12 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE CLOSES SPURIOUSLY	7.15E-03	O	7.15E-03
6 TO <12 INCHES PNEUMATIC DIAPHRAGM GLOBE VALVE FAILS TO OPEN	1.03E-02	SD	1.03E-02
6 TO <12 INCHES PNEUMATIC CYLINDER BALL VALVE CLOSE SPURIOUSLY	3.18E-02	O	3.18E-02
63341-TCV11 PNEUMATIC BALL VALVE FAILS TO OPEN	5.56E-05	SD	5.56E-05
6 TO <12 INCHES PNEUMATIC CYLINDER GATE VALVE OPENS SPURIOUSLY 6 TO <12 INCHES PNEUMATIC CYLINDER GATE VALVE CLOSES SPURIOUSLY	8.78E-03 8.78E-03	O	8.78E-03
6 TO <12 INCHES PNEUMATIC CYLINDER GATE VALVE FAILS TO OPEN	1.40E-02	SD	1.40E-02

3. Battery

CLASS I BATTERY LOW OUTPUT 24V BATTERY CHARGER POWER SUPPLY LOW OUTPUT	5.19E-02 1.84E-04	SD	2.60E-02

5. Bus

600V BUS BAD CONNECTION 40 VDC BUS BAD CONNECTION	1.42E-03 1.58E-03	O	1.79E-03

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
CLASS IV BUS BAD CONNECTION	2.26E-03		
4.16kV BUS BAD CONNECTION	4.47E-03		
CLASS III BUS BAD CONNECTION	2.74E-03		
250 VDC BUS BAD CONNECTION	5.82E-04		
48 V BUS BAD CONNECTION	8.20E-05		
208/120 V BUS BAD CONNECTION	1.15E-03		

9. Circuit Breaker

208/120 V CIRCUIT BREAKER OPENS SPURIOUSLY	2.59E-03	O	2.59E-03
208/120 V CIRCUIT BREAKER OPENS SPURIOUSLY	2.59E-03		
4.16 kV AND 13.8 kV CIRCUIT BREAKER FAILS TO OPEN	5.38E-03	SD	5.38E-03
4.16 kV CIRCUIT BREAKER ELECTRICAL BREAKER OPENS SPURIOUSLY	8.06E-03	O	8.06E-03
600 V BREAKER FAILS TO OPEN WHEN SIGNALLED	4.33E-04	SD	4.33E-04
600 V CIRCUIT BREAKER ELECTRICAL BREAKER OPENS SPURIOUSLY	3.47E-03	O	3.47E-03

10. Check Valve

<2 INCHES CHECK VALVE EXTERNAL LEAKAGE	2.99E-03	O	2.03E-02
<2 INCHES CHECK VALVE INTERNAL LEAKAGE	1.73E-02		
<2 INCHES CHECK VALVE FAILS TO CLOSE	2.30E-03	SD	1.38E-03
<2 INCHES CHECK VALVE FAILS TO OPEN	4.61E-04		
<2 INCHES PISTON CHECK VALVE EXTERNAL LEAKAGE	6.15E-04	O	1.23E-02
<2 INCHES PISTON CHECK VALVE INTERNAL LEAKAGE	1.17E-02		
<2 INCHES PISTON CHECK VALVE FAILS TO CLOSE	6.15E-04	SD	5.21E-04
<2 INCHES PISTON CHECK VALVE FAILS TO OPEN	4.26E-04		
12 TO <24 INCHES BUTTERFLY CHECK VALVE FAILS TO CLOSE	7.80E-05	SD	4.38E-05
12 TO <24 INCHES BUTTERFLY CHECK VALVE FAILS TO OPEN	9.64E-06		
12 TO <24 INCHES SWING CHECK VALVE EXTERNAL LEAKAGE	7.71E-03	O	7.71E-03
12 TO <24 INCHES SWING CHECK FAILS TO OPEN	8.70E-06	SD	1.29E-03

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
12 TO <24 INCHES SWING CHECK VALVE FAILS TO CLOSE	2.57E-03		
2 TO <6 INCHES CHECK VALVE FAILS TO CLOSE	9.20E-03	SD	5.40E-03
2 TO <6 INCHES CHECK VALVE FAILS TO OPEN	1.59E-03		
2 TO <6 INCHES SWING CHECK FAILS TO OPEN	7.97E-06	SD	7.97E-06
6 TO <12 INCHES SWING CHECK VALVE FAILS TO OPEN	5.16E-03	SD	5.16E-03
CHECK VALVE EXTERNAL LEAKAGE	3.84E-03	O	2.02E-02
CHECK VALVE INTERNAL LEAKAGE	1.64E-02		
CHECK VALVE FAILS TO CLOSE	2.79E-03	SD	1.57E-03
CHECK VALVE FAILS TO OPEN	3.49E-04		

18. Heat Exchanger

U-TUBE HEAT EXCHANGER INADEQUATE HEAT TRANSFER	2.67E-03	O	2.67E-03
U-TUBE HEAT EXCHANGER LOW OUTPUT	5.93E-05	SD	5.93E-05

19. Inverter

INVERTER DC TO AC LOW OUTPUT	8.98E-04	SD	8.98E-04
INVERTER DC TO AC SPURIOUS TRIP	1.23E-03	O	1.23E-03

20. Motor Operated Valve

12 TO <24 INCHES MOTORIZED GATE VALVE CLOSES SPURIOUSLY	4.48E-03	O	8.96E-03
12 TO <24 INCHES MOTORIZED GATE VALVE EXTERNAL LEAKAGE	4.48E-03		
12 TO <24 INCHES MOTORIZED GATE VALVE FAILS TO CLOSE	1.29E-02	SD	9.68E-03
12 TO <24 INCHES MOTORIZED GATE VALVE FAILS TO OPEN	6.46E-03		
2 TO <6 INCHES BUTTERFLY VALVE FAILS TO CLOSE	2.82E-03	SD	2.82E-03
2 TO <6 INCHES MOTORIZED GLOBE VALVE CLOSES SPURIOUSLY	4.48E-03	O	4.48E-03
2 TO <6 INCHES MOTORIZED GLOBE VALVE FAILS TO CLOSE	5.17E-02	SD	2.81E-02
2 TO <6 INCHES MOTORIZED GLOBE VALVE FAILS TO OPEN	4.48E-03		

Failure mode	**Failure rate, /yr**	**Conf.**	**Representative Failure Rate for Comparison, /yr**
6 TO <12 INCHES MOTORIZED GATE VALVE FAILS TO CLOSE 6 TO <12 INCHES MOTORIZED GATE VALVE FAILS TO OPEN	8.23E-03 1.14E-03	SD	4.69E-03
6 TO <12 INCHES MOTORIZED VALVE OPEN SPURIOUSLY	1.52E-03	O	1.52E-03
GLOBE VALVE FAILS TO CLOSE	1.95E-03	SD	1.95E-03

27. Pump (main safety systems)

<100 l/s CENTRIFUGAL HORIZONTAL PUMP LOW OUTPUT <100 l/s CENTRIFUGAL HORIZONTAL PUMP LOW OUTPUT	2.13E-02 2.13E-02	SD	2.13E-02
<100 l/s POSITIVE DISPLACEMENT PUMP LOW OUTPUT	3.82E-02	SD	3.82E-02
100 TO <200 l/s CENTRIFUGAL HORIZONTAL PUMP LOW OUTPUT	0.16	SD	1.60E-01
100 TO <200 l/s CENTRIFUGAL PUMP SEIZURE	1.34E-02	O	1.34E-02
200 TO <400 l/s CENTRIFUGAL HORIZONTAL PUMP LOW OUTPUT	8.76E-03	SD	8.76E-03
200 TO <400 l/s CENTRIFUGAL PUMP SEIZURE	8.05E-03	O	8.05E-03
200 TP <400 l/s CENTRIFUGAL VERTICAL PUMP LOW OUTPUT	8.05E-03	SD	8.05E-03
2000 l/s CENTRIFUGAL VERTICAL PUMP SEIZURE	6.71E-03	O	6.71E-03
400 TO <600 L/S CENTRIFUGAL HORIZONTAL PUMP LOW OUTPUT	1.29E-02	SD	1.29E-02
400 TO 600 L/S CENTRIFUGAL HORIZONTAL PUMP SEIZURE	8.95E-03	O	8.95E-03
600 TO <800 l/s CENTRIFUGAL VERTICAL PUMP NO OUTPUT	9.85E-03	SD	9.85E-03
600 TO <800 l/s CENTRIFUGAL VERTICAL PUMP SEIZURE	1.93E-03	O	1.93E-03
800 TO 1000 l/s CENTRIFUGAL VERTICAL PUMP SEIZURE	1.34E-02	O	1.34E-02
800 TO 1000 l/s CENTRIFUGAL VERTICAL PUMP LOW OUTPUT 800 TO 1000 l/s CENTRIFUGAL VERTICAL PUMP LOW OUTPUT	1.34E-02 2.32E-02	SD	1.83E-02
GREATER THAN 2000 L/S CENTRIFUGAL PUMP SEIZURE	1.67E-01	O	1.67E-01

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
13.8KV INDUCTION MOTOR FAILS TO START	3.90E-03	SD	3.90E-03
13.8 kV INDUCTION MOTOR FAILS SHORT CIRCUIT 13.8KV INDUCTION MOTOR FAILS WHILE RUNNING	3.83E-03 5.16E-03	O	8.99E-03
13.8kV VERTICAL INDUCTION MOTOR FAILS WHILE RUNNING	7.74E-03	O	7.74E-03
4.16 kV INDUCTION MOTOR FAILS TO START	3.71E-03	SD	3.71E-03
4.16 kV INDUCTION MOTOR FAILS SHORT CIRCUIT 4.16 kV INDUCTION MOTOR FAILS WHILE RUNNING	2.98E-03 1.25E-02	O	1.55E-02
600 V HORIZONTAL INDUCTION MOTOR FAILS TO START	2.24E-03	SD	2.24E-03
600 V HORIZONTAL INDUCTION MOTOR FAILS WHILE RUNNING	9.86E-02	O	9.86E-02
600 V INDUCTION MOTOR FAILS SHORT CIRCUIT 600V INDUCTION MOTOR FAILS WHILE RUNNING	1.27E-03 7.79E-02	O	7.92E-02
600V INDUCTION MOTOR FAILS TO START	6.35E-03	SD	6.35E-03
INDUCTION MOTOR FAILS TO START	4.56E-03	SD	4.56E-03
INDUCTION MOTOR FAILS WHILE RUNNING	6.30E-02	O	6.30E-02

29. Rectifier

EXCITER RECTIFIER TRANSFORMER OPEN CIRCUIT RECTIFIER DIODE OPEN CIRCUIT RECTIFIER DIODE SHORT CIRCUIT	7.85E-02 1.54E-04 4.63E-05	O	7.87E-02
EPS RECTIFIER LOW OUTPUT	1.87E-02	SD	1.87E-02
CLI RECTIFIER LOW OUTPUT	2.56E-03	SD	2.56E-03

30. Relief Valve

<2 INCHES SPRING RELIEF VALVE SPURIOUS OPERATION <2 INCHES SPRING RELIEF VALVE INTERNAL LEAKAGE <2 INCHES SPRING RELIEF VALVE EXTERNAL LEAKAGE	4.76E-03 1.96E-02 5.35E-03	O	2.97E-02
<2 INCHES SPRING RELIEF VALVE FAILS TO OPEN	3.57E-03	SD	5.35E-03

Failure mode	Failure rate, /yr	Conf.	Representative Failure Rate for Comparison, /yr
<2 INCHES SPRING RELIEF VALVE SETPOINT LOW	1.78E-03		
SPRING RELIEF VALVE INTERNAL LEAKAGE	2.02E-02	O	3.03E-02
SPRING RELIEF VALVE SPURIOUS OPERATION	4.75E-03		
SPRING RELIEF VALVE EXTERNAL LEAKAGE	5.35E-03		
SPRING RELIEF VALVE FAILS TO OPEN	3.57E-03	SD	5.35E-03
SPRING RELIEF VALVE SETPOINT LOW	1.78E-03		

34. Solenoid Valve

SOLENOID VALVE FAILS TO REMAIN INACTIVE	5.67E-05	O	8.17E-03
SOLENOID VALVE FAILS TO REMAIN ACTIVE	8.03E-04		
SOLENOID VALVE SHORT CIRCUIT	2.92E-04		
SOLENOID VALVE INTERNAL LEAKAGE	3.65E-03		
SOLENOID VALVE EXTERNAL LEAKAGE	3.80E-03		
FAILS TO DEACTIVATE	1.61E-03	SD	3.07E-03
SOLENOID VALVE FAILS TO ACTIVATE	2.19E-03		
SOLENOID VALVE SLOW OPERATION	1.17E-03		

35., 36. Tank

TANK RUPTURE	4.77E-06	O, SD	6.58E-03
TANK EXTERNAL LEAK	6.58E-03		

37. Transformer

POWER TRANSFORMER OPEN CIRCUIT	2.36E-03	O, SD	2.41E-02
POWER TRANSFORMER PHASE TO PHASE FAULT	2.36E-03		
POWER TRANSFORMER PHASE SHORT CIRCUIT	3.41E-03		
POWER TRANSFORMER PHASE COOLING FAILURE	1.60E-02		

Representative failure rates for sub-groups were averaged (in the case of multiple inputs) and divided by 8760 hours to convert them the /hr basis. (It was assumed that failure rates in the PSA model are presented in terms of per operating year.) The comparison to the corresponding generic values established in Table 10-12 is shown in Table 10-18. As can be seen, a reasonably good comparison is achieved – instances where a difference largely exceeds an order of magnitude are very few.

Table 10-18: Comparison of plant specific and established generic failure rates

#	SSC	Conf.	λ (/hr), Table 10-12	λ (/hr), PSA Model
1	AHU	O	1.5E-05	1.2E-06
		SD	1.1E-06	6.8E-09
2	AOV	O	3.5E-06	1.2E-06
		SD	1.7E-06	1.1E-06
3	Battery	SD	2.0E-06	3.0E-06
5	Bus	O	4.0E-07	2.0E-07
		SD	4.0E-08	2.0E-07
9	CB	O	1.5E-07	5.4E-07
		SD	3.5E-06	3.32E-07
10	Check Valve	O	7.3E-06	1.7E-06
		SD	1.0E-07	2.2E-07
18	Heat Exchanger	O	6.0E-07	3.0E-07
		SD	6.0E-07	6.8E-09
19	Inverter	O	5.0E-06	1.0E-07
		SD	5.0E-06	1.4E-07
20	MOV	O	3.2E-06	5.7E-07
		SD	1.4E-06	1.1E-06
27	Pump	O	5.0E-06	4.32E-06
		SD	2.0E-06	2.62E-06
29	Rectifier	O	4.0E-06	9.0E-06
		SD	4.0E-06	1.2E-06
30	Relief Valve	O	1.2E-07	3.4E-06
		SD	6.1E-06	6.1E-07
34	Solenoid Valve	SD	5.6E-07	3.5E-07
35	Tanks - Atmospheric	O	3.2E-08	7.5E-07
		SM	3.2E-08	7.5E-07
36	Tanks - High Pressure	O	4.3E-08	7.5E-07
37	Transformer	O	9.0E-07	2.7E-06
		SD	9.0E-07	2.7E-06

Additionally,

Table **10-19** shows the comparison of plant specific failure rates for pipe ruptures and breaks with generic values from the generic sources used. To address the aging impact, aging accelerations for piping from Table 10-12 will be “updated” with to these plant specific failure rates in order to obtain a “pseudo plant specific impact”.

Table 10-19: Comparison of plant specific pipe rupture (LOCA and Others) failure rates / frequencies with values from generic sources used

Pipe Break Category from PSA Model	Frequency, /yr	Mapping to Generic Category	Representative Frequency (Sum), /yr	Compared against, /yr (Note 1)	Remark
LOCA Categories					
VECCC - LARGE LOCA - CONTAINMENT BYPASS INTO MPECC	5.78E-12	Compare to Large LOCA frequency in NUREG/CR-6928.	1.00E-05	1.20E-06	PWR value. BWR = 7E-06 /yr
LLOCA - LARGE LOCA - NO CONTAINMENT BYPASS	1.00E-05				
GSLOCA - SMALL LOCA - LOSS OF GLAND SEAL COOLING TO ALL PHT PUMPS	1.71E-02	LOCA precursor. Aging impact addressed under respective cooling system.	N/A	N/A	
PRLB - SMALL LOCA - PIPE BREAK UPSTREAM OF PRESSURIZER RELIEF/STEAM BLEED VAL	1.00E-04	Compare to Small LOCA frequency in NUREG/CR-6928.	3.00E-03	6.00E-04	PWR value. BWR = 5E-04 /yr
SLHX - SMALL LOCA - MULTIPLE TUBE RUPTURES IN ANY RCW HX (CONTAINMENT BYPASS)	2.90E-06				
SLOCA - SMALL LOCA EQUIVALENT TO 2.5% RIH BREAK (INCLUDE LOCA3.4)	2.90E-03				
PTCTR - PRESSURE TUBE AND CALANDRIA TUBE RUPTURE	5.00E-04	Compare to PHT Pressure Tubes / Fuel Channels	5.00E-04	5.00E-04	
FBS - FEEDER STAGNATION BREAK	8.98E-05	Compare to PHT Feeders	8.98E-05	5.00E-04	
FMLONFE - FUELLING MACHINE INDUCED LOCA	1.14E-04	Very CANDU specific.	N/A	N/A	

Pipe Break Category from PSA Model	Frequency, /yr	Mapping to Generic Category	Representative Frequency (Sum), /yr	Compared against, /y (Note 1)r	Remark
NO FUEL EJECTION		No basis for comparison.			
FMLO - FUELLIING MACHINE INDUCED LOCA WITH FUEL EJECTION	3.52E-09				
FMEFF - FUELLING MACHINE INDUCED END FITTING FAILURE	3.03E-06				
FMD2O - FUELLING MACHINE INDUCED LOCA, FM ON REACTOR (INCLUDED WITHIN LOCA2.5)	3.26E-06	LOCA3.4 included in LOCA2.5 above. (Very small contribution.)	N/A	N/A	
LK - HTS LEAK - WITHIN OPERATING D2O FEED PUMP CAPACITY (NO CONTAINMENT BYPASS)	1.33E-01	Very CANDU specific. No basis for comparison.	N/A	N/A	
LKHX - HTS LEAK - HX SINGLE TUBE RUPTURE INTO RCW (CONTAINMENT BYPASS)	2.90E-04				
LKAGS - HTS LEAK - LEAK INTO ANNULUS GAS SYSTEM	5.37E-03				

SLB Categories

MSL3 - SMALL MAIN STEAM LINE FAILURES CAUSING LOW DEAERATOR LEVELS	2.27E-02	Compare to Steam Line Break/Leak Outside Containment from NUREG/CR-5750	2.58E-02	1.00E-02	Table 3-1, NUREG/CR-5750
MSL4 - MAIN STEAM LINE BREAK OVER MCR	2.09E-03				
MSL2 - MAIN STEAM LINE BREAK INSIDE TURBINE BUILDING	9.95E-04				

Pipe Break Category from PSA Model	Frequency, /yr	Mapping to Generic Category	Representative Frequency (Sum), /yr	Compared against, /y (Note 1)r	Remark
MSL1 - MAIN STEAM LINE BREAK INSIDE REACTOR BUILDING	4.42E-05	Compare to Steam Line Break/Leak Inside Containment (PWR) from NUREG/CR-5750	4.42E-05	1.00E-03	Table 3-1, NUREG/CR-5750
SGTR					
MSGTR - SMALL LOCA - MULTIPLE STEAM GENERATOR TUBE RUPTURE	8.42E-06	Compare to SGTR from NUREG/CR-6928.	8.50E-04	4.00E-03	
SGTR - HTS LEAK - STEAM GENERATOR TUBE RUPTURE	8.42E-04				
x	x	x	x	x	x
Other secondary breaks	**x**	**x**	**x**	**x**	**x**
FWB7 - SYMMETRIC SG BLOWDOWN LINE BREAK OUTSIDE RB	1.11E-04	Compare to FW Line Break from NUREG/CR-5750	4.35E-03	3.40E-03	Table 3-1, NUREG/CR-5750
FWB6 - SYMMETRIC SG BLOWDOWN LINE BREAK INSIDE RB	1.11E-04				
FWB5 - ASYMMETRIC SG BLOWDOWN LINE BREAK INSIDE RB	5.58E-04				
ASYMMETRIC FEEDWATER LINE BREAK OUTSIDE RB	1.49E-03				
FEEDWATER BREAK OVER MCR	7.34E-04				
SYMMETRIC FEEDWATER LINE BREAK OUTSIDE RB	2.48E-04				

Pipe Break Category from PSA Model	Frequency, /yr	Mapping to Generic Category	Representative Frequency (Sum), /yr	Compared against, /y (Note 1)r	Remark
ASYMMETRIC FEEDWATER LINE BREAK INSIDE RB DOWNSTREAM	1.00E-04				
ASYMMETRIC FEEDWATER LINE BREAK INSIDE RB UPSTREAM	1.00E-03				
CIOB - CALANDRIA INLET/OUTLET PIPE BREAK OUTSIDE CALANDRIA VAULT	2.86E-04	Very CANDU specific. No basis for comparison.	N/A	N/A	
MLBI - MODERATOR PIPE BREAK INSIDE CALANDRIA VAULT	1.00E-03				
CTLKAGS - CALANDRIA TUBE LEAKS INTO ANNULUS GAS	1.19E-05				
MHXS - MODERATOR HEAT EXCHANGER SINGLE TUBE RUPTURE	7.57E-04				
MHXM - MODERATOR HEAT EXCHANGER MULTIPLE TUBE RUPTURE	3.95E-07				
LARGE OUTLET BREAK ON CCW 60 INCH PIPE	2.49E-04	Compare to pipe rupture rates in CCW from NUREG/C-6982.	4.47E-03	7.70E-03	Take 2.75E-10 /ft-hr and app. 3500 ft for CCW from NUREG/CR-6928.
MEDIUM INLET BREAK ON CCW 60 INCH PIPE	4.99E-04				
MEDIUM NON-ISO BREAK ON CCW 60 INCH PIPE	1.62E-04				
MEDIUM OUTLET BREAK ON CCW 60 INCH PIPE	7.46E-04				
SMALL INLET BREAK ON CCW 60 INCH PIPE	9.99E-04				
SMALL NON-ISO BREAK ON CCW 60 INCH PIPE	3.24E-04				
SMALL OUTLET BREAK ON CCW 60 INCH PIPE	1.49E-03				
MEDIUM ISOLABLE BREAK ON RSW 12 INCH PIPE	7.93E-04	Compare to pipe rupture rates in ESW from	2.84E-03	3.40E-02	Take 8.5E-10 /ft-hr and app. 5000
MEDIUM ISOLABLE BREAK ON RSW 24 INCH PIPE	1.24E-04				

Pipe Break Category from PSA Model	Frequency, /yr	Mapping to Generic Category	Representative Frequency (Sum), /yr	Compared against, /y (Note 1)r	Remark
MEDIUM NON-ISOLABLE BREAK ON RSW 12 INCH PIPE	8.17E-06	NUREG/C-6982.			ft for ESW from NUREG/CR-6928.
MEDIUM NON-ISOLABLE BREAK ON RSW 24 INCH PIPE	2.05E-05				
SMALL ISOLABLE BREAK ON RSW 12 INCH PIPE	1.59E-03				
SMALL ISOLABLE BREAK ON RSW 24 INCH PIPE	2.48E-04				
SMALL NON-ISOLABLE BREAK ON RSW 12 INCH PIPE	1.63E-05				
SMALL NON-ISOLABLE BREAK ON RSW 24 INCH PIPE	4.11E-05				

Notes for

Table **10-19**:

1. 8000 operating hrs/yr assumed where relevant.

10.2.10 Final Aging Acceleration Rates

Based on the evaluations in previous sections, Table 10-20 presents the aging accelerations rates for the SSCs identified in section 4, to be used in the Aging PSA model.

The aging acceleration rates for these SSCs will be incorporated into the PSA model in two ways:

1. For those SSCs which are represented in the baseline PSA model, the final acceleration rate will be determined by “updating” the generic acceleration rate with corresponding failure rate in the PSA model. “Pseudo plant specific” acceleration will be obtained as a product of generic relative acceleration rate and plant specific failure rate. For these SSCs, relative aging acceleration rates are provided in Table 10-20. The aging impact will be propagated through the existing basic events in the PSA model.
2. For those SSCs which are not represented in the baseline PSA model, such as concrete structures, cabling, etc., new basic events will be created. To these new basic events, the aging acceleration rates estimated from the available sources will be directly applied. For these SSCs, absolute aging acceleration rates are provided in Table 10-20.

The aging acceleration values, relative or absolute, provided in Table 10-20, were derived from the established generic values provided in section 10.2.7 and CANDU data provided in section 10.2.8.

First, the generic aging acceleration rates and average failure rates from Table 10-12 were taken as a starting point. These values were established through the generic sources which include documents NUREG/CR-5248, NUREG/CR-5378, NUREG/CR-6928, EUR 24643 EN, EUR 23930 EN and others. They, mostly, reflect the experience of PWR, BWR and VVER plants.

The corresponding values established from the CANDU data (Phase 1 report) in the section 10.2.8, where available, were considered in the next step. Regarding the total averaged failure rates, the data from the Phase 1 report can provide an indication, but are not of the required level of detail needed for estimating the equipment failure rates (which was not the purpose of the study, either). Thus, these data were not considered for an attempt to "update" the equipment averaged failure rates. (With respect to this, the NUREG/CR-6982 is considered to provide much more reliable estimates for generic types of components.) The main purpose of the quantitative data presented in Phase 1 Report was to indicate possible trends and they are used in this sense: to (re)consider, where applicable, the generic acceleration rates in the light of implied relative yearly increases in numbers of failures, from Phase 1 Report.

From the above resources, the final relative (in the case of SSCs which are represented in the PSA model) or absolute acceleration rates (in the case of SSCs for which new basic events are needed) were established.

Table 10-20: Final aging acceleration rates

#	SSC	Conf.	Acceleration Rate(/hr/yr)	Relative Acceleration Rate (%/yr)	Basis
1	AHU	O		21%	Note 1
		SD		21%	Note 1

#	SSC	Conf.	Acceleration Rate(/hr/yr)	Relative Acceleration Rate (%/yr)	Basis
2	AOV	O		10%	Note 1
		SD		10%	Note 1
3	Battery	SD		34%	Note 1
4	Bolts - Connections	SM	1.0E-09		Note 2. Function level.
		SD	1.0E-09		Note 2. Function level.
5	Bus	O		11%	Note 1
		SD		11%	Note 1
6	Cable Connectors	O	4.9E-09		Related to "cable". Absolute value taken as established from generic sources (section 10.2.7). See comment under "cable".
7	Cables	O	2.4E-09		As below.
		SD	2.4E-09		Basic failure rate for cable is, in generic sources, based on the basic failure rate for a transformer (section 10.2.7). The referential plant specific PSA value is very similar to the one from NUREG/CR-6928. Therefore, absolute aging acceleration taken as is from generic sources (section 10.2.7).
8	Calandria Vault	O	1.0E-11		Note 2
9	CB	O		10%	Generic values (Table 10-12) increased by a factor, considering that, for a circuit breaker, Phase 1 Report indicates significantly higher acceleration rate, in both absolute terms, as well as in terms of relative yearly increase. (It is noted that there is a good agreement between generic average failure rates and indication from Phase 1 Report.)
		SD		10%	As above.
10	Check Valve	O		10%	Generic value of 10% (Table 10-12) retained, considering very good agreement with indication from Phase 1.
		SD		10%	Note 1. Also, as above.
11	Containment -	SD	1.0E-13		Note 2

#	SSC	Conf.	Acceleration Rate(/hr/yr)	Relative Acceleration Rate (%/yr)	Basis
	Concrete				
12	Containment - Foundations	SD	1.0E-13		Note 2
13	Containment - Penetrations	SD	1.0E-10		Note 2. Function level.
14	Containment - Steel	SD	1.0E-13		Note 2
15	Containment Isolation Valves	SD		N/A	Note 1. Will be addressed through specific valves, i.e. MOVs, AOVs or check valves.
16	EDG	SD	1E-06		Take 10 %/yr for the relative acceleration rate, considering the good agreement between relative acceleration rates in generic estimate and Phase 1 indication. Top-level EDG fault tree probabilities from the referential PSA are in good agreement with "lumped" EDG failure rate from NUREG/CR-6928 which is, approximately, 1E-05 /hr. Applying 10 %/yr to the baseline average failure rate of 1E-05/hr gives the absolute acceleration rate of 1E-06 /hr/yr.
17	Expansion Joints	O	3.0E-08		Note 2. System level.
		SD	3.0E-08		Note 2. System level.
18	Heat Exchanger	O		1%	Note 1. Rounded up to 1 %/yr.
		SD		1%	Note 1. Rounded up to 1 %/yr.
19	Inverter	O		5%	Since generic estimate is relatively low (5 %/yr), it was, conservatively, retained, even if Phase 1 indicates absence of any increase with time.
		SD		5%	As above.
20	MOV	O		40%	Generic estimate shows very sharp increase in failure rate due to aging, for MOVs. This appears to be in agreement with estimates based on Phase 1 data trending. Still, indicated (by the TIRGALEX, mostly) doubling time not much longer than one year was not felt to be realistic for

#	SSC	Conf.	Acceleration Rate(/hr/yr)	Relative Acceleration Rate (%/yr)	Basis
					the current status of MOVs in NPPs. Also, the population sample from Phase 1 was limited. The relative acceleration rate of 40% was chosen, as considered to be more representative of the current status.
		SD		40%	As above.
21	Other Concrete	O	1.0E-13		Note 2. Function level.
		SD	1.0E-13		Note 2. Function level.
22	Other Foundations	SD	1.0E-13		Note 2. Function level.
23	PHT Feeders	O		1%	Generic estimate of relative acceleration rate rounded to 1 %/yr, expecting that PHT piping acceleration rate should be relatively lower than for the other piping (3 %/yr).
24	PHT Fuel Channels	O			Addressed explicitly through specific elements.
25	PHT Pressure Tubes	O		1%	Generic estimate of relative acceleration rate rounded to 1 %/yr, expecting that PHT piping acceleration rate should be relatively lower than for the other piping (3 %/yr).
26a	Piping - PHT	O		1%	Generic estimate of relative acceleration rate rounded to 1 %/yr, expecting that PHT piping acceleration rate should be relatively lower than for the other piping (3 %/yr).
26b	Piping - other	O		3%	Trend value indicated by Phase 1 taken, as somewhat higher, but considering that it is close to the value indicated on the basis of generic estimate.
		SD		3%	As above.
27	Pump	O		10%	Relative acceleration rate of 10 %/yr taken based on the very good agreement between generic and Phase 1 indications.
		SD		10%	As above.

#	SSC	Conf.	Acceleration Rate(/hr/yr)	Relative Acceleration Rate (%/yr)	Basis
28	Reactivity Control Units	O	6E-07		Note 2. Function level.
29	Rectifier	O		3%	Note 1
		SD		3%	Note 1
30	Relief Valve	O		7%	Note 1
		SD		7%	Note 1
31	SDS1	SD	1E-10		Note 2
32	SG Shell Side	O	1E-12		Note 2
33	SG Tube Side	O		4%	Note 1
34	Solenoid Valve	SD		20%	Note 1. Generic estimate raised by a factor, based on the indication from Phase 1.
35	Tanks - Atmospheric	O		20%	Note 1
		SM		20%	Note 1
36	Tanks - High Pressure	O		1%	Note 1. Raised to 1 %/yr.
37	Transformer	O		1%	Note 1. Raised to 1 %/yr.
		SD		1%	Note 1. Raised to 1 %/yr.

Notes for Table 10-20:

1. Based on $\left(\frac{a}{\lambda}\right)$, %/yr, ratio from Table 10-12. Final, "pseudo plant specific", acceleration rate for this SSC will be obtained by applying this relative acceleration rate to the plant specific failure rate in the PSA model.
2. Taken directly from Table 10-12. This acceleration rate will be applied to the new basic event, representative of aging related failures of this SSC.

10.3 Sensitivity Case: Exponential Time Dependent Model for Aging Failure Rates

10.3.1 Establishing Exponential Time Dependent Aging Failure Rates for the Sensitivity Case

The purpose of this sensitivity case is to investigate how much would aging risk measures change toward the end of the projected period if the linear time dependent model for the aging failure rates is replaced by the exponential time dependent model. The basic assumption for the selection of the exponential model is that it should produce approximately the same number of failures during the first 10 years of operation, starting from $t = 0$ as established in section 6, as the corresponding linear model defined in the same section. This time frame of 10 years (calendar time) was selected on the basis that, given the range of failure rates in the baseline PSA model (mostly, 1E-06 /hr or lower) the exponential term λt would still be small enough so that, at least for the most of the cases, no significant difference should be expected between number of failures produced by the two considered models. On the other hand, the period of about 10 years of plant operation should be sufficient to show whether the pattern is linear or exponential (i.e. for much shorter times it would, most likely, not be possible to make any distinction).

Of course, this is an assumption and this sensitivity case should be seen as an attempt to provide some insights into possible departures from those results obtained with linear models, rather than an actual "alternative" estimate of aging risk.

Basic linear model was defined by the Eq. 2-4:

$$\lambda_{LIN}(t) = \lambda_0 + \lambda_{ag}(t) = \lambda_0 + at$$

Basic exponential model will be defined by the following equation:

$$\lambda_{EXP}(t) = \lambda_0 exp(bt) \qquad \text{Eq. 10-28}$$

The term "*b*" from Eq. 10-28 will be derived on the basis of the above discussed assumption from:

$$\int_{t=0}^{T_{10}} \lambda_{EXP}(t)dt = \int_{t=0}^{T_{10}} \lambda_{LIN}(t)dt \qquad \text{Eq. 10-29}$$

In the above equation, the term T_{10} represents the mentioned period of 10 years of operation (calendar time).

All expressions above are valid only if calendar time approximates the age of considered SSC. Since, in many instances, this is not the case, the term *t* needs to be replaced by the terms $t_{ag}(t)$, which represents the age as a function of (calendar) time.

Fully developed linear model which considers actual age of an SSC, together with AM activities, is presented by Eq. 6-1. For the present purpose (i.e. establishing the exponential model this sensitivity case) the "sawteeth" age model will be simplified to:

$$t_{ag}(t) = a(1-\rho)t = at_R(t) \qquad \text{Eq. 10-30}$$

where the term $t_R(t) = (1-\rho)t$ is referred to as effective age.

With this simplification, the expressions for the linear and exponential models can be rewritten as:

$$\frac{\lambda_{LIN}(t)}{\lambda_0} = 1 + \left(\frac{a}{\lambda_0}\right) t_R(t)$$

Eq. 10-31

$$\frac{\lambda_{EXP}(t)}{\lambda_0} = exp\left(b\, t_R(t)\right)$$

These simplified expressions will be taken as a basis for the derivation of constant "*b*". With them, the Eq. 10-29 becomes:

$$\int_{t_R=0}^{T_R} exp\left(b\, t_R\right) dt_R = \int_{t_R=0}^{T_R} \left(1 + \left(\frac{a}{\lambda_0}\right) t_R\right) dt_R \qquad \text{Eq. 10-32}$$

where

$$T_R = (1-\rho)T_{10} \qquad \text{Eq. 10-33}$$

By integrating Eq. 10-32, the following equation is obtained:

$$exp\left(bT_R\right) - 1 = \left[\left(\frac{a}{\lambda_0}\right)\frac{T_R^2}{2} + T_R\right] b \qquad \text{Eq. 10-34}$$

To establish the exponential time-dependent aging failure rate model under the stated assumptions, the above Eq. 10-34 needs to be solved for *b*. This equation was numerically solved for all SSCs from section 6. The resulting values of *b* for the SSCs from Table 6-1 (SSCs presented in the baseline PSA) are shown in Table 10-21. The resulting values of *b* for the SSCs from Table 6-3 (SSCs not presented in the baseline PSA) are shown in Table 10-22. The resulting failure rates / probabilities, as calculated by the exponential model are included in the same tables.

Table 10-21: Failure rate increases at 5, 10, 15 and 20 years from time zero for SSCs represented in baseline PSA – exponential model

#	SSC	b, /yr	Failure Rate Increase, % of λ_0			
			5 yr	10 yr	15 yr	20 yr
1	AHU	0.1450	3.7%	7.5%	11.5%	15.6%
2	AOV	0.0975	2.5%	5.0%	7.6%	10.2%
	AOV, RSW	0.0975	5.0%	10.2%	15.7%	21.5%
3	Battery	0.1450	3.7%	7.5%	11.5%	15.6%
5	Bus	0.1063	2.7%	5.5%	8.3%	11.2%
9	Circuit Breaker	0.0975	2.5%	5.0%	7.6%	10.2%
10	Check Valve	0.0975	2.5%	5.0%	7.6%	10.2%
	Check Valve, RSW	0.0975	5.0%	10.2%	15.7%	21.5%
18	Heat Exchanger	0.0100 (Note 1)	0.3%	0.5%	0.8%	1.0%
19	Inverter	0.0500	1.3%	2.5%	3.8%	5.1%
20	MOV	0.1450	3.7%	7.5%	11.5%	15.6%
	MOV, RSW	0.1425	7.4%	15.3%	23.8%	33.0%
23	PHT Feeders (Map to Feeders LOCA)	0.0100 (Note 1)	0.7%	0.0%	0.8%	1.5%
25	PHT Pressure Tubes (Map to Pressure Tube LOCA)	0.0100 (Note 1)	0.3%	0.5%	0.8%	1.0%
26b	Piping - other; Blowoff System (Map to	0.0250 (Note 1)	0.8%	1.5%	2.3%	3.0%

	SLB).					
	Piping - other; Boiler Feedwater System (Map to FWLB).	0.0250 (Note 1)	0.8%	1.5%	2.3%	3.0%
	Piping - other; Boiler Steam (Main Steam) System (Map to SLB).	0.0250 (Note 1)	0.8%	1.5%	2.3%	3.0%
	Piping - other; RSW	0.0300	1.5%	3.0%	4.6%	6.2%
26a	Piping - PHT (Map to ex-core LOCA)	0.0250 (Note 1)	2.2%	0.1%	2.3%	4.4%
27	Pump	0.0975	2.5%	5.0%	7.6%	10.2%
29	Rectifier	0.0250 (Note 1)	0.8%	1.5%	2.3%	3.0%
30	Relief Valve	0.0725	1.8%	3.7%	5.6%	7.5%
33	SG Tube Side (Map to SGTR)	0.0375	2.9%	0.1%	3.0%	5.9%
34	Solenoid Valve	0.1450	3.7%	7.5%	11.5%	15.6%
35, 36	Tank	0.1450	3.7%	7.5%	11.5%	15.6%
	Tank - Dousing System; EWS; SDS2	0.1430	7.4%	15.4%	23.9%	33.1%
37	Transformer	0.0100 (Note 1)	0.3%	0.5%	0.8%	1.0%

Notes for Table 10-22:

1. Relative acceleration rate is so small (e.g. 1%, 3%) that there is no difference between linear and exponential model, regarding the expected number of failures, over a range of "*b*" values (and over the span of 20 years).

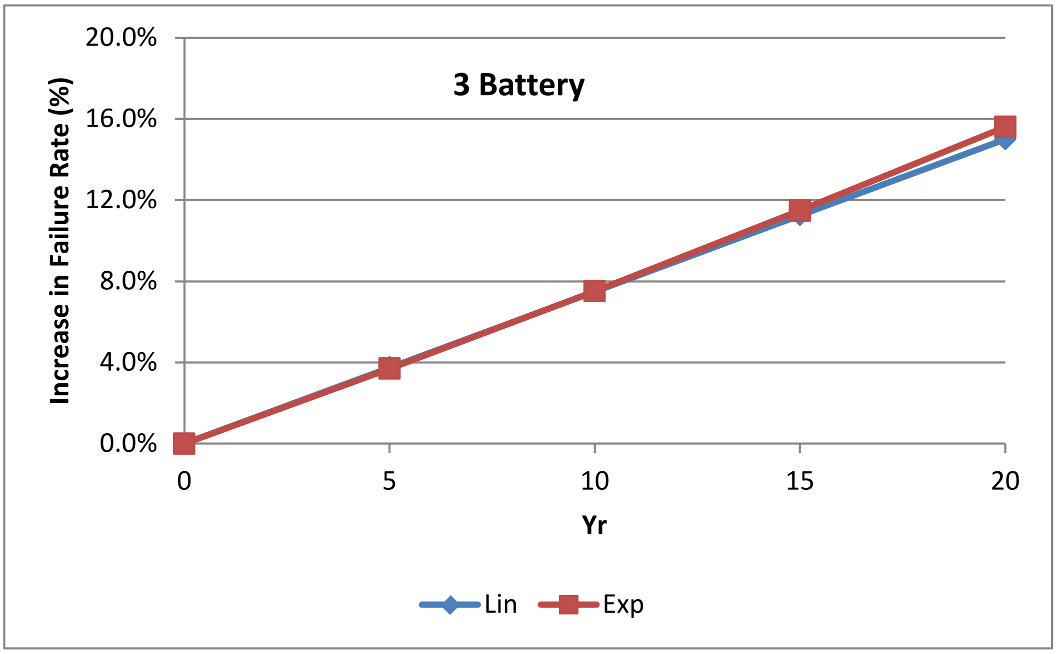
Table 10-21 provides the increases in failure rates for the SSCs presented in the baseline PSA model calculated with exponential model at five years interval, i.e. at 5, 10, 15 and 20 years from $t = 0$ as defined in section 6. The basis for the calculations was exponential expression under Eq. 10-31. As the values represent an increase with respect to the initial λ_0, the actual formula used for calculations was:

$$\frac{\lambda_{EXP,ag}(t)}{\lambda_0} = exp\left(b\,t_R(t)\right) - 1 \qquad \text{Eq. 10-35}$$

The increase brought in by the exponential model (as compared to the linear model) depends on the aging acceleration rate "*a*" and is, also, influenced by the age improvement factor "ρ". Larger increase is obtained for larger values of "*a*" and smaller values of "ρ".

The difference in failure rate increase at 20 years by two models, when normalized against the linear model, does not exceed 10% (Table 10-21 and Table 6-2). This comes from the relatively slow effective increase in failure rates of active SSCs. In many cases the difference is bounded by several percent and in a number of cases there is no difference between linear and exponential model, regarding the expected number of failures, over a range of "*b*" values (and over the span of 20 years).

Figure 10-8 shows, as an example, comparison of failure rate increases at all specified time points (i.e. 5, 10, 15 and 20 years from $t = 0$ for two selected SSC categories.



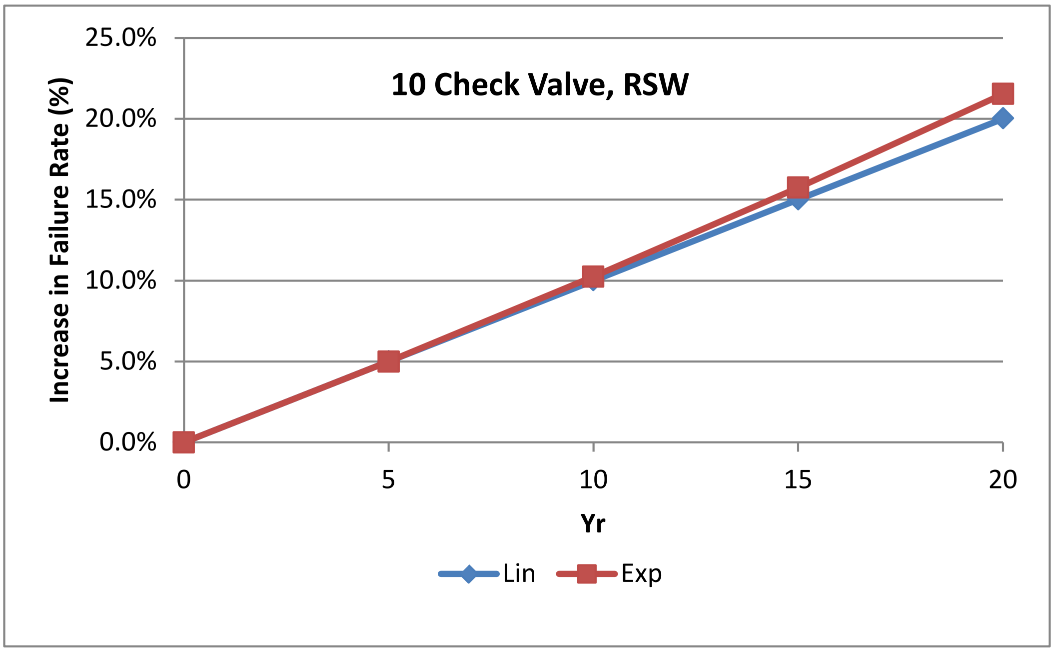


Figure 10-8: Comparison of failure rate increases for SSC categories battery and check valves from RSW

Table 10-22 provides the total probabilities (frequencies in the case of “O” configuration – initiator event) for the SSCs not presented in the baseline PSA model calculated with exponential model at five years interval, i.e. at 5, 10, 15 and 20 years fr6om $t = 0$ as defined in section 6.

The basis for the calculations was the formula for total failure probability from section 6.1.2 under Eq. 6-5:

$$Q(t) = Q_0 + \lfloor \lambda_{EXP,ag}(t)\ T_{\exp} \rfloor K$$

However, the increase in the failure rate, $\lambda_{EXP,ag}(t)$, to be input into the formula, was calculated on the basis of exponential expression under Eq. 10-31 above. In this case, the required value to be input to the formula represents the absolute increase in the failure rate (/hr) with respect to $t = 0$ (as defined in section 6). Therefore, the actual formula used for calculations was in the form:

$$\lambda_{EXP,ag}(t) = \lambda_0 [exp\ (b\, t_R(t)) - 1] \qquad \text{Eq. 10-36}$$

Other terms in the above formula for $Q(t)$, i.e. K, T_{exp} and Q_0, were, for the respective SSC, taken from section 6, Table 6-5.

Table 10-22: Probabilities (frequencies) at 5, 10, 15 and 20 years from time zero for SSCs not represented in baseline PSA – exponential model

#	SSC	b, /yr	Probability (Frequency for „O“ configuration – Initiators (1))			
			5 yr	10 yr	15 yr	20 yr
4	Bolts - Connections, SD, Containment	0.0709	6.67E-05	1.30E-04	2.06E-04	2.96E-04
	Bolts - Connections, SM, Emergency Coolant Injection (HP ECI Storage Tank)	0.0709	7.31E-08	1.43E-07	2.25E-07	3.24E-07
	Bolts - Connections, SD, Emergency Water Supply	0.0709	1.10E-06	2.14E-06	3.38E-06	4.87E-06
6	Cable Connectors, O, Dig. Comp. SDS1/2	0.1416	7.46E-07	1.45E-06	2.30E-06	3.31E-06
7	Cables, O, Boiler FW	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Boiler Steam (MS)	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Class I Power (250V DC Class I Power System)	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Class I Power (250V DC Class I Power System)	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Class II Power (Class II Distribution System)	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Class II Power (Class II Distribution System)	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Class III Distribution System	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Class III Distribution System	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Condenser Cooling Water (CCW) System	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Containment	0.0709	5.27E-05	1.03E-04	1.62E-04	2.34E-04
	Cables, SD, Emergency Core Cooling and Recovery	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04

#	SSC	b , /yr	Probability (Frequency for „O“ configuration – Initiators [(1)])			
			5 yr	10 yr	15 yr	20 yr
	Cables, SD, Emergency Power Supply	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, SD, Emergency Water Supply	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Instrument Air	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Instrument Air	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Liquid Zone System	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Primary Heat Transport	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Reactor Regulating System	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Recirculated Cooling Water	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Recirculated Cooling Water	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Safety System Programmable Digital Comparator Computers SDS1, SDS2	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, O, Shutdown System 1 (SDS1)	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Shutdown System 1 (SDS1)	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, O, Shutdown System 2 (SDS2)	0.1416	7.31E-08	1.42E-07	2.25E-07	3.24E-07
	Cables, SD, Shutdown System 2 (SDS2)	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
	Cables, SD, Standby Generators	0.1416	2.63E-05	5.13E-05	8.11E-05	1.17E-04
8	Calandria Vault, O	0.0709	3.05E-11	5.94E-11	9.39E-11	1.35E-10

#	SSC	b , /yr	Probability (Frequency for „O“ configuration – Initiators (1))			
			5 yr	10 yr	15 yr	20 yr
11	Containment - Concrete, SD	0.0354	1.33E-08	2.60E-08	4.11E-08	5.92E-08
12	Containment - Foundations, SD	0.0354	4.86E-08	1.20E-07	2.58E-07	4.79E-07
13	Containment - Penetrations, SD	0.0709	6.67E-06	1.30E-05	2.06E-05	2.96E-05
14	Containment - Steel, SD	0.0354	1.33E-08	2.60E-08	4.11E-08	5.92E-08
16	EDG, Standby Generators, SD	0.7086	1.10E-04	2.14E-04	3.38E-04	4.87E-04
	EDG, Emergency Power Supply, SD	0.7086	1.10E-04	2.14E-04	3.38E-04	4.87E-04
17	Expansion joints, O, Boiler Feedwater System	0.0709	9.14E-08	1.78E-07	2.82E-07	4.05E-07
	Expansion joints, O,Raw Service System	0.0709	9.14E-08	1.78E-07	2.82E-07	4.05E-07
	Expansion joints, SD,Raw Service System	0.0709	3.29E-05	6.41E-05	1.01E-04	1.46E-04
	Expansion joints, O, Recirculated Cooling Water System	0.0709	9.14E-08	1.78E-07	2.82E-07	4.05E-07
	Expansion joints, SD, Recirculated Cooling Water System	0.0709	3.29E-05	6.41E-05	1.01E-04	1.46E-04
21	Other Concrete, O, Boiler Feedwater System	0.0354	6.10E-13	1.19E-12	1.88E-12	2.70E-12
	Other Concrete, O, Cooling Water Intake and Discharge	0.1416	1.52E-13	2.97E-13	4.69E-13	6.75E-13
	Other Concrete, SD, Emergency Water Supply	0.1416	5.48E-11	1.07E-10	1.69E-10	2.43E-10
22	Other Foundations, SD, Emergency Water Supply	0.0354	4.86E-08	1.20E-07	2.58E-07	4.79E-07
26b	Piping, SD, Boiler Emergency Cooling	0.1416	5.48E-06	1.07E-05	1.69E-05	2.43E-05

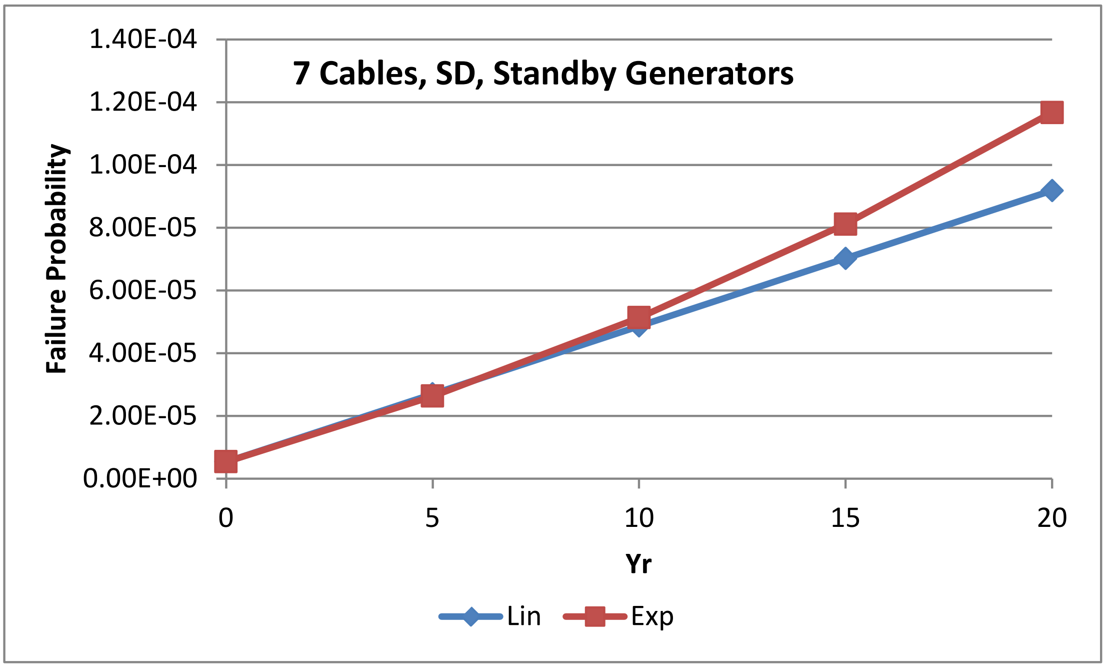
#	SSC	b , /yr	Probability (Frequency for „O“ configuration – Initiators [1])			
			5 yr	10 yr	15 yr	20 yr
	Piping, SM, Dousing System	0.0709	3.66E-07	7.13E-07	1.13E-06	1.62E-06
	Piping, SD, Emergency Core Cooling and Recovery	0.1416	1.64E-05	3.20E-05	5.07E-05	7.29E-05
	Piping, SD, Emergency Power Supply	0.1416	1.64E-06	3.20E-06	5.07E-06	7.29E-06
	Piping, SD, Emergency Water Supply	0.0709	1.10E-05	2.14E-05	3.38E-05	4.87E-05
	Piping, O, Recirculated Cooling Water	0.1416	6.09E-08	1.19E-07	1.88E-07	2.70E-07
	Piping, SD, Recirculated Cooling Water	0.1416	2.19E-05	4.27E-05	6.76E-05	9.72E-05
	Piping, O, Shutdown Cooling System	0.1416	3.05E-08	5.93E-08	9.38E-08	1.35E-07
	Piping, SD, Shutdown System 2 (SDS2)	0.1416	2.74E-06	5.34E-06	8.44E-06	1.21E-05
	Piping, SD, Standby Generators	0.1416	1.64E-06	3.20E-06	5.07E-06	7.29E-06
28	Reactivity Control Units, O	0.1416	9.14E-07	1.78E-06	2.81E-06	4.05E-06
31	Shutdown System 1 (SDS1), SD	0.1416	5.48E-08	1.07E-07	1.69E-07	2.43E-07
32	SG Shell Side, O	0.1416	1.52E-12	2.97E-12	4.69E-12	6.75E-12

Notes for Table 10-22:

1. In the case of “O” configuration, Q has the units of λ, i.e. /hr.

The increase brought in by the exponential model ($\left(Q_{EXP}(20yr)-Q_0\right)$ as compared to $\left(Q_{LIN}(20yr)-Q_0\right)$) is some 30% higher, in most of the cases (Table 10-22 and Table 6-6; initial probability value Q_0 was taken, as already noted above, from Table 6-5).

Figure 10-9 shows, as an example, comparison of failure probability increases at all specified time points (i.e. 5, 10, 15 and 20 years from $t = 0$ for two selected SSC categories.



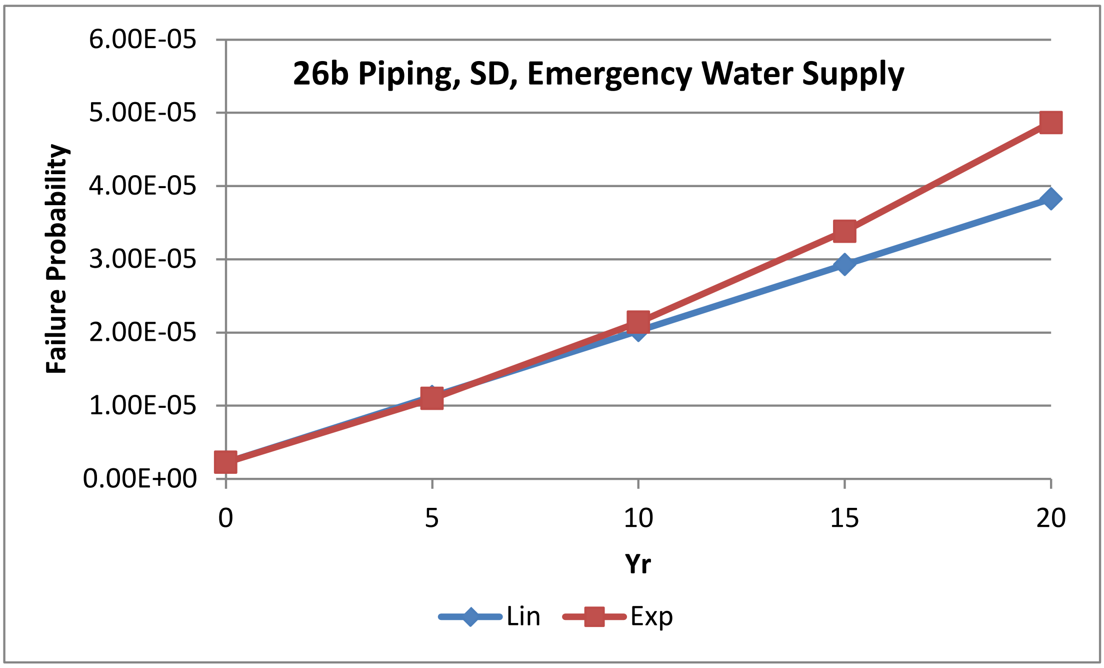


Figure 10-9: Comparison of failure probability increases for two SSC categories not presented in the baseline PSA model

10.3.2 SCDF and LRF Results at 20 Years

Aging risk calculations were performed for 20 years after the 0 time point, in accordance with the same quantification procedure presented in section 6.2.4 but with failure rates and new basic event probabilities as established in the section 10.3.1.

The results of the aging risk quantifications are summarized in

Table 10-23 below. For comparison, the corresponding values obtained with linear model are provided (from Table 7-1, 20 years).

Table 10-23: SCDF and LRF results of the aging risk quantification (1/year) – exponential model

	20 Years - Exponential	**20 Years - Linear**
SCDF-AP	2.050E-05	1.85E-05
SDCF-SD	7.835E-06	7.72E-06
LRF-AP	1.239E-07	1.11E-07
LRF-SD	9.151E-08	9.13E-08

Table 10-24shows the relative increase in all four risk measures, as calculated according to the described procedure and assumptions. The last column shows relative increase at 20 years as compared to the linear failure rate model (Table 7-2).

Table 10-24: : SCDF and LRF Results for Exponential Model Expressed as Percentages of Results at *t =0*

	0 Year	**20 Years**	$\frac{Exp - Lin}{Lin} 100\%$ **at 20 Years**
SCDF-AP	100%	188%	11%
SDCF-SD	100%	113%	1%
LRF-AP	100%	191%	12%
LRF-SD	100%	102%	0%

Altogether, the SCDF (at-power and shutdown modes) would, with described exponential failure rate model, increase by 59% at 20 years, with respect to the same metric at $t = 0$. Analogously, the total LRF (at-power and shutdown modes) would, with described exponential failure rate model, increase by 40% at 20 years, with respect to the same metric at $t = 0$.

If compared absolutely to the results at 20 years by the linear model (Table 7-2), the exponential model gives 8% higher SCDF (at-power and shutdown modes) and 6% higher LRF SCDF (at-power and shutdown modes).

The figures below (**Figure 10-10** through **Figure 10-13**) demonstrate the contribution of initiating events to the different risk metrics.

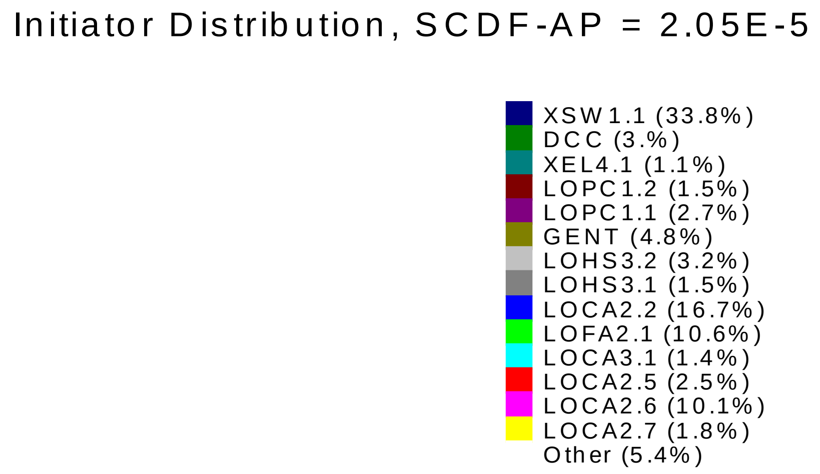


Figure 10-10: Contribution of the Initiating Events to SCDF At Power at Time 20 Years

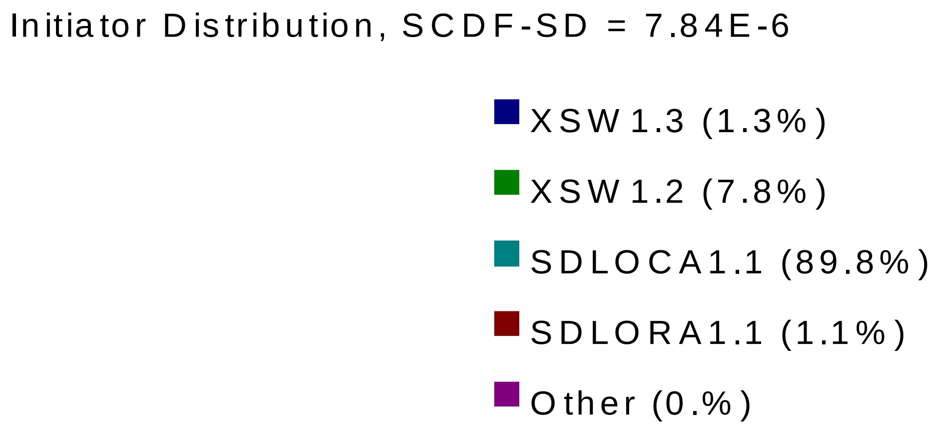


Figure 10-11: Contribution of the Initiating Events to SCDF At Shutdown at Time 20 Years

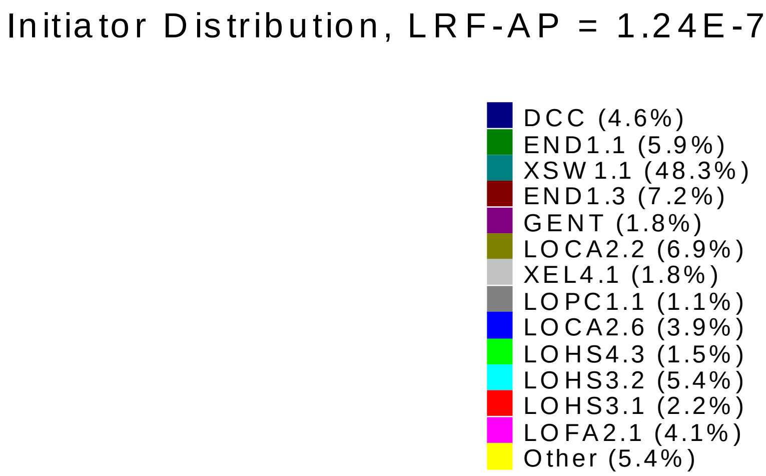


Figure 10-12: Contribution of the Initiating Events to LRF At Power at Time 20 Years

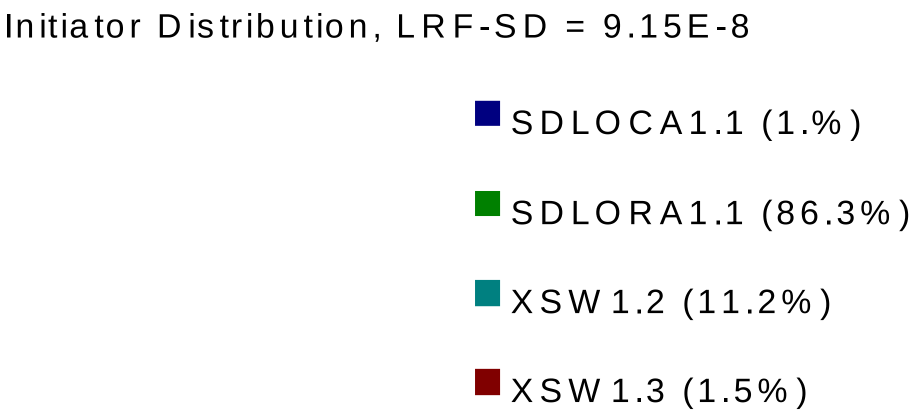


Figure 10-13: Contribution of the Initiating Events to LRF At Shutdown at Time 20 Years

As noted in section 10.3.1, the purpose of this sensitivity case was to investigate how much would aging risk measures change toward the end of the projected period (i.e. 20 years) if the linear time dependent model for the aging failure rates is replaced by the exponential time dependent model. It is important to consider that no attempt was made to establish the exponential models by means of statistics and curve fitting, due to the lack of input data. (As already discussed in section 2.4, primary means for selecting the type of the time dependent failure rate models for aging risk assessments remain to be statistical approaches.) The whole (exponential) model was established upon one major assumption: it should produce approximately the same number of failures during the first 10 years of operation, starting from time zero as the corresponding linear model. Use of such exponential model in this sensitivity case should be seen as an attempt to provide some insights into possible departures from the results obtained with linear models, and not as an actual "alternative" estimate of aging risk.

The above presented results should be viewed and considered in this context. The differences (at projected time of 20 years) with regard to the results with linear model are considered to be relatively small (11% increase for SCDF and 12% increase for LRF at power). It is important to note that these differences are small when compared to the differences in results which could be observed by varying the parameters within the linear models (e.g. aging improvement factors), as pointed in section 6.1. (Here, it is noted that the above differences would, probably, be larger if shorter time period than 10 years for the approximately same number of failures was selected under the initial assumption. However, it is not believed that this would change the general insight.) This points to a conclusion that larger uncertainty in APSA results may come from parameters within a time dependent failure rate model, rather than from different possible time dependent models.

10.4 Lists of Minimal Cut Sets from the Aging Risk Quantification

Provided in four sub-sections below are lists of minimal cutsets for the four considered risk metrics (SCDF-AP, SCDF-SD, LRF-AP and LRF-SD) at three considered time points (*t = 0*, *10* and *20* years) each.

Note: The lists were cut at first 100 MCSs.

10.4.1 SDCF At Power - Time 0 Year

Cutset Report

SCDF-AP = 1.09E-05 (Probability)

Probability	%	Inputs...				
3.56E-07	3.3%	DCC	34320-VSMALL--ZJ	63332HS46-----ZJ	RECOV-ECC-SML	34320-VSMALLZJD1
2.58E-07	5.6%	XSW1.1LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1		
2.58E-07	8.0%	XSW1.1LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1		
2.58E-07	10.4%	XSW1.1LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1		
2.58E-07	12.7%	XSW1.1LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1		
2.57E-07	15.1%	LOPC1.2	34320-VSMALL--ZJ	OPRZHTR1	RECOV-ECC-SML	34320-VSMALLZJD1
1.63E-07	16.6%	LOFA2.1	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	18.1%	LOFA2.1	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	19.6%	LOFA2.1	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	21.1%	LOFA2.1	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	22.6%	LOCA2.6	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	24.0%	LOCA2.6	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	25.4%	LOCA2.6	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	26.9%	LOCA2.6	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2
8.63E-08	27.7%	END1.3 OCC				
6.74E-08	28.3%	LOFA2.1	6361FMSSV-FC3CCF			
6.44E-08	28.9%	LOCA2.6	6361FMSSV-FC3CCF			
5.56E-08	29.4%	XSW1.1CABLE.AGING.BUXA				
5.56E-08	29.9%	XSW1.1CABLE.AGING.BUXC				

5.56E-08	30.4%	XSW1.1CABLE.AGING.BUYA
5.56E-08	30.9%	XSW1.1CABLE.AGING.BUYC
4.68E-08	31.4%	LOCA4.3 ORT2 DCCX.IN.CONTR 3210TCVMCCD---ZJ 3210TCVMCCD-ZJD1
4.62E-08	31.8%	XSW1.1GRID.LOSS.SLOW SG2.AVAIL 5560BY-BAT1C--LO
4.60E-08	32.2%	XSW1.1SG1.AVAIL GRID.LOSS.SLOW 5560BY-BAT1A--LO
4.45E-08	32.6%	XSW1.1LOOP1.BREAK 3334VYDPV3---AFO OPCTLFEEDP1
4.45E-08	33.0%	XSW1.1LOOP1.BREAK 3334VYDPV4---AFO OPCTLFEEDP1
4.45E-08	33.4%	XSW1.1LOOP2.BREAK 3334VYDPV1---AFO OPCTLFEEDP1
4.45E-08	33.8%	XSW1.1LOOP2.BREAK 3334VYDPV2---AFO OPCTLFEEDP1
4.38E-08	34.2%	LOFA2.1 7134PV506#1-2CCF
4.19E-08	34.6%	LOCA2.6 7134PV506#1-2CCF
4.04E-08	35.0%	DCC 34320-VSMALL--ZJ 63332OPR-MAN--ZJ 63332PC35#1---ZJ RECOV-ECC-SML 63332PC35#1-ZJD2 34320-VSMALLZJD1
3.56E-08	35.3%	LOCA3.1 LOOP1.BREAK 3334V-PPRV3--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	35.7%	LOCA3.1 LOOP1.BREAK 3334V-PPRV4--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	36.0%	LOCA3.1 LOOP2.BREAK 3334V-PPRV1--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	36.3%	LOCA3.1 LOOP2.BREAK 3334V-PPRV2--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.32E-08	36.6%	XSW1.1LOOP1.BREAK 3334TA-PV3----RU OPCTLFEEDP1
3.32E-08	36.9%	XSW1.1LOOP1.BREAK 3334TA-PV4----RU OPCTLFEEDP1
3.32E-08	37.2%	XSW1.1LOOP2.BREAK 3334TA-PV1----RU OPCTLFEEDP1
3.32E-08	37.5%	XSW1.1LOOP2.BREAK 3334TA-PV2----RU OPCTLFEEDP1
3.06E-08	37.8%	LOFA2.1 3461V-MMV47--COS
2.92E-08	38.1%	LOCA2.6 3461V-MMV47--COS
2.82E-08	38.3%	LOFA2.1 LOOP1.BREAK 3334VYDPV3---AFO OPCTLFEEDP1 OPCTLFEEDP2
2.82E-08	38.6%	LOFA2.1 LOOP1.BREAK 3334VYDPV4---AFO OPCTLFEEDP1 OPCTLFEEDP2
2.82E-08	38.9%	LOFA2.1 LOOP2.BREAK 3334VYDPV1---AFO OPCTLFEEDP1 OPCTLFEEDP2

2.82E-08	39.1%	LOFA2.1	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2	
2.81E-08	39.4%	LOCA2.7	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2	
2.81E-08	39.6%	LOCA2.7	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2	
2.81E-08	39.9%	LOCA2.7	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2	
2.81E-08	40.2%	LOCA2.7	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2	
2.70E-08	40.4%	LOCA2.6	LOOP1.BREAK	3334VYDPV3---AFO	OPCTLFEEDP1	OPCTLFEEDP2	
2.70E-08	40.6%	LOCA2.6	LOOP1.BREAK	3334VYDPV4---AFO	OPCTLFEEDP1	OPCTLFEEDP2	
2.70E-08	40.9%	LOCA2.6	LOOP2.BREAK	3334VYDPV1---AFO	OPCTLFEEDP1	OPCTLFEEDP2	
2.70E-08	41.1%	LOCA2.6	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2	
2.60E-08	41.4%	LOFA2.1	3432H-PHX1--~-IH	RCW.FACTOR			
2.60E-08	41.6%	LOFA2.1	RCW.FACTOR	3432H-PHX1--%-IH			
2.48E-08	41.9%	LOCA2.6	3432H-PHX1--~-IH	RCW.FACTOR			
2.48E-08	42.1%	LOCA2.6	RCW.FACTOR	3432H-PHX1--%-IH			
2.48E-08	42.3%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22E---FO	RECOV-ECC-SML		
2.48E-08	42.5%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22W---FO	RECOV-ECC-SML		
2.25E-08	42.7%	XSW1.1OP-EWS-ECC	3332TT70-20/1CCF				
2.14E-08	42.9%	LOPC1.2	34320-VSMALL--ZJ	63332HS46-----ZJ	RECOV-ECC-SML		34320-VSMALLZJD1
2.10E-08	43.1%	LOFA2.1	LOOP1.BREAK	3334TA-PV3----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.10E-08	43.3%	LOFA2.1	LOOP1.BREAK	3334TA-PV4----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.10E-08	43.5%	LOFA2.1	LOOP2.BREAK	3334TA-PV1----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.10E-08	43.7%	LOFA2.1	LOOP2.BREAK	3334TA-PV2----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.01E-08	43.9%	LOCA2.6	LOOP1.BREAK	3334TA-PV3----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.01E-08	44.1%	LOCA2.6	LOOP1.BREAK	3334TA-PV4----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.01E-08	44.3%	LOCA2.6	LOOP2.BREAK	3334TA-PV1----RU	OPCTLFEEDP1	OPCTLFEEDP2	
2.01E-08	44.5%	LOCA2.6	LOOP2.BREAK	3334TA-PV2----RU	OPCTLFEEDP1	OPCTLFEEDP2	
1.99E-08	44.6%	LOFA2.1	P1.RUNNING	3432V-AV099--ACE			

1.99E-08	44.8%	LOFA2.1	P2.RUNNING	3432V-AV099--ACE			
1.99E-08	45.0%	LOPC2.1	34320-VSMALL--ZJ	OPIC1	RECOV-ECC-SML	34320-VSMALLZJD1	
1.91E-08	45.2%	LOCA2.6	P1.RUNNING	3432V-AV099--ACE			
1.91E-08	45.4%	LOCA2.6	P2.RUNNING	3432V-AV099--ACE			
1.77E-08	45.5%	LOHS3.2	3614VRCPSV-1-CCF	5290RC-RF1---ELO			
1.73E-08	45.7%	LOFA2.1	3432H-PHX1--%-LO				
1.70E-08	45.8%	XSW1.1	LOOP1.BREAK	3334SV3#1/2--CCF	OPCTLFEEDP1		
1.70E-08	46.0%	XSW1.1	LOOP1.BREAK	3334SV4#1/2--CCF	OPCTLFEEDP1		
1.70E-08	46.1%	XSW1.1	LOOP2.BREAK	3334SV1#1/2--CCF	OPCTLFEEDP1		
1.70E-08	46.3%	XSW1.1	LOOP2.BREAK	3334SV2#1/2--CCF	OPCTLFEEDP1		
1.66E-08	46.5%	LOPC1.1	34320-VSMALL--ZJ	3526VDAPV90--BFC	RECOV-ECC-SML		
1.66E-08	46.6%	LOCA2.6	3432H-PHX1--%-LO				
1.61E-08	46.8%	XSW1.1	3332TT70-20/1CCF	529009QBUD--%DUD	529009QBUC--%DUC		
1.58E-08	46.9%	LOCA2.2	7134VBA218---EFO	7134VBA217---EFO	7134VBCP914->EFC		
1.58E-08	47.0%	LOCA2.2	7134VBA220---EFO	7134VBA219---EFO	7134VBCP914->EFC		
1.56E-08	47.2%	XSW1.1	3312PMP.TTRIP-ZJ	3312TE-RTD---CCF			
1.55E-08	47.3%	GENT	34320-VSMALL--ZJ	4323TT-TT----CCF	RECOV-ECC-SML		
1.51E-08	47.5%	LOCA2.2	6361FMSSV-FC-CCF	7134VBCP914->EFC			
1.49E-08	47.6%	GENT	34320-VSMALL--ZJ	3750ERIE-----CCF	RECOV-ECC-SML		
1.47E-08	47.7%	GENT	34320-VSMALL--ZJ	OPIC3	3332VYDPV12--BCC	RECOV-ECC-SML	34320-VSMALLZJD1
1.47E-08	47.9%	GENT	34320-VSMALL--ZJ	OPIC3	3332VYDPV13--BCC	RECOV-ECC-SML	34320-VSMALLZJD1
1.47E-08	48.0%	GENT	34320-VSMALL--ZJ	OPIC3	3332VYDPV3---BCC	RECOV-ECC-SML	34320-VSMALLZJD1
1.47E-08	48.1%	GENT	34320-VSMALL--ZJ	OPIC3	3332VYDPV4---BCC	RECOV-ECC-SML	34320-VSMALLZJD1
1.39E-08	48.3%	XSW1.1	OP-EWS-ECC	3332TE70-20/1CCF			
1.19E-08	48.4%	DCC	3614VRCPSV---CCF	5290RC-RF1---ELO			
1.16E-08	48.5%	LOCA2.7	6361FMSSV-FC3CCF				

1.13E-08	48.6%	XSW1.1	GRID.LOSS.SLOW	SG2.AVAIL	5560BY-BAT1C--SM			
1.12E-08	48.7%	XSW1.1	SG1.AVAIL	GRID.LOSS.SLOW	5560BY-BAT1A--SM			
1.11E-08	48.8%	GENT	34320-VSMALL--ZJ	OPIC3	3332VQ-12#10--CC	RECOV-ECC-SML	34320-VSMALLZJD1	
1.11E-08	48.9%	GENT	34320-VSMALL--ZJ	OPIC3	3332VQ-13#10--CC	RECOV-ECC-SML	34320-VSMALLZJD1	

10.4.2 SDCF at power - time 10 years

Cutset Report

SCDF-AP = 1.46E-05 (Probability)

Probability	%	Inputs...				
5.01E-07	3.4%	XSW1.1	CABLE.AGING.BUXA			
5.01E-07	6.9%	XSW1.1	CABLE.AGING.BUXC			
5.01E-07	10.3%	XSW1.1	CABLE.AGING.BUYA			
5.01E-07	13.7%	XSW1.1	CABLE.AGING.BUYC			
3.56E-07	16.1%	DCC	34320-VSMALL--ZJ	63332HS46-----ZJ	RECOV-ECC-SML	34320-VSMALLZJD1
2.58E-07	17.9%	XSW1.1	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	
2.58E-07	19.7%	XSW1.1	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	
2.58E-07	21.4%	XSW1.1	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	
2.58E-07	23.2%	XSW1.1	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	
2.57E-07	25.0%	LOPC1.2	34320-VSMALL--ZJ	OPRZHTR1	RECOV-ECC-SML	34320-VSMALLZJD1
1.63E-07	26.1%	LOFA2.1	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	27.2%	LOFA2.1	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	28.3%	LOFA2.1	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.63E-07	29.4%	LOFA2.1	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	30.5%	LOCA2.6	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	31.6%	LOCA2.6	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	32.7%	LOCA2.6	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
1.56E-07	33.7%	LOCA2.6	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2

8.63E-08	34.3%	END1.3 OCC
7.07E-08	34.8%	LOFA2.1 6361FMSSV-FC3CCF
6.76E-08	35.3%	LOCA2.6 6361FMSSV-FC3CCF
4.96E-08	35.6%	XSW1.1GRID.LOSS.SLOW SG2.AVAIL 5560BY-BAT1C--LO
4.94E-08	35.9%	XSW1.1SG1.AVAIL GRID.LOSS.SLOW 5560BY-BAT1A--LO
4.69E-08	36.3%	LOCA4.3 ORT2 DCCX.IN.CONTR 3210TCVMCCD---ZJ 3210TCVMCCD-ZJD1
4.65E-08	36.6%	XSW1.1LOOP1.BREAK 3334VYDPV3---AFO OPCTLFEEDP1
4.65E-08	36.9%	XSW1.1LOOP1.BREAK 3334VYDPV4---AFO OPCTLFEEDP1
4.65E-08	37.2%	XSW1.1LOOP2.BREAK 3334VYDPV1---AFO OPCTLFEEDP1
4.65E-08	37.5%	XSW1.1LOOP2.BREAK 3334VYDPV2---AFO OPCTLFEEDP1
4.61E-08	37.8%	LOFA2.1 7134PV506#1-2CCF
4.41E-08	38.2%	LOCA2.6 7134PV506#1-2CCF
4.04E-08	38.4%	DCC 34320-VSMALL--ZJ 63332OPR-MAN--ZJ 63332PC35#1---ZJ RECOV-ECC-SML 63332PC35#1-ZJD2 34320-VSMALLZJD1
3.56E-08	38.7%	LOCA3.1 LOOP1.BREAK 3334V-PPRV3--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	38.9%	LOCA3.1 LOOP1.BREAK 3334V-PPRV4--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	39.2%	LOCA3.1 LOOP2.BREAK 3334V-PPRV1--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.56E-08	39.4%	LOCA3.1 LOOP2.BREAK 3334V-PPRV2--ALO OPCTLFEEDP1 OPCTLFEEDP2
3.32E-08	39.6%	XSW1.1LOOP1.BREAK 3334TA-PV3----RU OPCTLFEEDP1
3.32E-08	39.9%	XSW1.1LOOP1.BREAK 3334TA-PV4----RU OPCTLFEEDP1
3.32E-08	40.1%	XSW1.1LOOP2.BREAK 3334TA-PV1----RU OPCTLFEEDP1
3.32E-08	40.3%	XSW1.1LOOP2.BREAK 3334TA-PV2----RU OPCTLFEEDP1
3.28E-08	40.5%	LOFA2.1 3461V-MMV47--COS
3.25E-08	40.8%	LOPC1.1 ECC.CABLE 3523VY-V22E---FO
3.25E-08	41.0%	LOPC1.1 ECC.CABLE 3523VY-V22W---FO
3.14E-08	41.2%	LOCA2.6 3461V-MMV47--COS

2.95E-08	41.4%	LOFA2.1	LOOP1.BREAK	3334VYDPV3---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.95E-08	41.6%	LOFA2.1	LOOP1.BREAK	3334VYDPV4---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.95E-08	41.8%	LOFA2.1	LOOP2.BREAK	3334VYDPV1---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.95E-08	42.0%	LOFA2.1	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.82E-08	42.2%	LOCA2.6	LOOP1.BREAK	3334VYDPV3---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.82E-08	42.4%	LOCA2.6	LOOP1.BREAK	3334VYDPV4---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.82E-08	42.6%	LOCA2.6	LOOP2.BREAK	3334VYDPV1---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.82E-08	42.8%	LOCA2.6	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	43.0%	LOCA2.7	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	43.2%	LOCA2.7	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	43.4%	LOCA2.7	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	43.5%	LOCA2.7	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.61E-08	43.7%	LOFA2.1	3432H-PHX1--~-IH	RCW.FACTOR		
2.61E-08	43.9%	LOFA2.1	RCW.FACTOR	3432H-PHX1--%-IH		
2.54E-08	44.1%	LOFA2.1	CABLE.AGING.BUXA			
2.54E-08	44.3%	LOFA2.1	CABLE.AGING.BUXC			
2.54E-08	44.4%	LOFA2.1	CABLE.AGING.BUYA			
2.54E-08	44.6%	LOFA2.1	CABLE.AGING.BUYC			
2.50E-08	44.8%	LOCA2.6	3432H-PHX1--~-IH	RCW.FACTOR		
2.50E-08	44.9%	LOCA2.6	RCW.FACTOR	3432H-PHX1--%-IH		
2.48E-08	45.1%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22E---FO	RECOV-ECC-SML	
2.48E-08	45.3%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22W---FO	RECOV-ECC-SML	
2.43E-08	45.4%	LOCA2.6	CABLE.AGING.BUXA			
2.43E-08	45.6%	LOCA2.6	CABLE.AGING.BUXC			
2.43E-08	45.8%	LOCA2.6	CABLE.AGING.BUYA			
2.43E-08	45.9%	LOCA2.6	CABLE.AGING.BUYC			

2.26E-08	46.1%	END1.3 ECC.CABLE
2.25E-08	46.3%	XSW1.1OP-EWS-ECC 3332TT70-20/1CCF
2.17E-08	46.4%	LOPC1.1 ECC.CABLE 3526VDAPV90--BFC
2.14E-08	46.6%	LOPC1.2 34320-VSMALL--ZJ 63332HS46-----ZJ RECOV-ECC-SML 34320-VSMALLZJD1
2.10E-08	46.7%	LOFA2.1 LOOP1.BREAK 3334TA-PV3----RU OPCTLFEEDP1 OPCTLFEEDP2
2.10E-08	46.8%	LOFA2.1 LOOP1.BREAK 3334TA-PV4----RU OPCTLFEEDP1 OPCTLFEEDP2
2.10E-08	47.0%	LOFA2.1 LOOP2.BREAK 3334TA-PV1----RU OPCTLFEEDP1 OPCTLFEEDP2
2.10E-08	47.1%	LOFA2.1 LOOP2.BREAK 3334TA-PV2----RU OPCTLFEEDP1 OPCTLFEEDP2
2.03E-08	47.3%	LOPC1.1 ECC.PIPE 3523VY-V22E---FO
2.03E-08	47.4%	LOPC1.1 ECC.PIPE 3523VY-V22W---FO
2.03E-08	47.5%	GENT ECC.CABLE 4323TT-TT----CCF
2.01E-08	47.7%	LOCA2.6 LOOP1.BREAK 3334TA-PV3----RU OPCTLFEEDP1 OPCTLFEEDP2
2.01E-08	47.8%	LOCA2.6 LOOP1.BREAK 3334TA-PV4----RU OPCTLFEEDP1 OPCTLFEEDP2
2.01E-08	48.0%	LOCA2.6 LOOP2.BREAK 3334TA-PV1----RU OPCTLFEEDP1 OPCTLFEEDP2
2.01E-08	48.1%	LOCA2.6 LOOP2.BREAK 3334TA-PV2----RU OPCTLFEEDP1 OPCTLFEEDP2
1.99E-08	48.2%	LOFA2.1 P1.RUNNING 3432V-AV099--ACE
1.99E-08	48.4%	LOFA2.1 P2.RUNNING 3432V-AV099--ACE
1.99E-08	48.5%	LOPC2.1 34320-VSMALL--ZJ OPIC1 RECOV-ECC-SML 34320-VSMALLZJD1
1.95E-08	48.6%	GENT ECC.CABLE 3750ERIE-----CCF
1.91E-08	48.8%	LOCA2.6 P1.RUNNING 3432V-AV099--ACE
1.91E-08	48.9%	LOCA2.6 P2.RUNNING 3432V-AV099--ACE
1.86E-08	49.0%	LOHS3.2 3614VRCPSV-1-CCF 5290RC-RF1---ELO
1.82E-08	49.2%	XSW1.1LOOP1.BREAK 3334SV3#1/2--CCF OPCTLFEEDP1
1.82E-08	49.3%	XSW1.1LOOP1.BREAK 3334SV4#1/2--CCF OPCTLFEEDP1
1.82E-08	49.4%	XSW1.1LOOP2.BREAK 3334SV1#1/2--CCF OPCTLFEEDP1
1.82E-08	49.5%	XSW1.1LOOP2.BREAK 3334SV2#1/2--CCF OPCTLFEEDP1

1.75E-08	49.6%	LOFA2.1	3432H-PHX1--%-LO		
1.67E-08	49.8%	LOCA2.6	3432H-PHX1--%-LO		
1.66E-08	49.9%	LOCA2.2	7134VBA218---EFO	7134VBA217---EFO	7134VBCP914->EFC
1.66E-08	50.0%	LOCA2.2	7134VBA220---EFO	7134VBA219---EFO	7134VBCP914->EFC
1.66E-08	50.1%	LOCA2.2	6361FMSSV-FC-CCF	7134VBCP914->EFC	

10.4.3 SDCF at power - time 20 years

Cutset Report

SCDF-AP = 1.85E-05 (Probability)

Probability	%	Inputs...				
9.46E-07	5.1%	XSW1.1	CABLE.AGING.BUXA			
9.46E-07	10.2%	XSW1.1	CABLE.AGING.BUXC			
9.46E-07	15.4%	XSW1.1	CABLE.AGING.BUYA			
9.46E-07	20.5%	XSW1.1	CABLE.AGING.BUYC			
3.56E-07	22.4%	DCC	34320-VSMALL--ZJ	63332HS46-----ZJ	RECOV-ECC-SML	34320-VSMALLZJD1
2.58E-07	23.8%	XSW1.1	LOOP1.BREAK 3334V-PPRV3--ALO	OPCTLFEEDP1		
2.58E-07	25.2%	XSW1.1	LOOP1.BREAK 3334V-PPRV4--ALO	OPCTLFEEDP1		
2.58E-07	26.6%	XSW1.1	LOOP2.BREAK 3334V-PPRV1--ALO	OPCTLFEEDP1		
2.58E-07	28.0%	XSW1.1	LOOP2.BREAK 3334V-PPRV2--ALO	OPCTLFEEDP1		
2.57E-07	29.4%	LOPC1.2	34320-VSMALL--ZJ	OPRZHTR1	RECOV-ECC-SML	34320-VSMALLZJD1
1.63E-07	30.3%	LOFA2.1	LOOP1.BREAK 3334V-PPRV3--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.63E-07	31.2%	LOFA2.1	LOOP1.BREAK 3334V-PPRV4--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.63E-07	32.1%	LOFA2.1	LOOP2.BREAK 3334V-PPRV1--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.63E-07	32.9%	LOFA2.1	LOOP2.BREAK 3334V-PPRV2--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.56E-07	33.8%	LOCA2.6	LOOP1.BREAK 3334V-PPRV3--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.56E-07	34.6%	LOCA2.6	LOOP1.BREAK 3334V-PPRV4--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.56E-07	35.5%	LOCA2.6	LOOP2.BREAK 3334V-PPRV1--ALO	OPCTLFEEDP1 OPCTLFEEDP2		
1.56E-07	36.3%	LOCA2.6	LOOP2.BREAK 3334V-PPRV2--ALO	OPCTLFEEDP1 OPCTLFEEDP2		

8.63E-08	36.8%	END1.3 OCC					
7.41E-08	37.2%	LOFA2.1	6361FMSSV-FC3CCF				
7.08E-08	37.6%	LOCA2.6	6361FMSSV-FC3CCF				
6.14E-08	37.9%	LOPC1.1	ECC.CABLE	3523VY-V22E---FO			
6.14E-08	38.2%	LOPC1.1	ECC.CABLE	3523VY-V22W---FO			
5.30E-08	38.5%	XSW1.1GRID.LOSS.SLOW		SG2.AVAIL	5560BY-BAT1C--LO		
5.28E-08	38.8%	XSW1.1SG1.AVAIL	GRID.LOSS.SLOW		5560BY-BAT1A--LO		
4.96E-08	39.1%	LOCA4.3	ORT2 DCCX.IN.CONTR		3210TCVMCCD---ZJ	3210TCVMCCD-ZJD1	
4.90E-08	39.4%	XSW1.1LOOP1.BREAK	3334VYDPV3---AFO		OPCTLFEEDP1		
4.90E-08	39.6%	XSW1.1LOOP1.BREAK	3334VYDPV4---AFO		OPCTLFEEDP1		
4.90E-08	39.9%	XSW1.1LOOP2.BREAK	3334VYDPV1---AFO		OPCTLFEEDP1		
4.90E-08	40.2%	XSW1.1LOOP2.BREAK	3334VYDPV2---AFO		OPCTLFEEDP1		
4.82E-08	40.4%	LOFA2.1	7134PV506#1-2CCF				
4.80E-08	40.7%	LOFA2.1	CABLE.AGING.BUXA				
4.80E-08	40.9%	LOFA2.1	CABLE.AGING.BUXC				
4.80E-08	41.2%	LOFA2.1	CABLE.AGING.BUYA				
4.80E-08	41.5%	LOFA2.1	CABLE.AGING.BUYC				
4.61E-08	41.7%	LOCA2.6	7134PV506#1-2CCF				
4.59E-08	42.0%	LOCA2.6	CABLE.AGING.BUXA				
4.59E-08	42.2%	LOCA2.6	CABLE.AGING.BUXC				
4.59E-08	42.5%	LOCA2.6	CABLE.AGING.BUYA				
4.59E-08	42.7%	LOCA2.6	CABLE.AGING.BUYC				
4.26E-08	42.9%	END1.3 ECC.CABLE					
4.10E-08	43.2%	LOPC1.1	ECC.CABLE	3526VDAPV90--BFC			
4.04E-08	43.4%	DCC 34320-VSMALL--ZJ		63332OPR-MAN--ZJ	63332PC35#1---ZJ	RECOV-ECC-SML	63332PC35#1-ZJD2 34320-VSMALLZJD1

3.84E-08	43.6%	LOPC1.1	ECC.PIPE	3523VY-V22E---FO		
3.84E-08	43.8%	LOPC1.1	ECC.PIPE	3523VY-V22W---FO		
3.83E-08	44.0%	GENT	ECC.CABLE	4323TT-TT----CCF		
3.68E-08	44.2%	GENT	ECC.CABLE	3750ERIE-----CCF		
3.56E-08	44.4%	LOCA3.1	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
3.56E-08	44.6%	LOCA3.1	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
3.56E-08	44.8%	LOCA3.1	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
3.56E-08	45.0%	LOCA3.1	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2
3.52E-08	45.2%	LOFA2.1	3461V-MMV47--COS			
3.37E-08	45.3%	LOCA2.6	3461V-MMV47--COS			
3.32E-08	45.5%	XSW1.1LOOP1.BREAK	3334TA-PV3----RU	OPCTLFEEDP1		
3.32E-08	45.7%	XSW1.1LOOP1.BREAK	3334TA-PV4----RU	OPCTLFEEDP1		
3.32E-08	45.9%	XSW1.1LOOP2.BREAK	3334TA-PV1----RU	OPCTLFEEDP1		
3.32E-08	46.1%	XSW1.1LOOP2.BREAK	3334TA-PV2----RU	OPCTLFEEDP1		
3.11E-08	46.2%	LOFA2.1	LOOP1.BREAK	3334VYDPV3---AFO	OPCTLFEEDP1	OPCTLFEEDP2
3.11E-08	46.4%	LOFA2.1	LOOP1.BREAK	3334VYDPV4---AFO	OPCTLFEEDP1	OPCTLFEEDP2
3.11E-08	46.6%	LOFA2.1	LOOP2.BREAK	3334VYDPV1---AFO	OPCTLFEEDP1	OPCTLFEEDP2
3.11E-08	46.7%	LOFA2.1	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.97E-08	46.9%	LOCA2.6	LOOP1.BREAK	3334VYDPV3---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.97E-08	47.1%	LOCA2.6	LOOP1.BREAK	3334VYDPV4---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.97E-08	47.2%	LOCA2.6	LOOP2.BREAK	3334VYDPV1---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.97E-08	47.4%	LOCA2.6	LOOP2.BREAK	3334VYDPV2---AFO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	47.5%	LOCA2.7	LOOP1.BREAK	3334V-PPRV3--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	47.7%	LOCA2.7	LOOP1.BREAK	3334V-PPRV4--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	47.8%	LOCA2.7	LOOP2.BREAK	3334V-PPRV1--ALO	OPCTLFEEDP1	OPCTLFEEDP2
2.81E-08	48.0%	LOCA2.7	LOOP2.BREAK	3334V-PPRV2--ALO	OPCTLFEEDP1	OPCTLFEEDP2

2.66E-08	48.1%	END1.3	ECC.PIPE			
2.62E-08	48.3%	LOFA2.1	3432H-PHX1--~-IH	RCW.FACTOR		
2.62E-08	48.4%	LOFA2.1	RCW.FACTOR	3432H-PHX1--%-IH		
2.56E-08	48.6%	LOPC1.1	ECC.PIPE	3526VDAPV90--BFC		
2.51E-08	48.7%	LOCA2.6	3432H-PHX1--~-IH	RCW.FACTOR		
2.51E-08	48.8%	LOCA2.6	RCW.FACTOR	3432H-PHX1--%-IH		
2.48E-08	49.0%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22E---FO	RECOV-ECC-SML	
2.48E-08	49.1%	LOPC1.1	34320-VSMALL--ZJ	3523VY-V22W---FO	RECOV-ECC-SML	
2.40E-08	49.2%	GENT	ECC.PIPE	4323TT-TT----CCF		
2.30E-08	49.3%	GENT	ECC.PIPE	3750ERIE-----CCF		
2.25E-08	49.5%	XSW1.1	OP-EWS-ECC	3332TT70-20/1CCF		
2.14E-08	49.6%	LOPC1.2	34320-VSMALL--ZJ	63332HS46-----ZJ	RECOV-ECC-SML	34320-VSMALLZJD1
2.10E-08	49.7%	LOFA2.1	LOOP1.BREAK	3334TA-PV3----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.10E-08	49.8%	LOFA2.1	LOOP1.BREAK	3334TA-PV4----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.10E-08	49.9%	LOFA2.1	LOOP2.BREAK	3334TA-PV1----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.10E-08	50.0%	LOFA2.1	LOOP2.BREAK	3334TA-PV2----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.01E-08	50.2%	LOCA2.6	LOOP1.BREAK	3334TA-PV3----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.01E-08	50.3%	LOCA2.6	LOOP1.BREAK	3334TA-PV4----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.01E-08	50.4%	LOCA2.6	LOOP2.BREAK	3334TA-PV1----RU	OPCTLFEEDP1	OPCTLFEEDP2
2.01E-08	50.5%	LOCA2.6	LOOP2.BREAK	3334TA-PV2----RU	OPCTLFEEDP1	OPCTLFEEDP2
1.99E-08	50.6%	LOFA2.1	P1.RUNNING	3432V-AV099--ACE		
1.99E-08	50.7%	LOFA2.1	P2.RUNNING	3432V-AV099--ACE		
1.99E-08	50.8%	LOPC2.1	34320-VSMALL--ZJ	OPIC1	RECOV-ECC-SML	34320-VSMALLZJD1
1.95E-08	50.9%	LOHS3.2	3614VRCPSV-1-CCF	5290RC-RF1---ELO		
1.95E-08	51.0%	XSW1.1	LOOP1.BREAK	3334SV3#1/2--CCF	OPCTLFEEDP1	
1.95E-08	51.1%	XSW1.1	LOOP1.BREAK	3334SV4#1/2--CCF	OPCTLFEEDP1	

1.95E-08	51.2%	XSW1.1	LOOP2.BREAK	3334SV1#1/2--CCF	OPCTLFEEDP1
1.95E-08	51.3%	XSW1.1	LOOP2.BREAK	3334SV2#1/2--CCF	OPCTLFEEDP1
1.91E-08	51.4%	LOCA2.6	P1.RUNNING	3432V-AV099--ACE	
1.91E-08	51.5%	LOCA2.6	P2.RUNNING	3432V-AV099--ACE	
1.82E-08	51.6%	LOCA2.2	6361FMSSV-FC-CCF	7134VBCP914->EFC	

10.4.4 SDCF at shutdown - time 0 year

Cutset Report

SCDF-SD = 6.92E-06 (Probability)

Probability	%	Inputs...					
1.58E-07	2.3%	XSW1.2OMKUP-SD	OMKECC-DI	OMKECC-DI-D1			
1.49E-07	4.4%	XSW1.23614VRCPSV---CCF					
1.30E-07	6.3%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134VBCP914->EFC	OMKECC-DI-D1	
1.23E-07	8.1%	SDLOCA1.1	7134VBCP914->EFC	3614VRCPSV---CCF			
1.18E-07	9.8%	XSW1.2OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1		
9.74E-08	11.2%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134VBCP914->EFC	OMKECC-SD-D1
4.43E-08	11.8%	XSW1.3OECCML-SD1	OPHTSBR	OECCML-SD1-D1			
3.06E-08	12.3%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>ECE	OMKECC-DI-D1	
3.06E-08	12.7%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>EIL	OMKECC-DI-D1	
3.04E-08	13.2%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-DI	3210TCVMCCDSD-ZJ	OMKECC-DI-D1
2.89E-08	13.6%	SDLOCA1.1	7134V-AV8185>ECE	3614VRCPSV---CCF			
2.89E-08	14.0%	SDLOCA1.1	7134V-AV8185>EIL	3614VRCPSV---CCF			
2.87E-08	14.4%	SDLOCA1.1	DCCX.IN.CONTR	3210TCVMCCDSD-ZJ	3614VRCPSV---CCF		
2.30E-08	14.7%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>ECE	OMKECC-SD-D1
2.30E-08	15.1%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>EIL	OMKECC-SD-D1
2.29E-08	15.4%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	15.7%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	16.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	16.4%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1

2.29E-08	16.7%	SDLOCA1.1	RCW.PUMP.CONFBS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.1%	SDLOCA1.1	RCW.PUMP.CONFDS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.4%	SDLOCA1.1	RCW.PUMP.CONFUS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.7%	SDLOCA1.1	RCW.PUMP.CONFWS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.28E-08	18.0%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	3210TCVMCCDSD-ZJ	OMKECC-SD-D1
2.17E-08	18.4%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	3614VRCPSV---CCF			
2.17E-08	18.7%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	3614VRCPSV---CCF			
2.17E-08	19.0%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	3614VRCPSV---CCF			
2.17E-08	19.3%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	3614VRCPSV---CCF			
2.17E-08	19.6%	SDLOCA1.1	RCW.PUMP.CONFBS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.17E-08	19.9%	SDLOCA1.1	RCW.PUMP.CONFDS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.17E-08	20.2%	SDLOCA1.1	RCW.PUMP.CONFUS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.17E-08	20.6%	SDLOCA1.1	RCW.PUMP.CONFWS	5322302BUF--~C-F	3614VRCPSV---CCF			
1.86E-08	20.8%	SDLOCA1.1	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	5522282568C4>E68	OMKECC-DI-D1	
1.83E-08	21.1%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
1.76E-08	21.3%	XSW1.23432V-SSV-DE-CCF						
1.76E-08	21.6%	SDLOCA1.1	7134-PCV914C--ZJ	5522282568C4>E68	3614VRCPSV---CCF			
1.73E-08	21.8%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	3614VRCPSV---CCF			
1.72E-08	22.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.3%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.6%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.8%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1

1.72E-08 23.1% SDLOCA1.1 RCW.PUMP.CONFBS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.3% SDLOCA1.1 RCW.PUMP.CONFDS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.6% SDLOCA1.1 RCW.PUMP.CONFUS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.8% SDLOCA1.1 RCW.PUMP.CONFWS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.54E-08 24.1% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-DI OMKECC-DI-D1

1.52E-08 24.3% XSW1.2DA.PATH.UNAV 3461EFORO1----LO RFT.PATH.UNAV

1.49E-08 24.5% XSW1.33614VRCPSV---CCF

1.45E-08 24.7% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR 3614VRCPSV---CCF

1.45E-08 24.9% SDLOCA1.1 7134VBCP914->EFC 3432V-SSV-DE-CCF

1.40E-08 25.1% SDLOCA1.1 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5522282568C4>E68 OMKECC-SD-D1

1.37E-08 25.3% SDLOCA1.1 0643282PL634>I34 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

1.25E-08 25.5% SDLOCA1.1 DA.PATH.UNAV 3461EFORO1----LO 7134VBCP914->EFC RFT.PATH.UNAV

1.15E-08 25.7% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

7.52E-09 25.8% SDLOCA1.1 DCCX.IN.CONTR DA.PATH.UNAV 3461EFORO1----LO 3210TCVMCCDSD-ZJ 4323HS104-----ZJ 3210TCVMCCSDZJD1

6.91E-09 25.9% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL118>I18 OMKECC-DI-D1

6.91E-09 26.0% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL177>I77 OMKECC-DI-D1

6.53E-09 26.1% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL118>I18 3614VRCPSV---CCF

6.53E-09 26.2% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL177>I77 3614VRCPSV---CCF

6.42E-09 26.2% SDLOCA1.1 OMKUP-SD OMKECC-DI 3210TCV6/8-->CCF OMKECC-DI-D1

6.34E-09 26.3% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL177>I77 0643282PL118>I18 OMKECC-DI-D1

6.30E-09 26.4% SDLOCA1.1 OMKUP-SD OMKECC-DI 7134VBCP914->EFO OMKECC-DI-D1

6.07E-09 26.5% SDLOCA1.1 3210TCV6/8-->CCF 3614VRCPSV---CCF

5.99E-09 26.6% SDLOCA1.1 DCCX.IN.CONTR 0643282PL177>I77 0643282PL118>I18 3614VRCPSV---CCF

5.95E-09 26.7% SDLOCA1.1 7134VBCP914->EFO 3614VRCPSV---CCF

5.84E-09 26.8% XSW1.2DA.PATH.UNAV RFT.PATH.UNAV 3461VGCPV7---CFC

5.19E-09 26.8% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL118>I18 OMKECC-SD-D1

5.19E-09 26.9% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL177>I77 OMKECC-SD-D1

4.82E-09 27.0% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 3210TCV6/8-->CCF OMKECC-SD-D1

4.81E-09 27.1% SDLOCA1.1 DA.PATH.UNAV 7134VBCP914->EFC RFT.PATH.UNAV 3461VGCPV7---CFC

4.76E-09 27.1% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL177>I77 0643282PL118>I18 OMKECC-SD-D1

4.73E-09 27.2% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 7134VBCP914->EFO OMKECC-SD-D1

3.75E-09 27.3% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFAS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.3% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFBS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.4% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFCS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.4% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFDS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFES WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFFS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.6% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFGS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09	27.6%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFHS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	27.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFIS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	27.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFJS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	27.8%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFKS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	27.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFLS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	27.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFMS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFNS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFOS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFPS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFQS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.2%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFRS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.2%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFSS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFTS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFUS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
3.75E-09	28.4%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFVS	WINTER.MODEPUMP.RUN.WINTER	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1

3.75E-09 28.4% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFWS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 28.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFXS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.68E-09 28.6% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 3210TT11A/C->CCF OMKECC-DI-D1

3.54E-09 28.6% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFAS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.54E-09 28.7% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFBS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.54E-09 28.7% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFCS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

10.4.5 SDCF at shutdown - time 10 years

Cutset Report

SCDF-SD = 7.13E-06 (Probability)

Probability	%	Inputs...					
1.58E-07	2.2%	XSW1.2OMKUP-SD	OMKECC-DI	OMKECC-DI-D1			
1.56E-07	4.4%	XSW1.23614VRCPSV---CCF					
1.36E-07	6.3%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134VBCP914->EFC	OMKECC-DI-D1	
1.35E-07	8.2%	SDLOCA1.1	7134VBCP914->EFC	3614VRCPSV---CCF			
1.18E-07	9.9%	XSW1.2OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1		
1.02E-07	11.3%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134VBCP914->EFC	OMKECC-SD-D1
4.43E-08	11.9%	XSW1.3OECCML-SD1	OPHTSBR	OECCML-SD1-D1			
3.06E-08	12.4%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>ECE	OMKECC-DI-D1	
3.06E-08	12.8%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>EIL	OMKECC-DI-D1	
3.04E-08	13.2%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-DI	3210TCVMCCDSD-ZJ	OMKECC-DI-D1
3.03E-08	13.6%	SDLOCA1.1	7134V-AV8185>ECE	3614VRCPSV---CCF			
3.03E-08	14.1%	SDLOCA1.1	7134V-AV8185>EIL	3614VRCPSV---CCF			
3.01E-08	14.5%	SDLOCA1.1	DCCX.IN.CONTR	3210TCVMCCDSD-ZJ	3614VRCPSV---CCF		
2.30E-08	14.8%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>ECE	OMKECC-SD-D1
2.30E-08	15.1%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>EIL	OMKECC-SD-D1
2.29E-08	15.5%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	15.8%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	16.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1
2.29E-08	16.4%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1

2.29E-08	16.7%	SDLOCA1.1	RCW.PUMP.CONFBS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.1%	SDLOCA1.1	RCW.PUMP.CONFDS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.4%	SDLOCA1.1	RCW.PUMP.CONFUS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	17.7%	SDLOCA1.1	RCW.PUMP.CONFWS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.28E-08	18.0%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	3210TCVMCCDSD-ZJ	OMKECC-SD-D1
2.27E-08	18.3%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	3614VRCPSV---CCF			
2.27E-08	18.7%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	3614VRCPSV---CCF			
2.27E-08	19.0%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	3614VRCPSV---CCF			
2.27E-08	19.3%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	3614VRCPSV---CCF			
2.27E-08	19.6%	SDLOCA1.1	RCW.PUMP.CONFBS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.27E-08	19.9%	SDLOCA1.1	RCW.PUMP.CONFDS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.27E-08	20.3%	SDLOCA1.1	RCW.PUMP.CONFUS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.27E-08	20.6%	SDLOCA1.1	RCW.PUMP.CONFWS	5322302BUF--~C-F	3614VRCPSV---CCF			
1.89E-08	20.8%	XSW1.23432V-SSV-DE-CCF						
1.86E-08	21.1%	SDLOCA1.1	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	5522282568C4>E68	OMKECC-DI-D1	
1.84E-08	21.4%	SDLOCA1.1	7134-PCV914C--ZJ	5522282568C4>E68	3614VRCPSV---CCF			
1.83E-08	21.6%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
1.81E-08	21.9%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	3614VRCPSV---CCF			
1.72E-08	22.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.4%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.6%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	22.8%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1

1.72E-08 23.1% SDLOCA1.1 RCW.PUMP.CONFBS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.3% SDLOCA1.1 RCW.PUMP.CONFDS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.6% SDLOCA1.1 RCW.PUMP.CONFUS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 23.8% SDLOCA1.1 RCW.PUMP.CONFWS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.64E-08 24.0% SDLOCA1.1 7134VBCP914->EFC 3432V-SSV-DE-CCF

1.56E-08 24.3% XSW1.33614VRCPSV---CCF

1.54E-08 24.5% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-DI OMKECC-DI-D1

1.52E-08 24.7% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR 3614VRCPSV---CCF

1.52E-08 24.9% XSW1.2DA.PATH.UNAV 3461EFORO1----LO RFT.PATH.UNAV

1.40E-08 25.1% SDLOCA1.1 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5522282568C4>E68 OMKECC-SD-D1

1.37E-08 25.3% SDLOCA1.1 0643282PL634>I34 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

1.32E-08 25.5% SDLOCA1.1 DA.PATH.UNAV 3461EFORO1----LO 7134VBCP914->EFC RFT.PATH.UNAV

1.15E-08 25.6% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

7.52E-09 25.7% SDLOCA1.1 DCCX.IN.CONTR DA.PATH.UNAV 3461EFORO1----LO 3210TCVMCCDSD-ZJ 4323HS104-----ZJ 3210TCVMCCSDZJD1

6.91E-09 25.8% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL118>I18 OMKECC-DI-D1

6.91E-09 25.9% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL177>I77 OMKECC-DI-D1

6.86E-09 26.0% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL118>I18 3614VRCPSV---CCF

6.86E-09 26.1% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL177>I77 3614VRCPSV---CCF

6.74E-09 26.2% SDLOCA1.1 OMKUP-SD OMKECC-DI 3210TCV6/8-->CCF OMKECC-DI-D1

6.68E-09 26.3% SDLOCA1.1 3210TCV6/8-->CCF 3614VRCPSV---CCF

6.61E-09 26.4% SDLOCA1.1 OMKUP-SD OMKECC-DI 7134VBCP914->EFO OMKECC-DI-D1

6.55E-09 26.5% SDLOCA1.1 7134VBCP914->EFO 3614VRCPSV---CCF

6.34E-09 26.6% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL177>I77 0643282PL118>I18 OMKECC-DI-D1

6.29E-09 26.7% SDLOCA1.1 DCCX.IN.CONTR 0643282PL177>I77 0643282PL118>I18 3614VRCPSV---CCF

6.14E-09 26.8% XSW1.2DA.PATH.UNAV RFT.PATH.UNAV 3461VGCPV7---CFC

5.31E-09 26.8% SDLOCA1.1 DA.PATH.UNAV 7134VBCP914->EFC RFT.PATH.UNAV 3461VGCPV7---CFC

5.19E-09 26.9% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL118>I18 OMKECC-SD-D1

5.19E-09 27.0% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL177>I77 OMKECC-SD-D1

5.06E-09 27.1% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 3210TCV6/8-->CCF OMKECC-SD-D1

4.96E-09 27.1% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 7134VBCP914->EFO OMKECC-SD-D1

4.76E-09 27.2% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL177>I77 0643282PL118>I18 OMKECC-SD-D1

3.75E-09 27.2% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFAS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.3% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFBS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.3% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFCS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.4% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFDS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFES WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFFS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 27.6% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFGS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09	27.6%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFHS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFIS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFJS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.8%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFKS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.8%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFLS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFMS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	27.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFNS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFOS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFPS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFQS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFRS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.2%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFSS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.2%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFTS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFUS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					
3.75E-09	28.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFVS	WINTER.MODEPUMP.RUN.WINTER	
OMKUP-SD	OMKECC-DI	OMKECC-DI-D1					

3.75E-09 28.4% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFWS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.75E-09 28.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFXS WINTER.MODEPUMP.RUN.WINTER OMKUP-SD OMKECC-DI OMKECC-DI-D1

3.72E-09 28.5% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFAS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.72E-09 28.6% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFBS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.72E-09 28.6% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFCS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.72E-09 28.7% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFDS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

10.4.6 SDCF at shutdown - time 20 years

Cutset Report

SCDF-SD = 7.72E-06 (Probability)

Probability	%	Inputs...					
1.64E-07	2.1%	XSW1.23614VRCPSV---CCF					
1.58E-07	4.2%	XSW1.2OMKUP-SD	OMKECC-DI	OMKECC-DI-D1			
1.48E-07	6.1%	SDLOCA1.1	7134VBCP914->EFC	3614VRCPSV---CCF			
1.43E-07	7.9%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134VBCP914->EFC	OMKECC-DI-D1	
1.18E-07	9.5%	XSW1.2OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1		
1.07E-07	10.8%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134VBCP914->EFC	OMKECC-SD-D1
4.43E-08	11.4%	XSW1.3OECCML-SD1	OPHTSBR	OECCML-SD1-D1			
3.18E-08	11.8%	SDLOCA1.1	7134V-AV8185>ECE	3614VRCPSV---CCF			
3.18E-08	12.2%	SDLOCA1.1	7134V-AV8185>EIL	3614VRCPSV---CCF			
3.15E-08	12.6%	SDLOCA1.1	DCCX.IN.CONTR	3210TCVMCCDSD-ZJ	3614VRCPSV---CCF		
3.06E-08	13.0%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>ECE	OMKECC-DI-D1	
3.06E-08	13.4%	SDLOCA1.1	OMKUP-SD	OMKECC-DI	7134V-AV8185>EIL	OMKECC-DI-D1	
3.04E-08	13.8%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-DI	3210TCVMCCDSD-ZJ	OMKECC-DI-D1
2.38E-08	14.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	3614VRCPSV---CCF		
2.38E-08	14.5%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	3614VRCPSV---CCF		
2.38E-08	14.8%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	3614VRCPSV---CCF		
2.38E-08	15.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	3614VRCPSV---CCF		
2.38E-08	15.4%	SDLOCA1.1	RCW.PUMP.CONFBS	5322302BUF--~C-F	3614VRCPSV---CCF		
2.38E-08	15.7%	SDLOCA1.1	RCW.PUMP.CONFDS	5322302BUF--~C-F	3614VRCPSV---CCF		

2.38E-08	16.0%	SDLOCA1.1	RCW.PUMP.CONFUS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.38E-08	16.3%	SDLOCA1.1	RCW.PUMP.CONFWS	5322302BUF--~C-F	3614VRCPSV---CCF			
2.30E-08	16.6%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>ECE	OMKECC-SD-D1	
2.30E-08	16.9%	SDLOCA1.1	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7134V-AV8185>EIL	OMKECC-SD-D1	
2.29E-08	17.2%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
2.29E-08	17.5%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
2.29E-08	17.8%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
2.29E-08	18.1%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFRS	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
2.29E-08	18.4%	SDLOCA1.1	RCW.PUMP.CONFBS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	18.7%	SDLOCA1.1	RCW.PUMP.CONFDS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	19.0%	SDLOCA1.1	RCW.PUMP.CONFUS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.29E-08	19.3%	SDLOCA1.1	RCW.PUMP.CONFWS	OMKUP-SD	OMKECC-DI	5322302BUF--~C-F	OMKECC-DI-D1	
2.28E-08	19.6%	SDLOCA1.1	DCCX.IN.CONTR	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	3210TCVMCCDSD-ZJ	OMKECC-SD-D1
2.03E-08	19.8%	XSW1.23432V-SSV-DE-CCF						
1.93E-08	20.1%	SDLOCA1.1	7134-PCV914C--ZJ	5522282568C4>E68	3614VRCPSV---CCF			
1.90E-08	20.3%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	3614VRCPSV---CCF			
1.86E-08	20.6%	SDLOCA1.1	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	5522282568C4>E68	OMKECC-DI-D1	
1.84E-08	20.8%	SDLOCA1.1	7134VBCP914->EFC	3432V-SSV-DE-CCF				
1.83E-08	21.0%	SDLOCA1.1	0643282PL634>I34	7134-PCV914C--ZJ	OMKUP-SD	OMKECC-DI	OMKECC-DI-D1	
1.72E-08	21.3%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFGS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	21.5%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFLS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
1.72E-08	21.7%	SDLOCA1.1	5322302BUE--~C-E	RCW.PUMP.CONFMS	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1

1.72E-08 21.9% SDLOCA1.1 5322302BUE--~C-E RCW.PUMP.CONFRS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

1.72E-08 22.2% SDLOCA1.1 RCW.PUMP.CONFBS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 22.4% SDLOCA1.1 RCW.PUMP.CONFDS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 22.6% SDLOCA1.1 RCW.PUMP.CONFUS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.72E-08 22.8% SDLOCA1.1 RCW.PUMP.CONFWS OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5322302BUF--~C-F OMKECC-SD-D1

1.64E-08 23.0% XSW1.33614VRCPSV---CCF

1.60E-08 23.2% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR 3614VRCPSV---CCF

1.54E-08 23.4% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-DI OMKECC-DI-D1

1.52E-08 23.6% XSW1.2DA.PATH.UNAV 3461EFORO1----LO RFT.PATH.UNAV

1.40E-08 23.8% SDLOCA1.1 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 5522282568C4>E68 OMKECC-SD-D1

1.38E-08 24.0% SDLOCA1.1 DA.PATH.UNAV 3461EFORO1----LO 7134VBCP914->EFC RFT.PATH.UNAV

1.37E-08 24.2% SDLOCA1.1 0643282PL634>I34 7134-PCV914C--ZJ OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

1.15E-08 24.3% SDLOCA1.1 6434CXO353:X>-HO DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB OMKECC-SD-D1

7.52E-09 24.4% SDLOCA1.1 DCCX.IN.CONTR DA.PATH.UNAV 3461EFORO1----LO 3210TCVMCCDSD-ZJ 4323HS104-----ZJ 3210TCVMCCSDZJD1

7.32E-09 24.5% SDLOCA1.1 3210TCV6/8-->CCF 3614VRCPSV---CCF

7.19E-09 24.6% SDLOCA1.1 7134VBCP914->EFO 3614VRCPSV---CCF

7.18E-09 24.7% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL118>I18 3614VRCPSV---CCF

7.18E-09 24.8% SDLOCA1.1 DCCX.IN.CONTR 0643282PL146>I46 0643282PL177>I77 3614VRCPSV---CCF

7.05E-09 24.9% SDLOCA1.1 OMKUP-SD OMKECC-DI 3210TCV6/8-->CCF OMKECC-DI-D1

6.92E-09 25.0% SDLOCA1.1 OMKUP-SD OMKECC-DI 7134VBCP914->EFO OMKECC-DI-D1

6.91E-09 25.1% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL118>I18 OMKECC-DI-D1

6.91E-09 25.2% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL146>I46 0643282PL177>I77 OMKECC-DI-D1

6.59E-09 25.2% SDLOCA1.1 DCCX.IN.CONTR 0643282PL177>I77 0643282PL118>I18 3614VRCPSV---CCF

6.43E-09 25.3% XSW1.2DA.PATH.UNAV RFT.PATH.UNAV 3461VGCPV7---CFC

6.34E-09 25.4% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-DI 0643282PL177>I77 0643282PL118>I18 OMKECC-DI-D1

5.81E-09 25.5% SDLOCA1.1 DA.PATH.UNAV 7134VBCP914->EFC RFT.PATH.UNAV 3461VGCPV7---CFC

5.30E-09 25.6% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 3210TCV6/8-->CCF OMKECC-SD-D1

5.20E-09 25.6% SDLOCA1.1 OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 7134VBCP914->EFO OMKECC-SD-D1

5.19E-09 25.7% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL118>I18 OMKECC-SD-D1

5.19E-09 25.8% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL146>I46 0643282PL177>I77 OMKECC-SD-D1

4.76E-09 25.8% SDLOCA1.1 DCCX.IN.CONTR OMKUP-SD OMKECC-SD -ECC.DIRECT.PROB 0643282PL177>I77 0643282PL118>I18 OMKECC-SD-D1

3.94E-09 25.9% SDLOCA1.1 7134V-AV8185>ECE 3432V-SSV-DE-CCF

3.94E-09 25.9% SDLOCA1.1 7134V-AV8185>EIL 3432V-SSV-DE-CCF

3.91E-09 26.0% SDLOCA1.1 DCCX.IN.CONTR 3210TCVMCCDSD-ZJ 3432V-SSV-DE-CCF

3.89E-09 26.0% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFAS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09 26.1% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFBS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09 26.1% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFCS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09 26.2% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFDS WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09 26.2% SDLOCA1.1 5322302BUF-->C-F 5322302BUE-->C-E RCW.PUMP.CONFES WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09	26.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFFS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.3%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFGS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.4%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFHS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.4%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFIS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.5%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFJS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.5%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFKS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.6%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFLS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.6%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFMS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFNS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.7%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFOS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.8%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFPS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.8%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFQS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFRS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	26.9%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFSS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF
3.89E-09	27.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFTS	WINTER.MODEPUMP.RUN.WINTER 3614VRCPSV---CCF

3.89E-09	27.0%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFUS	WINTER.MODEPUMP.RUN.WINTER	3614VRCPSV---CCF
3.89E-09	27.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFVS	WINTER.MODEPUMP.RUN.WINTER	3614VRCPSV---CCF
3.89E-09	27.1%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFWS	WINTER.MODEPUMP.RUN.WINTER	3614VRCPSV---CCF
3.89E-09	27.2%	SDLOCA1.1	5322302BUF-->C-F	5322302BUE-->C-E	RCW.PUMP.CONFXS	WINTER.MODEPUMP.RUN.WINTER	3614VRCPSV---CCF
3.82E-09	27.2%	SDLOCA1.1	DCCX.IN.CONTR	3210TT11A/C->CCF	3614VRCPSV---CCF		

10.4.7 LRF at power - time 0 year

Cutset Report

LRF-AP = 6.50E-08 (Probability)

Probability	%	Inputs...				
2.78E-09	4.3%	END1.1 ORSB2	3730INVPS1---VLO			
1.93E-09	7.3%	END1.3 OCC	3432SW-ZS75-O-FC			
1.78E-09	10.0%	END1.1 ORSB2	3411TD-PT-1--CCF			
1.57E-09	12.4%	END1.3 ORT3	3730INVPS1---VLO			
1.00E-09	13.9%	END1.3 ORT3	3411TD-PT-1--CCF			
9.49E-10	15.4%	END1.3 OCC	OP-DOUS2			
6.07E-10	16.3%	END1.1 ORSB2	MCAS.ON.MANUAL			
5.51E-10	17.2%	END1.1 ORSB2	3730INVPS1---VSP			
5.27E-10	18.0%	END1.3 OCC	3432MS-89B3---OP			
3.51E-10	18.5%	XSW1.1OBPC3	OP-DOUS3			
3.42E-10	19.1%	END1.3 ORT3	MCAS.ON.MANUAL			
3.12E-10	19.5%	XSW1.1LOOP1.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV3--ALO	OPCTLFEEDP1
3.12E-10	20.0%	XSW1.1LOOP1.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV4--ALO	OPCTLFEEDP1
3.12E-10	20.5%	XSW1.1LOOP2.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV1--ALO	OPCTLFEEDP1
3.12E-10	21.0%	XSW1.1LOOP2.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV2--ALO	OPCTLFEEDP1
3.11E-10	21.5%	END1.3 ORT3	3730INVPS1---VSP			
2.82E-10	21.9%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO	
2.55E-10	22.3%	XSW1.1529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316RU-RD200--FC	
2.36E-10	22.6%	END1.1 ORSB2	3732MBCCA----CCF			

2.32E-10	23.0%	END1.2 ORSB	3730INVPS1---VLO				
2.22E-10	23.3%	END1.1 ORSB2	5512EX-TSW2A--OC				
2.01E-10	23.7%	END1.1 ORSB2	3732SMHHS-2-C-OS				
1.95E-10	24.0%	LOHS3.2	3614VRCPSV-1-CCF	OP-EVS3	5290RC-RF1---ELO		
1.90E-10	24.2%	DCC	3614VRCPSV---CCF	7316RU-RD200--FC	5290RC-RF1---ELO		
1.65E-10	24.5%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5290RC-RF1---ELO		
1.58E-10	24.7%	XSW1.1529009QBUD--%DUD	529009QBUC--%DUC	3332TE70-20/1CCF	7316RU-RD200--FC		
1.49E-10	25.0%	XSW1.1529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316EFNTK1:NZ-NO		
1.48E-10	25.2%	END1.2 ORSB	3411TD-PT-1--CCF				
1.37E-10	25.4%	LOHS3.1	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO		
1.33E-10	25.6%	END1.3 ORT3	3732MBCCA----CCF				
1.31E-10	25.8%	DCC	OP-EVS3	3614VRCPSV---CCF	5290RC-RF1---ELO		
1.27E-10	26.0%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	26.2%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	26.4%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	26.6%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	26.8%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	27.0%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	27.2%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.27E-10	27.4%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF

1.27E-10 27.6% LOCA2.2 RCW.PUMP.CONF5 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 27.8% LOCA2.2 RCW.PUMP.CONF5 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 28.0% LOCA2.2 RCW.PUMP.CONF6 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 28.2% LOCA2.2 RCW.PUMP.CONF6 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 28.4% LOCA2.2 RCW.PUMP.CONF7 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 28.6% LOCA2.2 RCW.PUMP.CONF7 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 28.8% LOCA2.2 RCW.PUMP.CONF8 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.27E-10 29.0% LOCA2.2 RCW.PUMP.CONF8 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

1.25E-10 29.1% END1.3 ORT3 5512EX-TSW2A--OC

1.13E-10 29.3% END1.3 ORT3 3732SMHHS-2-C-OS

1.12E-10 29.5% LOHS3.2 3614VRCPSV-1-CCF 7316RU-RD200--FC 5521EX-TSW1B--FT 5521EX-TSW1A--FT

1.12E-10 29.7% LOHS3.2 3614VRCPSV-1-CCF 7316RU-RD200--FC 5521EX-TSW1C--FT 5521EX-TSW1A--FT

1.12E-10 29.8% LOHS3.2 3614VRCPSV-1-CCF 7316RU-RD200--FC 5521EX-TSW1C--FT 5521EX-TSW1B--FT

1.11E-10 30.0% DCC 3614VRCPSV---CCF 7316EFNTK1:NZ-NO 5290RC-RF1---ELO

9.68E-11 30.2% LOHS4.3 ORT1 3471VYDPV12--CCF

9.46E-11 30.3% LOHS3.1 3614VRCPSV-1-CCF OP-EVS3 5290RC-RF1---ELO

9.41E-11 30.4% END1.1 ORSB2 5522EC-8:4216EOS

9.40E-11 30.6% LOCA2.2 RCW.PUMP.CONF1 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 30.7% LOCA2.2 RCW.PUMP.CONF2 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 30.9% LOCA2.2 RCW.PUMP.CONF3 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 31.0% LOCA2.2 RCW.PUMP.CONF4 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 31.2% LOCA2.2 RCW.PUMP.CONF5 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 31.3% LOCA2.2 RCW.PUMP.CONF6 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 31.5% LOCA2.2 RCW.PUMP.CONF7 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.40E-11 31.6% LOCA2.2 RCW.PUMP.CONF8 SUMMER.MODE PUMP.RUN.SUMMER 7111-FSDB&WSF-FF 7316RU-RD200--FC 7111PV78#1/2-CCF

9.26E-11 31.7% XSW1.1529009QBUD--%DUD 529009QBUC--%DUC 3332TE70-20/1CCF 7316EFNTK1:NZ-NO

9.15E-11 31.9% XSW1.1LOOP1.BREAK 3334V-PPRV3--ALO 7316RU-RD200--FC 3432SW-ZS75-O-FC OPCTLFEEDP1

9.15E-11 32.0% XSW1.1LOOP1.BREAK 3334V-PPRV4--ALO 7316RU-RD200--FC 3432SW-ZS75-O-FC OPCTLFEEDP1

9.15E-11 32.2% XSW1.1LOOP2.BREAK 3334V-PPRV1--ALO 7316RU-RD200--FC 3432SW-ZS75-O-FC OPCTLFEEDP1

9.15E-11 32.3% XSW1.1LOOP2.BREAK 3334V-PPRV2--ALO 7316RU-RD200--FC 3432SW-ZS75-O-FC OPCTLFEEDP1

8.01E-11 32.4% LOHS3.1 3614VRCPSV-1-CCF 7316EFNTK1:NZ-NO 5290RC-RF1---ELO

7.50E-11 32.5% DCC 3614VRCPSV---CCF 7316RU-RD200--FC 5521EX-TSW1B--FT 5521EX-TSW1A--FT

7.50E-11 32.7% DCC 3614VRCPSV---CCF 7316RU-RD200--FC 5521EX-TSW1C--FT 5521EX-TSW1A--FT

7.50E-11 32.8% DCC 3614VRCPSV---CCF 7316RU-RD200--FC 5521EX-TSW1C--FT 5521EX-TSW1B--FT

7.45E-11 32.9% LOCA2.2 RCW.PUMP.CONF1 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316EFNTK1:NZ-NO 7111PV78#1/2-CCF

7.45E-11 33.0% LOCA2.2 RCW.PUMP.CONF1 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316EFNTK1:NZ-NO 7111PV78#1/2-CCF

7.45E-11 33.1% LOCA2.2 RCW.PUMP.CONF2 WINTER.MODEPUMP.RUN.WINTER 7111-FSDB&WSF-FF 7316EFNTK1:NZ-NO 7111PV78#1/2-CCF

7.45E-11 33.2% LOCA2.2 RCW.PUMP.CONF2 WINTER.MODEPUMP.STBY.WINTER 7111-FSDB&WSF-FF 7316EFNTK1:NZ-NO 7111PV78#1/2-CCF

7.45E-11	33.3%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	33.5%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	33.6%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	33.7%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	33.8%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	33.9%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.0%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.1%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.3%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.4%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.5%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.45E-11	34.6%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316EFNTK1:NZ-NO
7111PV78#1/2-CCF						
7.14E-11	34.7%	XSW1.1OBPC3	3432SW-ZS75-O-FC			
7.12E-11	34.8%	END1.3 OCC	3432RLM634KK--SC			
6.73E-11	34.9%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXA		
6.73E-11	35.0%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXC		
6.73E-11	35.1%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYA		
6.73E-11	35.2%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYC		

6.54E-11	35.3%	DCC	3614VRCPSV---CCF	3461EFORO1----LO	7316RU-RD200--FC		
6.53E-11	35.4%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5521EX-TSW1B--FT	5521EX-TSW1A--FT	
6.53E-11	35.5%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5521EX-TSW1C--FT	5521EX-TSW1A--FT	
6.53E-11	35.6%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5521EX-TSW1C--FT	5521EX-TSW1B--FT	
6.33E-11	35.7%	XSW1.1LOOP1.BREAK OP-EVS3		3334V-PPRV3--ALO	3432SW-ZS75-O-FC	OPCTLFEEDP1	

10.4.8 LRF at power - time 10 years

Cutset Report

LRF-AP = 8.69E-08 (Probability)

Probability	%	Inputs...				
2.80E-09	3.2%	END1.1 ORSB2	3730INVPS1---VLO			
1.93E-09	5.4%	END1.3 OCC	3432SW-ZS75-O-FC			
1.78E-09	7.5%	END1.1 ORSB2	3411TD-PT-1--CCF			
1.58E-09	9.3%	END1.3 ORT3	3730INVPS1---VLO			
1.00E-09	10.5%	END1.3 ORT3	3411TD-PT-1--CCF			
9.49E-10	11.5%	END1.3 OCC	OP-DOUS2			
6.07E-10	12.2%	END1.1 ORSB2	MCAS.ON.MANUAL			
6.06E-10	12.9%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXA		
6.06E-10	13.6%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXC		
6.06E-10	14.3%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYA		
6.06E-10	15.0%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYC		
5.56E-10	15.7%	END1.1 ORSB2	3730INVPS1---VSP			
5.27E-10	16.3%	END1.3 OCC	3432MS-89B3---OP			
3.51E-10	16.7%	XSW1.1OBPC3	OP-DOUS3			
3.42E-10	17.1%	END1.3 ORT3	MCAS.ON.MANUAL			
3.13E-10	17.4%	END1.3 ORT3	3730INVPS1---VSP			
3.12E-10	17.8%	XSW1.1LOOP1.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV3--ALO	OPCTLFEEDP1
3.12E-10	18.2%	XSW1.1LOOP1.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV4--ALO	OPCTLFEEDP1
3.12E-10	18.5%	XSW1.1LOOP2.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV1--ALO	OPCTLFEEDP1

3.12E-10	18.9%	XSW1.1	LOOP2.BREAK	OP-EVS4	OP-DOUS2	3334V-PPRV2--ALO	OPCTLFEEDP1
3.07E-10	19.2%	LOHS4.3	ORT1	SDS2C.CABLE			
2.96E-10	19.6%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO		
2.55E-10	19.9%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316RU-RD200--FC	
2.36E-10	20.1%	END1.1	ORSB2	3732MBCCA----CCF			
2.33E-10	20.4%	END1.2	ORSB	3730INVPS1---VLO			
2.33E-10	20.7%	END1.1	ORSB2	5512EX-TSW2A--OC			
2.17E-10	20.9%	XSW1.1	7316RU-RD200--FC	5521EX-TSW1A--FT	CABLE.AGING.BUYA		
2.17E-10	21.2%	XSW1.1	7316RU-RD200--FC	5521EX-TSW1C--FT	CABLE.AGING.BUYC		
2.05E-10	21.4%	LOHS3.2	3614VRCPSV-1-CCF	OP-EVS3	5290RC-RF1---ELO		
2.01E-10	21.6%	END1.1	ORSB2	3732SMHHS-2-C-OS			
1.99E-10	21.9%	DCC	3614VRCPSV---CCF	7316RU-RD200--FC	5290RC-RF1---ELO		
1.78E-10	22.1%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUXA		
1.78E-10	22.3%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUXC		
1.78E-10	22.5%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUYA		
1.78E-10	22.7%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUYC		
1.73E-10	22.9%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5290RC-RF1---ELO		
1.58E-10	23.1%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TE70-20/1CCF	7316RU-RD200--FC	
1.50E-10	23.2%	XSW1.1	OP-EVS3	5521EX-TSW1A--FT	CABLE.AGING.BUYA		
1.50E-10	23.4%	XSW1.1	OP-EVS3	5521EX-TSW1C--FT	CABLE.AGING.BUYC		
1.49E-10	23.6%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316EFNTK1:NZ-NO	
1.48E-10	23.8%	END1.2	ORSB	3411TD-PT-1--CCF			
1.44E-10	23.9%	LOHS3.1	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO		
1.38E-10	24.1%	DCC	OP-EVS3	3614VRCPSV---CCF	5290RC-RF1---ELO		
1.33E-10	24.2%	END1.3	ORT3	3732MBCCA----CCF			

1.33E-10	24.4%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	24.5%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	24.7%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	24.9%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.0%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.2%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.3%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.5%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.6%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.8%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	25.9%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	26.1%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	26.2%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	26.4%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.33E-10	26.5%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF

1.33E-10	26.7%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.32E-10	26.8%	END1.3 ORT3	5512EX-TSW2A--OC				
1.29E-10	27.0%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1B--FT	5521EX-TSW1A--FT	
1.29E-10	27.1%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1C--FT	5521EX-TSW1A--FT	
1.29E-10	27.3%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1C--FT	5521EX-TSW1B--FT	
1.27E-10	27.4%	XSW1.17316EFNTK1:NZ-NO	5521EX-TSW1A--FT	CABLE.AGING.BUYA			
1.27E-10	27.6%	XSW1.17316EFNTK1:NZ-NO	5521EX-TSW1C--FT	CABLE.AGING.BUYC			
1.23E-10	27.7%	XSW1.1OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUXA			
1.23E-10	27.9%	XSW1.1OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUXC			
1.23E-10	28.0%	XSW1.1OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUYA			
1.23E-10	28.1%	XSW1.1OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUYC			
1.17E-10	28.3%	DCC	3614VRCPSV---CCF	7316EFNTK1:NZ-NO	5290RC-RF1---ELO		
1.13E-10	28.4%	END1.3 ORT3	3732SMHHS-2-C-OS				
1.10E-10	28.5%	XSW1.1OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUXA			
1.10E-10	28.7%	XSW1.1OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUXC			
1.10E-10	28.8%	XSW1.1OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUYA			
1.10E-10	28.9%	XSW1.1OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUYC			
1.04E-10	29.0%	XSW1.17316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUXA			
1.04E-10	29.2%	XSW1.17316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUXC			
1.04E-10	29.3%	XSW1.17316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUYA			
1.04E-10	29.4%	XSW1.17316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUYC			
1.03E-10	29.5%	LOHS4.3	ORT1	3471VYDPV12--CCF			
9.93E-11	29.6%	LOHS3.1	3614VRCPSV-1-CCF	OP-EVS3	5290RC-RF1---ELO		
9.89E-11	29.7%	END1.1 ORSB2	5522EC-8:4216EOS				

9.83E-11	29.9%	LOCA2.2	RCW.PUMP.CONF1	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.0%	LOCA2.2	RCW.PUMP.CONF2	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.1%	LOCA2.2	RCW.PUMP.CONF3	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.2%	LOCA2.2	RCW.PUMP.CONF4	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.3%	LOCA2.2	RCW.PUMP.CONF5	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.4%	LOCA2.2	RCW.PUMP.CONF6	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.5%	LOCA2.2	RCW.PUMP.CONF7	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.83E-11	30.6%	LOCA2.2	RCW.PUMP.CONF8	SUMMER.MODE	PUMP.RUN.SUMMER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
9.26E-11	30.8%	XSW1.1529009QBUD--%DUD	529009QBUC--%DUC	3332TE70-20/1CCF	7316EFNTK1:NZ-NO		
9.15E-11	30.9%	XSW1.1LOOP1.BREAK	3334V-PPRV3--ALO	7316RU-RD200--FC	3432SW-ZS75-O-FC	OPCTLFEEDP1	
9.15E-11	31.0%	XSW1.1LOOP1.BREAK	3334V-PPRV4--ALO	7316RU-RD200--FC	3432SW-ZS75-O-FC	OPCTLFEEDP1	
9.15E-11	31.1%	XSW1.1LOOP2.BREAK	3334V-PPRV1--ALO	7316RU-RD200--FC	3432SW-ZS75-O-FC	OPCTLFEEDP1	
9.15E-11	31.2%	XSW1.1LOOP2.BREAK	3334V-PPRV2--ALO	7316RU-RD200--FC	3432SW-ZS75-O-FC	OPCTLFEEDP1	
8.75E-11	31.3%	XSW1.1OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUXA			
8.75E-11	31.4%	XSW1.1OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUXC			
8.75E-11	31.5%	XSW1.1OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUYA			
8.75E-11	31.6%	XSW1.1OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUYC			

10.4.9 LRF at power - time 20 years

Cutset Report

LRF-AP = 1.11E-07 (Probability)

Probability	%	Inputs...		
2.92E-09	2.6%	END1.1 ORSB2	3730INVPS1---VLO	
1.93E-09	4.4%	END1.3 OCC	3432SW-ZS75-O-FC	
1.78E-09	6.0%	END1.1 ORSB2	3411TD-PT-1--CCF	
1.65E-09	7.5%	END1.3 ORT3	3730INVPS1---VLO	
1.14E-09	8.5%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXA
1.14E-09	9.5%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUXC
1.14E-09	10.5%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYA
1.14E-09	11.6%	XSW1.1OP-EVS4	OP-DOUS2	CABLE.AGING.BUYC
1.00E-09	12.5%	END1.3 ORT3	3411TD-PT-1--CCF	
9.49E-10	13.3%	END1.3 OCC	OP-DOUS2	
6.07E-10	13.9%	END1.1 ORSB2	MCAS.ON.MANUAL	
5.88E-10	14.4%	LOHS4.3	ORT1	SDS2C.CABLE
5.80E-10	14.9%	END1.1 ORSB2	3730INVPS1---VSP	
5.27E-10	15.4%	END1.3 OCC	3432MS-89B3---OP	
4.29E-10	15.8%	XSW1.17316RU-RD200--FC	5521EX-TSW1A--FT	CABLE.AGING.BUYA
4.29E-10	16.2%	XSW1.17316RU-RD200--FC	5521EX-TSW1C--FT	CABLE.AGING.BUYC
3.51E-10	16.5%	XSW1.1OBPC3	OP-DOUS3	
3.42E-10	16.8%	END1.3 ORT3	MCAS.ON.MANUAL	
3.36E-10	17.1%	XSW1.17316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUXA

3.36E-10	17.4%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUXC	
3.36E-10	17.7%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUYA	
3.36E-10	18.0%	XSW1.1	7316RU-RD200--FC	3432SW-ZS75-O-FC	CABLE.AGING.BUYC	
3.27E-10	18.3%	END1.3 ORT3	3730INVPS1---VSP			
3.12E-10	18.6%	XSW1.1	LOOP1.BREAK OP-EVS4	OP-DOUS2	3334V-PPRV3--ALO	OPCTLFEEDP1
3.12E-10	18.9%	XSW1.1	LOOP1.BREAK OP-EVS4	OP-DOUS2	3334V-PPRV4--ALO	OPCTLFEEDP1
3.12E-10	19.1%	XSW1.1	LOOP2.BREAK OP-EVS4	OP-DOUS2	3334V-PPRV1--ALO	OPCTLFEEDP1
3.12E-10	19.4%	XSW1.1	LOOP2.BREAK OP-EVS4	OP-DOUS2	3334V-PPRV2--ALO	OPCTLFEEDP1
3.10E-10	19.7%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO	
2.97E-10	20.0%	XSW1.1	OP-EVS3	5521EX-TSW1A--FT	CABLE.AGING.BUYA	
2.97E-10	20.2%	XSW1.1	OP-EVS3	5521EX-TSW1C--FT	CABLE.AGING.BUYC	
2.55E-10	20.5%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316RU-RD200--FC
2.51E-10	20.7%	XSW1.1	7316EFNTK1:NZ-NO	5521EX-TSW1A--FT	CABLE.AGING.BUYA	
2.51E-10	20.9%	XSW1.1	7316EFNTK1:NZ-NO	5521EX-TSW1C--FT	CABLE.AGING.BUYC	
2.45E-10	21.1%	END1.1 ORSB2	5512EX-TSW2A--OC			
2.44E-10	21.4%	END1.2 ORSB	3730INVPS1---VLO			
2.36E-10	21.6%	END1.1 ORSB2	3732MBCCA----CCF			
2.33E-10	21.8%	XSW1.1	OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUXA	
2.33E-10	22.0%	XSW1.1	OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUXC	
2.33E-10	22.2%	XSW1.1	OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUYA	
2.33E-10	22.4%	XSW1.1	OP-EVS3	3432SW-ZS75-O-FC	CABLE.AGING.BUYC	
2.20E-10	22.6%	XSW1.1	CONT.BOLT	CABLE.AGING.BUXA		
2.20E-10	22.8%	XSW1.1	CONT.BOLT	CABLE.AGING.BUXC		
2.20E-10	23.0%	XSW1.1	CONT.BOLT	CABLE.AGING.BUYA		
2.20E-10	23.2%	XSW1.1	CONT.BOLT	CABLE.AGING.BUYC		
2.20E-10	23.4%	LORA1.1	SDS2C.CABLE	SDS1C.CABLE		

2.15E-10	23.6%	LOHS3.2	3614VRCPSV-1-CCF	OP-EVS3	5290RC-RF1---ELO	
2.09E-10	23.8%	DCC	3614VRCPSV---CCF	7316RU-RD200--FC	5290RC-RF1---ELO	
2.08E-10	24.0%	XSW1.1	OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUXA	
2.08E-10	24.2%	XSW1.1	OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUXC	
2.08E-10	24.3%	XSW1.1	OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUYA	
2.08E-10	24.5%	XSW1.1	OP-MKUPCV2	OP-DOUS2	CABLE.AGING.BUYC	
2.01E-10	24.7%	END1.1	ORSB2	3732SMHHS-2-C-OS		
1.97E-10	24.9%	XSW1.1	7316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUXA	
1.97E-10	25.1%	XSW1.1	7316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUXC	
1.97E-10	25.2%	XSW1.1	7316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUYA	
1.97E-10	25.4%	XSW1.1	7316EFNTK1:NZ-NO	3432SW-ZS75-O-FC	CABLE.AGING.BUYC	
1.82E-10	25.6%	LOHS3.2	3614VRCPSV-1-CCF	7316EFNTK1:NZ-NO	5290RC-RF1---ELO	
1.74E-10	25.7%	XSW1.1	CONT.CABLE	CABLE.AGING.BUXA		
1.74E-10	25.9%	XSW1.1	CONT.CABLE	CABLE.AGING.BUXC		
1.74E-10	26.1%	XSW1.1	CONT.CABLE	CABLE.AGING.BUYA		
1.74E-10	26.2%	XSW1.1	CONT.CABLE	CABLE.AGING.BUYC		
1.65E-10	26.4%	XSW1.1	OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUXA	
1.65E-10	26.5%	XSW1.1	OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUXC	
1.65E-10	26.7%	XSW1.1	OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUYA	
1.65E-10	26.8%	XSW1.1	OP-DOUS2	7316RU-RD200--FC	CABLE.AGING.BUYC	
1.58E-10	26.9%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TE70-20/1CCF	7316RU-RD200--FC
1.50E-10	27.1%	LOHS3.1	3614VRCPSV-1-CCF	7316RU-RD200--FC	5290RC-RF1---ELO	
1.49E-10	27.2%	XSW1.1	529009QBUD--%DUD	529009QBUC--%DUC	3332TT70-20/1CCF	7316EFNTK1:NZ-NO
1.48E-10	27.3%	END1.2	ORSB	3411TD-PT-1--CCF		
1.48E-10	27.5%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1B--FT	5521EX-TSW1A--FT
1.48E-10	27.6%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1C--FT	5521EX-TSW1A--FT

1.48E-10	27.7%	LOHS3.2	3614VRCPSV-1-CCF	7316RU-RD200--FC	5521EX-TSW1C--FT	5521EX-TSW1B--FT	
1.44E-10	27.9%	DCC	OP-EVS3	3614VRCPSV---CCF	5290RC-RF1---ELO		
1.44E-10	28.0%	LOCA2.2	SDS2C.CABLE	SDS1C.CABLE			
1.42E-10	28.1%	XSW1.17314PV17/18ILCCF	CABLE.AGING.BUXA				
1.42E-10	28.3%	XSW1.17314PV17/18ILCCF	CABLE.AGING.BUXC				
1.42E-10	28.4%	XSW1.17314PV17/18ILCCF	CABLE.AGING.BUYA				
1.42E-10	28.5%	XSW1.17314PV17/18ILCCF	CABLE.AGING.BUYC				
1.42E-10	28.6%	XSW1.17314PV21/22ILCCF	CABLE.AGING.BUXA				
1.42E-10	28.8%	XSW1.17314PV21/22ILCCF	CABLE.AGING.BUXC				
1.42E-10	28.9%	XSW1.17314PV21/22ILCCF	CABLE.AGING.BUYA				
1.42E-10	29.0%	XSW1.17314PV21/22ILCCF	CABLE.AGING.BUYC				
1.39E-10	29.2%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.3%	LOCA2.2	RCW.PUMP.CONF1	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.4%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.5%	LOCA2.2	RCW.PUMP.CONF2	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.7%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.8%	LOCA2.2	RCW.PUMP.CONF3	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	29.9%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	30.0%	LOCA2.2	RCW.PUMP.CONF4	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF
1.39E-10	30.2%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC	7111PV78#1/2-CCF

1.39E-10	30.3%	LOCA2.2	RCW.PUMP.CONF5	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	30.4%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	30.5%	LOCA2.2	RCW.PUMP.CONF6	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	30.7%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	30.8%	LOCA2.2	RCW.PUMP.CONF7	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	30.9%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.RUN.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.39E-10	31.0%	LOCA2.2	RCW.PUMP.CONF8	WINTER.MODEPUMP.STBY.WINTER	7111-FSDB&WSF-FF	7316RU-RD200--FC 7111PV78#1/2-CCF
1.38E-10	31.2%	END1.3 ORT3	5512EX-TSW2A--OC			
1.33E-10	31.3%	END1.3 ORT3	3732MBCCA----CCF			

10.4.10 LRF at shutdown - time 0 year

Cutset Report

LRF-SD = 8.94E-08 (Probability)

Probability	%	Inputs...					
2.37E-09	2.6%	XSW1.2	3614VRCPSV---CCF	7316RU-RD200--FC			
1.39E-09	4.2%	XSW1.2	3614VRCPSV---CCF	7316EFNTK1:NZ-NO			
4.31E-10	4.7%	XSW1.2	3614VRCPSV---CCF	3411RU-RD4----FC			
3.41E-10	5.1%	XSW1.2	3614VRCPSV---CCF	3411PI-MKCV-%BRU			
2.98E-10	5.4%	XSW1.2	OP-EVS1	3614VRCPSV---CCF			
2.98E-10	5.7%	XSW1.2	OP-MKUPCV1	3614VRCPSV---CCF			
2.80E-10	6.0%	XSW1.2	3432V-SSV-DE-CCF	7316RU-RD200--FC			
2.71E-10	6.3%	XSW1.2	3614VRCPSV---CCF	7314ATEV20----OP			
2.71E-10	6.7%	XSW1.2	3614VRCPSV---CCF	7314ATEV21----OP			
2.42E-10	6.9%	XSW1.2	DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316RU-RD200--FC	
2.40E-10	7.2%	SDLORA1.1	8332ERCRE1GJ-CCF	8232ERCRE1DF-CCF			
2.37E-10	7.5%	XSW1.3	3614VRCPSV---CCF	7316RU-RD200--FC			
1.64E-10	7.6%	XSW1.2	3432V-SSV-DE-CCF	7316EFNTK1:NZ-NO			
1.50E-10	7.8%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
1.50E-10	8.0%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
1.50E-10	8.1%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
1.42E-10	8.3%	XSW1.2	DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316EFNTK1:NZ-NO	
1.39E-10	8.5%	XSW1.3	3614VRCPSV---CCF	7316EFNTK1:NZ-NO			
1.24E-10	8.6%	SDLORA1.1	8332AMCAF1---CCF	8232ERCRE1DF-CCF			

1.24E-10	8.7%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1---CCF			
1.10E-10	8.9%	SDLORA1.1	8332ERCRE1GJ-CCF	3173MXSSAM---CCF			
1.03E-10	9.0%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.1%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.2%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.3%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.00E-10	9.4%	SDLORA1.1	8331AU2AFGJ3-CCF	8232ERCRE1DF-CCF			
9.29E-11	9.5%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316RU-RD200--FC		
8.94E-11	9.6%	XSW1.22131-PARS-OP	3614VRCPSV---CCF				
8.80E-11	9.7%	XSW1.23614VRCPSV---CCF	7316EFORO300--NO				
7.77E-11	9.8%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
7.77E-11	9.9%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
7.77E-11	10.0%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.44E-11	10.1%	SDLORA1.1	8332AMCAF1---CCF	8232AMCAF1---CCF			
6.30E-11	10.1%	XSW1.2OP-EVS2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1	
6.30E-11	10.2%	XSW1.2OP-MKUPCV2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1	
6.26E-11	10.3%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
6.26E-11	10.3%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
6.26E-11	10.4%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.18E-11	10.5%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	8234TD-FT1D---HD	
6.18E-11	10.6%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	8234TD-FT2D---HD	
6.18E-11	10.6%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	8234TD-FT3D---HD	
6.18E-11	10.7%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	8234TD-FT4D---HD	
5.89E-11	10.8%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT1D---HD
5.89E-11	10.8%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT2D---HD
5.89E-11	10.9%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT3D---HD

5.89E-11	11.0%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8234TD-FT4D---HD	
5.89E-11	11.0%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8234TD-FT1D---HD	
5.89E-11	11.1%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8234TD-FT2D---HD	
5.89E-11	11.2%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8234TD-FT3D---HD	
5.89E-11	11.2%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8234TD-FT4D---HD	
5.80E-11	11.3%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-D.UNSAFE	
5.80E-11	11.4%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-FS1DO	PDC-D.UNSAFE	
5.80E-11	11.4%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8220COPPDC-DS1DO		
5.80E-11	11.5%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8220COPPDC-FS1DO		
5.80E-11	11.5%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-F.UNSAFE	
5.80E-11	11.6%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8220COPPDC-DS1DO		
5.70E-11	11.7%	SDLORA1.1	8332AMCAF1---CCF	3173MXSSAM---CCF			
5.44E-11	11.7%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316EFNTK1:NZ-NO		
5.39E-11	11.8%	XSW1.23614VRCPSV---CCF	7314V-AV24--%BOE				
5.39E-11	11.9%	XSW1.23614VRCPSV---CCF	7314V-AV25--%BOE				
5.33E-11	11.9%	SDLORA1.1	COND.LOOP1.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.0%	SDLORA1.1	COND.LOOP2.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.0%	SDLORA1.1	COND.LOOP3.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.1%	SDLORA1.1	COND.LOOP4.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.19E-11	12.2%	SDLORA1.1	8331AU2AFGJ3-CCF	8232AMCAF1---CCF			
5.11E-11	12.2%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1DF-CCF			
5.11E-11	12.3%	XSW1.23432V-SSV-DE-CCF	3411RU-RD4----FC				
4.73E-11	12.3%	XSW1.2OP-EVS2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
4.73E-11	12.4%	XSW1.2OP-MKUPCV2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
4.64E-11	12.4%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V201V203-CCF	7316RU-RD200--FC		
4.64E-11	12.5%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V202V204-CCF	7316RU-RD200--FC		

4.60E-11	12.5%	SDLORA1.1	8331AU2AFGJ3-CCF	3173MXSSAM---CCF			
4.31E-11	12.6%	XSW1.33614VRCPSV---CCF	3411RU-RD4----FC				
4.30E-11	12.6%	SDLORA1.1	COND.LOOP1.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	12.7%	SDLORA1.1	COND.LOOP2.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	12.7%	SDLORA1.1	COND.LOOP3.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	12.8%	SDLORA1.1	COND.LOOP4.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.16E-11	12.8%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-D.UNSAFE	
4.16E-11	12.9%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1F---LO	PDC-D.UNSAFE	
4.16E-11	12.9%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232ERCRE1D---LO		
4.16E-11	13.0%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232ERCRE1F---LO		
4.16E-11	13.0%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-F.UNSAFE	
4.16E-11	13.0%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8232ERCRE1D---LO		
4.09E-11	13.1%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-D.UNSAFE	
4.09E-11	13.1%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6F-S-LO	PDC-D.UNSAFE	
4.09E-11	13.2%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232AMSAF6D-S-LO		
4.09E-11	13.2%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232AMSAF6F-S-LO		
4.09E-11	13.3%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-F.UNSAFE	
4.09E-11	13.3%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8232AMSAF6D-S-LO		
4.04E-11	13.4%	XSW1.23432V-SSV-DE-CCF	3411PI-MKCV-%BRU				
3.94E-11	13.4%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-F.UNSAFE
3.94E-11	13.5%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-F.UNSAFE
3.94E-11	13.5%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-F.UNSAFE
3.94E-11	13.5%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	PDC-F.UNSAFE
3.94E-11	13.6%	SDLORA1.1	COND.LOOP1.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-D.UNSAFE
3.94E-11	13.6%	SDLORA1.1	COND.LOOP2.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-D.UNSAFE
3.94E-11	13.7%	SDLORA1.1	COND.LOOP3.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-D.UNSAFE

3.94E-11	13.7%	SDLORA1.1	COND.LOOP4.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	PDC-D.UNSAFE
3.76E-11	13.8%	XSW1.2OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	7316RU-RD200--FC	OMKECC-SD-D1
3.53E-11	13.8%	XSW1.2OP-EVS1	3432V-SSV-DE-CCF				

10.4.11 LRF at shutdown - time 10 years

Cutset Report

LRF-SD = 9.03E-08 (Probability)

Probability	%	Inputs...					
2.48E-09	2.8%	XSW1.23614VRCPSV---CCF	7316RU-RD200--FC				
1.45E-09	4.4%	XSW1.23614VRCPSV---CCF	7316EFNTK1:NZ-NO				
4.53E-10	4.9%	XSW1.23614VRCPSV---CCF	3411RU-RD4----FC				
3.58E-10	5.3%	XSW1.23614VRCPSV---CCF	3411PI-MKCV-%BRU				
3.13E-10	5.6%	XSW1.2OP-EVS1	3614VRCPSV---CCF				
3.13E-10	6.0%	XSW1.2OP-MKUPCV1	3614VRCPSV---CCF				
3.01E-10	6.3%	XSW1.23432V-SSV-DE-CCF	7316RU-RD200--FC				
2.84E-10	6.6%	XSW1.23614VRCPSV---CCF	7314ATEV20----OP				
2.84E-10	6.9%	XSW1.23614VRCPSV---CCF	7314ATEV21----OP				
2.48E-10	7.2%	XSW1.33614VRCPSV---CCF	7316RU-RD200--FC				
2.42E-10	7.5%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316RU-RD200--FC		
2.40E-10	7.7%	SDLORA1.1	8332ERCRE1GJ-CCF	8232ERCRE1DF-CCF			
1.76E-10	7.9%	XSW1.23432V-SSV-DE-CCF	7316EFNTK1:NZ-NO				
1.50E-10	8.1%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
1.50E-10	8.3%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
1.50E-10	8.4%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
1.45E-10	8.6%	XSW1.33614VRCPSV---CCF	7316EFNTK1:NZ-NO				
1.42E-10	8.7%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316EFNTK1:NZ-NO		
1.24E-10	8.9%	SDLORA1.1	8332AMCAF1---CCF	8232ERCRE1DF-CCF			

1.24E-10	9.0%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1---CCF			
1.10E-10	9.1%	SDLORA1.1	8332ERCRE1GJ-CCF	3173MXSSAM---CCF			
1.03E-10	9.2%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.4%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.5%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.6%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.00E-10	9.7%	SDLORA1.1	8331AU2AFGJ3-CCF	8232ERCRE1DF-CCF			
9.75E-11	9.8%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316RU-RD200--FC		
9.38E-11	9.9%	XSW1.22131-PARS-OP	3614VRCPSV---CCF				
9.23E-11	10.0%	XSW1.23614VRCPSV---CCF	7316EFORO300--NO				
7.77E-11	10.1%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
7.77E-11	10.2%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
7.77E-11	10.3%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.44E-11	10.3%	SDLORA1.1	8332AMCAF1---CCF	8232AMCAF1---CCF			
6.30E-11	10.4%	XSW1.2OP-EVS2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1	
6.30E-11	10.5%	XSW1.2OP-MKUPCV2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1	
6.26E-11	10.6%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
6.26E-11	10.6%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
6.26E-11	10.7%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.18E-11	10.8%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	8234TD-FT1D---HD	
6.18E-11	10.8%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	8234TD-FT2D---HD	
6.18E-11	10.9%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	8234TD-FT3D---HD	
6.18E-11	11.0%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	8234TD-FT4D---HD	
5.89E-11	11.0%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT1D---HD
5.89E-11	11.1%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT2D---HD
5.89E-11	11.2%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT3D---HD

5.89E-11	11.2%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT4D---HD
5.89E-11	11.3%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT1D---HD
5.89E-11	11.4%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT2D---HD
5.89E-11	11.4%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT3D---HD
5.89E-11	11.5%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT4D---HD
5.80E-11	11.6%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-D.UNSAFE	
5.80E-11	11.6%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-FS1DO	PDC-D.UNSAFE	
5.80E-11	11.7%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8220COPPDC-DS1DO	
5.80E-11	11.7%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8220COPPDC-FS1DO	
5.80E-11	11.8%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-F.UNSAFE	
5.80E-11	11.9%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8220COPPDC-DS1DO	
5.71E-11	11.9%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316EFNTK1:NZ-NO		
5.70E-11	12.0%	SDLORA1.1	8332AMCAF1---CCF	3173MXSSAM---CCF			
5.65E-11	12.1%	XSW1.23614VRCPSV---CCF	7314V-AV24--%BOE				
5.65E-11	12.1%	XSW1.23614VRCPSV---CCF	7314V-AV25--%BOE				
5.48E-11	12.2%	XSW1.23432V-SSV-DE-CCF	3411RU-RD4----FC				
5.33E-11	12.2%	SDLORA1.1	COND.LOOP1.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.3%	SDLORA1.1	COND.LOOP2.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.4%	SDLORA1.1	COND.LOOP3.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.4%	SDLORA1.1	COND.LOOP4.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.19E-11	12.5%	SDLORA1.1	8331AU2AFGJ3-CCF	8232AMCAF1---CCF			
5.11E-11	12.5%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1DF-CCF			
4.88E-11	12.6%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V201V203-CCF	7316RU-RD200--FC		
4.88E-11	12.6%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V202V204-CCF	7316RU-RD200--FC		
4.73E-11	12.7%	XSW1.2OP-EVS2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
4.73E-11	12.7%	XSW1.2OP-MKUPCV2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1

4.60E-11	12.8%	SDLORA1.1	8331AU2AFGJ3-CCF	3173MXSSAM---CCF			
4.53E-11	12.9%	XSW1.33614VRCPSV---CCF	3411RU-RD4----FC				
4.33E-11	12.9%	XSW1.23432V-SSV-DE-CCF	3411PI-MKCV-%BRU				
4.30E-11	12.9%	SDLORA1.1	COND.LOOP1.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.0%	SDLORA1.1	COND.LOOP2.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.0%	SDLORA1.1	COND.LOOP3.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.1%	SDLORA1.1	COND.LOOP4.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.16E-11	13.1%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-D.UNSAFE	
4.16E-11	13.2%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1F---LO	PDC-D.UNSAFE	
4.16E-11	13.2%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8232ERCRE1D---LO	
4.16E-11	13.3%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8232ERCRE1F---LO	
4.16E-11	13.3%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-F.UNSAFE	
4.16E-11	13.4%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8232ERCRE1D---LO	
4.09E-11	13.4%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-D.UNSAFE	
4.09E-11	13.5%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6F-S-LO	PDC-D.UNSAFE	
4.09E-11	13.5%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8232AMSAF6D-S-LO	
4.09E-11	13.5%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8232AMSAF6F-S-LO	
4.09E-11	13.6%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-F.UNSAFE	
4.09E-11	13.6%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8232AMSAF6D-S-LO	
3.94E-11	13.7%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-F.UNSAFE
3.94E-11	13.7%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-F.UNSAFE
3.94E-11	13.8%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-F.UNSAFE
3.94E-11	13.8%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	PDC-F.UNSAFE
3.94E-11	13.9%	SDLORA1.1	COND.LOOP1.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-D.UNSAFE
3.94E-11	13.9%	SDLORA1.1	COND.LOOP2.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-D.UNSAFE
3.94E-11	13.9%	SDLORA1.1	COND.LOOP3.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-D.UNSAFE

3.94E-11	14.0%	SDLORA1.1	COND.LOOP4.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	PDC-D.UNSAFE
3.78E-11	14.0%	XSW1.2OP-EVS1	3432V-SSV-DE-CCF				
3.78E-11	14.1%	XSW1.2OP-MKUPCV1	3432V-SSV-DE-CCF				

10.4.12 LRF at shutdown - time 20 years

Cutset Report

LRF-SD = 9.12E-08 (Probability)

Probability	%	Inputs...					
2.60E-09	2.9%	XSW1.23614VRCPSV---CCF	7316RU-RD200--FC				
1.52E-09	4.5%	XSW1.23614VRCPSV---CCF	7316EFNTK1:NZ-NO				
4.74E-10	5.0%	XSW1.23614VRCPSV---CCF	3411RU-RD4----FC				
3.75E-10	5.5%	XSW1.23614VRCPSV---CCF	3411PI-MKCV-%BRU				
3.27E-10	5.8%	XSW1.2OP-EVS1	3614VRCPSV---CCF				
3.27E-10	6.2%	XSW1.2OP-MKUPCV1	3614VRCPSV---CCF				
3.23E-10	6.5%	XSW1.23432V-SSV-DE-CCF	7316RU-RD200--FC				
2.98E-10	6.8%	XSW1.23614VRCPSV---CCF	7314ATEV20----OP				
2.98E-10	7.2%	XSW1.23614VRCPSV---CCF	7314ATEV21----OP				
2.60E-10	7.5%	XSW1.33614VRCPSV---CCF	7316RU-RD200--FC				
2.42E-10	7.7%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316RU-RD200--FC		
2.40E-10	8.0%	SDLORA1.1	8332ERCRE1GJ-CCF	8232ERCRE1DF-CCF			
1.89E-10	8.2%	XSW1.23432V-SSV-DE-CCF	7316EFNTK1:NZ-NO				
1.52E-10	8.4%	XSW1.33614VRCPSV---CCF	7316EFNTK1:NZ-NO				
1.50E-10	8.5%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
1.50E-10	8.7%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
1.50E-10	8.9%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
1.42E-10	9.0%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	3461EFORO1----LO	7316EFNTK1:NZ-NO		
1.24E-10	9.1%	SDLORA1.1	8332AMCAF1---CCF	8232ERCRE1DF-CCF			

1.24E-10	9.3%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1---CCF			
1.10E-10	9.4%	SDLORA1.1	8332ERCRE1GJ-CCF	3173MXSSAM---CCF			
1.03E-10	9.5%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.6%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.7%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.03E-10	9.9%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT-D--CCF		
1.02E-10	10.0%	XSW1.2	DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316RU-RD200--FC	
1.00E-10	10.1%	SDLORA1.1	8331AU2AFGJ3-CCF	8232ERCRE1DF-CCF			
9.82E-11	10.2%	XSW1.2	2131-PARS-OP	3614VRCPSV---CCF			
9.67E-11	10.3%	XSW1.2	3614VRCPSV---CCF	7316EFORO300--NO			
7.77E-11	10.4%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
7.77E-11	10.5%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8332AMCAF1---CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
7.77E-11	10.5%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8332AMCAF1---CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.44E-11	10.6%	SDLORA1.1	8332AMCAF1---CCF	8232AMCAF1---CCF			
6.30E-11	10.7%	XSW1.2	OP-EVS2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1
6.30E-11	10.8%	XSW1.2	OP-MKUPCV2	OP-ECCSD	OMKECC-DI	OMKUP-SD	OMKECC-DI-D1
6.26E-11	10.8%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-D.UNSAFE
6.26E-11	10.9%	SDLORA1.1	8220COPPDC-ES1GF	8220COPPDC-FS1GF	8331AU2AFGJ3-CCF	PDC-E.UNSAFE	PDC-F.UNSAFE
6.26E-11	11.0%	SDLORA1.1	8220COPPDC-FS1GF	8220COPPDC-DS1GF	8331AU2AFGJ3-CCF	PDC-F.UNSAFE	PDC-D.UNSAFE
6.18E-11	11.0%	SDLORA1.1	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	8234TD-FT1D---HD	
6.18E-11	11.1%	SDLORA1.1	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	8234TD-FT2D---HD	
6.18E-11	11.2%	SDLORA1.1	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	8234TD-FT3D---HD	
6.18E-11	11.2%	SDLORA1.1	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	8234TD-FT4D---HD	
5.98E-11	11.3%	XSW1.2	DA.PATH.UNAV	RFT.PATH.UNAV	3461VGCPV7---CFC	7316EFNTK1:NZ-NO	
5.92E-11	11.4%	XSW1.2	3614VRCPSV---CCF	7314V-AV24--%BOE			
5.92E-11	11.4%	XSW1.2	3614VRCPSV---CCF	7314V-AV25--%BOE			

5.89E-11	11.5%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT1D---HD
5.89E-11	11.6%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT2D---HD
5.89E-11	11.6%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT3D---HD
5.89E-11	11.7%	SDLORA1.1	8220COPPDC-ES1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8234TD-FT4D---HD
5.89E-11	11.8%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT1D---HD
5.89E-11	11.8%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT2D---HD
5.89E-11	11.9%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT3D---HD
5.89E-11	11.9%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8234TD-FT4D---HD
5.88E-11	12.0%	XSW1.23432V-SSV-DE-CCF	3411RU-RD4----FC				
5.80E-11	12.1%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-D.UNSAFE	
5.80E-11	12.1%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8220COPPDC-FS1DO	PDC-D.UNSAFE	
5.80E-11	12.2%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8220COPPDC-DS1DO	
5.80E-11	12.3%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE	8220COPPDC-FS1DO	
5.80E-11	12.3%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8220COPPDC-ES1DO	PDC-F.UNSAFE	
5.80E-11	12.4%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE	8220COPPDC-DS1DO	
5.70E-11	12.5%	SDLORA1.1	8332AMCAF1---CCF	3173MXSSAM---CCF			
5.38E-11	12.5%	XSW1.2EAL.MAN.CLS	-3432L--PM1OVERSM	5521EX-TSW1A--FT	CABLE.AGING.BUYA		
5.33E-11	12.6%	SDLORA1.1	COND.LOOP1.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.6%	SDLORA1.1	COND.LOOP2.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.7%	SDLORA1.1	COND.LOOP3.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.33E-11	12.7%	SDLORA1.1	COND.LOOP4.HTLF1	8332AMCAF1---CCF	8234TD-FT-D--CCF		
5.19E-11	12.8%	SDLORA1.1	8331AU2AFGJ3-CCF	8232AMCAF1---CCF			
5.11E-11	12.9%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V201V203-CCF	7316RU-RD200--FC		
5.11E-11	12.9%	XSW1.2DA.PATH.UNAV	RFT.PATH.UNAV	4113V202V204-CCF	7316RU-RD200--FC		
5.11E-11	13.0%	SDLORA1.1	8332ERCRE1GJ-CCF	8232AMCAF1DF-CCF			
4.74E-11	13.0%	XSW1.33614VRCPSV---CCF	3411RU-RD4----FC				

4.73E-11	13.1%	XSW1.2OP-EVS2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
4.73E-11	13.1%	XSW1.2OP-MKUPCV2	OP-ECCSD	OMKUP-SD	OMKECC-SD	-ECC.DIRECT.PROB	OMKECC-SD-D1
4.65E-11	13.2%	XSW1.23432V-SSV-DE-CCF	3411PI-MKCV-%BRU				
4.60E-11	13.2%	SDLORA1.1	8331AU2AFGJ3-CCF	3173MXSSAM---CCF			
4.30E-11	13.3%	SDLORA1.1	COND.LOOP1.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.3%	SDLORA1.1	COND.LOOP2.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.4%	SDLORA1.1	COND.LOOP3.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.30E-11	13.4%	SDLORA1.1	COND.LOOP4.HTLF1	8331AU2AFGJ3-CCF	8234TD-FT-D--CCF		
4.16E-11	13.5%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-D.UNSAFE	
4.16E-11	13.5%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232ERCRE1F---LO	PDC-D.UNSAFE	
4.16E-11	13.6%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232ERCRE1D---LO		
4.16E-11	13.6%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232ERCRE1F---LO		
4.16E-11	13.6%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232ERCRE1E---LO	PDC-F.UNSAFE	
4.16E-11	13.7%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8232ERCRE1D---LO		
4.09E-11	13.7%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-D.UNSAFE	
4.09E-11	13.8%	SDLORA1.1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8232AMSAF6F-S-LO	PDC-D.UNSAFE	
4.09E-11	13.8%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232AMSAF6D-S-LO		
4.09E-11	13.9%	SDLORA1.1	8220COPPDC-ES1GF	8332ERCRE1GJ-CCF	PDC-E.UNSAFE8232AMSAF6F-S-LO		
4.09E-11	13.9%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	8232AMSAF6E-S-LO	PDC-F.UNSAFE	
4.09E-11	14.0%	SDLORA1.1	8220COPPDC-FS1GF	8332ERCRE1GJ-CCF	PDC-F.UNSAFE8232AMSAF6D-S-LO		
4.06E-11	14.0%	XSW1.2OP-EVS1	3432V-SSV-DE-CCF				
4.06E-11	14.0%	XSW1.2OP-MKUPCV1	3432V-SSV-DE-CCF				
3.94E-11	14.1%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP1.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-F.UNSAFE
3.94E-11	14.1%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP2.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-F.UNSAFE
3.94E-11	14.2%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP3.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-F.UNSAFE
3.94E-11	14.2%	SDLORA1.1	8220COPPDC-FS1GF	COND.LOOP4.HTLF1	8332ERCRE1GJ-CCF	8234TD-FT4E---HD	PDC-F.UNSAFE

3.94E-11	14.3%	SDLORA1.1	COND.LOOP1.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT1E---HD	PDC-D.UNSAFE
3.94E-11	14.3%	SDLORA1.1	COND.LOOP2.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT2E---HD	PDC-D.UNSAFE
3.94E-11	14.3%	SDLORA1.1	COND.LOOP3.HTLF1	8220COPPDC-DS1GF	8332ERCRE1GJ-CCF	8234TD-FT3E---HD	PDC-D.UNSAFE