Summary of Environmental Fatigue Analysis Results for the US-APWR Reactor Coolant Loop Branch Piping

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Abstract

This report provides the Environmental Fatigue analyses results of Reactor Coolant Loop (RCL) Branch Piping in support of the US-APWR DCD Review process and complies with USNRC Regulator Guide 1.207 (Reference 2).

Based on the results summarized in this report, it is concluded that the US-APWR RCL Branch Piping satisfies the recommendations for environmental fatigue contained in USNRC Regulatory Guide 1.207.

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List of Acronyms

The following list defines the acronyms used in this document.

ANL	Argonne National Laboratory
ASME	American Society of Mechanical Engineers
DCD	Design Control Document
DO	Dissolved oxygen
DVI	Direct Vessel Injection
JSME	Japan Society of Mechanical Engineering
LWR	Light Water Reactor
PZR	Pressurizer
PWR	Pressurized Water Reactor
RCL	Reactor Coolant Loop
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHRS	Residual Heat Removal System
R.G	Regulator Guide
RT	Room Temperature
RV	Reactor Vessel
SIS	Safety Injection System
SG	Steam Generator
USNRC	U.S. Nuclear Regulatory Commission
CVCS	Chemical and Volume Control System

1.0 INTRODUCTION

This report summarizes environmental fatigue analysis for class 1 branch piping in Section III of the ASME Code (Reference 1).It has been prepared in support of the US-APWR DCD Review process and complies with USNRC Regulator Guide 1.207 (Reference 2),.

The pressure boundary of the class 1 branch piping which are in contact with the primary coolant fluid are required to be evaluated for fatigue incorporating the life reduction of the metal components due to the effect of the light-water reactor (LWR) environment.

Environmental fatigue analysis has been performed in accordance with the Regulatory Guide 1.207. The methodology includes calculation of the usage factor in air based on ASME Code analysis procedure with the new fatigue design curve developed from the Argonne National Laboratory (ANL) model, and then employing the environmental correction factor (F_{en}) as described in NUREG/CR-6909 (References 3).

This analysis report provides the environmental fatigue analysis results for US-APWR Class 1 branch piping. Fatigue analyses in air based on ASME Code Section III had been previously submitted to the USNRC.

The environmental fatigue analyses for other Class 1 components of the US-APWR are documented in a separate report (References 8).

2.0 SUMMARY OF RESULTS AND CONCLUSION

The most limiting results for environmental fatigue for each pipe segment are listed in Table 2-1.

Based on the results summarized in this report, it is concluded that the Class 1 branch piping in Section III of the ASME Code for US-APWR satisfies the recommendations for environmental fatigue contained in USNRC Regulatory Guide 1.207.

Table 2.0-1 Summary of Environmental Fatigue Evaluation for Class 1 Branch Piping (1/2)

Piping	Material	Usage Factor in air based on ASME[1)]	NUREG (air) U[2)]	NUREG (LWR) U_{en}[3)]
RC01 Pressurizer Surge Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RC02 Pressurizer Spray Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RC03 Pressurizer Safety Depressurization Valve Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RC04 Pressurizer Safety Valve Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RH01 RHR Suction Loop A Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RH02 RHR Suction Loop B Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RH05 RHR Return Loop A Line	SA-312(Sml)TP316 (Austenic stainless steel)			
RH06 RHR Return Loop B Line	SA-312(Sml)TP316 (Austenic stainless steel)			
SI01 Accumulator Loop A Line	SA-312(Sml)TP316 (Austenic stainless steel)			
SI02 Accumulator Loop B Line	SA-312(Sml)TP316 (Austenic stainless steel)			
SI05 DVI A Line	SA-312(Sml)TP316 (Austenic stainless steel)			
SI06 DVI B Line	SA-312(Sml)TP316 (Austenic stainless steel)			
CS01 CVCS Charging Line	SA-312(Sml)TP316 (Austenic stainless steel)			
CS02 CVCS Let Down Line	SA-312(Sml)TP316 (Austenic stainless steel)			
CS04 CVCS Seal Injection A Line	SA-312(Sml)TP316 (Austenic stainless steel)			
CS05 CVCS Seal Injection B Line	SA-312(Sml)TP316 (Austenic stainless steel)			

Table 2.0-1 Summary of Environmental Fatigue Evaluation for Class 1 Branch Piping (2/2)

Piping	Material	Usage Factor in air based on ASME[1)]	NUREG (air) U[2)]	NUREG (LWR) U_{en}[3)]
CS06 CVCS Seal Injection C Line	SA-312(Sml)TP316 (Austenic stainless steel)			
CS07 CVCS Seal Injection D Line	SA-312(Sml)TP316 (Austenic stainless steel)			

Note:
1) Cumulative usage factor in air based on ASME fatigue design curve
2) Cumulative usage factor in air based on NUREG/CR-6909 fatigue design curve
3) Cumulative usage factor in LWR environment
4) The environmental fatigue requirement is satisfied, because cumulative usage factor based on the NUREG new fatigue curve is less than 0.0689 (See Sec. 8).

3.0 NOMENCLATURE

Table 3.0-1 Symbol and Definition

Symbol	Definition
α	Coefficient of thermal expansion
C_1, C_2, C_3	Secondary stress indices
ε	Strain
$\dot{\varepsilon}$	Strain rate
$\Delta\varepsilon_k$	Increment of strain for the k-th increment segment
$\dot{\varepsilon}'_k$	Strain rate for the k-th increment segment
ε_A	Strain for transient A
ε_B	Strain for transient B
$\dot{\varepsilon}'$	Transformed strain rate
E	Modulus of elasticity of the material
F_{en}	Environmental fatigue correction factor
$F_{en,nom}$	Nominal environmental fatigue correction factor
$F_{en\ i}$	Environmental fatigue correction factor for "i" th stress cycle
$F_{en,k}$	Environmental fatigue correction factor for the k-th increment segment
$F_{en,A}$	Environmental fatigue correction factor for transient A
$F_{en,B}$	Environmental fatigue correction factor for transient B
K_e	Multiplier in the fatigue (NB-3228.5 of ASME Code)
K_1, K_2, K_3	Local stress indices
ni	Number of cycles of load set
Ni	Allowable number of stress cycles
υ	Poisson's ratio
O'	Transformed dissolved oxygen
Salt	Alternating stress intensity
Sp	Peak stress intensity
$\Delta Sp_{dom,k}$	Incremeent of dominant stress of Sp for the k-th increment segment
T'	Transformed temperature
T_k	Temperature for the k-th increment segment
ΔT_1	Absolute value of the range of the temperature difference between the temperature of the outside T_0 and the temperature of the inside surface T_1 of the piping product assuming moment generating equivalent linear temperature distribution.
ΔT_2	Absolute valve of the range for that partion of the nonlinear thermal gradient through the wall thickness not included in ΔT_1.

Symbol	Definition
T_a-T_b	Structual discontinuity temperature difference range
U	Cumulative usage factor in air
U_i	Usage factor in air
U_{en}	Cumulative usage factor in LWR environment
$U_{en\ i}$	Usage factor in LWR environment

4.0 ASSUMPTIONS AND OPEN ITEMS

4.1 Assumptions

There are no assumptions in this analysis Report.

4.2 Open Items

There are no open items in this analysis Report.

5.0 ACCEPTANCE CRITERIA

The usage factor is calculated based on the ASME procedure with the new fatigue design curves, which are provided in NUREG/CR-6909, Appendix A Figure A.3 (Reference 3). The usage factor is multiplied by F_{en} to obtain the cumulative usage factor in the LWR environment. The acceptance criteria is that the cumulative usage factor in the LWR environment U_{en} does not exceed the limit of 1.0.

$$U_{en} = U_1 \cdot F_{en,1} + U_2 \cdot F_{en,2} + U_3 \cdot F_{en,3} + U_i \cdot F_{en,i} ..... + U_n \cdot F_{en,n} \leq 1.0$$

6.0 CALCULATION

6.1 Analysis Approach

USNRC R.G 1.207 describes an acceptable methodology for evaluating environment fatigue effects. The regulatory guide describes the F_{en} method with “modified rate approach” for calculating F_{en}, which is provided in NUREG/CR-6909.

The calculated F_{en} values are then used to incorporate environmental effects into fatigue evaluation in air calculations. This fatigue evaluation employs ASME Code analysis procedures with the new fatigue design curves, which are provided in NUREG/CR-6909, Appendix A, Figures A.3.

Figure 6.1-1 shows the environmental fatigue analysis approach in this report, where P4TEDIA and CEFF-N are MHI proprietary computer code. These codes are described in Section 7.

Except for using the new fatigue design curve, the part of the fatigue analysis using ABAQUS, P4TEDIA and PIPESTRESS in Figure 6.1-1 is the same as the fatigue analysis in air for the class 1 branch piping based on ASME Code Section III which had been submitted to the USNRC (References 6).

The thermal stress (ΔT1, ΔT2, Ta-Tb) time histories during the transients together with temperature time histories were processed in P4TEDIA and were used as an input for CEFF-N, which performs the F_{en} calculations, and environmental fatigue calculations.

6.2 Basic Consideration

NUREG/CR-6909 Appendix A provides the additional guidance for use to determine the parameters. However, it is incomplete for analysis of F_{en} under the loading histories.

The following analytic procedures associated with F_{en} were adopted.

1) The effect of elastic-plastic correction factor (Ke) per NB-3228.5 of ASME Code on strain rate was neglected.

   The Ke factor causes a higher strain that increase the strain rate, which in turn lowers the F_{en}. Thus neglecting Ke is conservative.

2) For load pairs in an environmental usage factor calculation that are based on seismic loading, F_{en}=1.0.

   Seismic loading occurs too quickly for environmental effects.

3) For the transformed temperature, the highest metal temperature for each increment segment in the strain history was used.

   NUREG/CR-6909 supports this approach in that the maximum temperature can be used to perform the most conservative evaluation.

4) For strain calculation, the modulus of elasticity (E) at the room temperature was used.

5) For determination of strain rate by combination of pressure, moment, ΔT_1, ΔT_2, and T_a-T_b, the guidance by JSME (Reference 4) was used.

$$S_P = \underbrace{K_1 C_1 \frac{P_o D_o}{2t}}_{\text{Pressure term}} + \underbrace{K_2 C_2 \frac{D_o}{2I} M_i}_{\text{Moment term}} + \underbrace{\frac{1}{2(1-\nu)} K_3 E \alpha |\Delta T_1|}_{\Delta T_1 \text{term}} + \underbrace{K_3 C_3 E_{ab} \times |\alpha_a T_a - \alpha_b T_b|}_{T_a\text{-}T_b \text{ term}} + \underbrace{\frac{1}{1-\nu} E \alpha |\Delta T_2|}_{\Delta T_2 \text{ term}}$$

   That is, when ΔT_1, ΔT_2, or T_a-T_b is dominant, the strain rate is calculated from the time history of the dominant strain.

6.3 Environmental Fatigue Analysis Methodology

1) The equation to calculate the environmental fatigue correction factor

   Environmental fatigue analysis is performed in accordance with NUREG/CR-6909 (Reference 3), using the environmental fatigue correction factor. The environmental cumulative usage factor U_{en} is calculated by multiplying the cumulative usage factor in air U (S-N curves are from NUREG/CR-6909) obtained according to the ASME B&PV Code, Section III NB3600 (Reference 1) by the environmental fatigue correction factor F_{en}.

   Environmental cumulative usage factor

$$U_{en} = \sum_{i=1}^{n} U_i \times F_{en,i} \quad (1)$$

Environmental fatigue correction factor

・Austenitic stainless steel

$$F_{en,nom} = \exp\left(0.734 - T'O'\dot{\varepsilon}'\right) \tag{2}$$

$T' = 0$ $\quad (T < 150℃)$

$T' = (T - 150)/175$ $\quad (150 \le T < 325℃)$

$T' = 1$ $\quad (T \ge 325℃)$

$\dot{\varepsilon}' = 0$ $\quad (\dot{\varepsilon} > 0.4\%/s)$

$\dot{\varepsilon}' = \ln(\dot{\varepsilon}/0.4)$ $\quad (0.0004 \le \dot{\varepsilon} \le 0.4\%/s)$

$\dot{\varepsilon}' = \ln(0.0004/0.4)$ $\quad (\dot{\varepsilon} < 0.0004\%/s)$

$O' = 0.281$ $\quad (all \quad Do \quad levels)$

2) Threshold

For the peak stress intensity Salt below the threshold of 28.3 ksi in equation (2), the environmental fatigue correction factor, F_{en}, is 1.0.

$$F_{en,nom} = 1.0 \qquad \left(S_{alt} \le 28.3ksi(195MPa)\right) \tag{3}$$

Here, 28.3ksi is equal to 0.1% strain amplitude.

3) The modified-rate approach

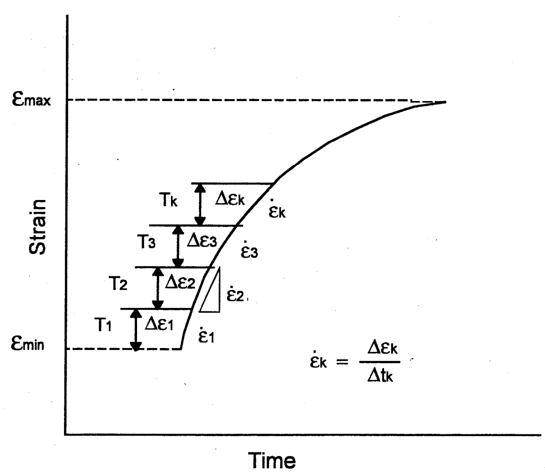
When the terms ΔT_1, ΔT_2, and (T_a-T_b) are dominant, the inner surface temperature of the metal and the strain rate are obtained by reading the results of the processing of P4TEDIA, and the environmental fatigue correction factor F_{en} is calculated using the modified-rate approach.

The strain ε, the weighted denominator in equation (4), is the sum of the strain increments $\Delta\varepsilon_k$. Then, if the strain history does not show a monotonic increase, ε is the sum of the strain increments in the portion for calculating strain rate to be described later, but not the value calculated from the peak stress.

Modified-rate approach

$$F_{en} = \sum_{k=1}^{n} F_{en,k}\left(\dot{\varepsilon}_k, T_k\right)\frac{\Delta\varepsilon_k}{\varepsilon} \tag{4}$$

$$\varepsilon = \sum_{k=1}^{n} \Delta\varepsilon_k \tag{5}$$



4) F_{en} for a combination of transients

The environmental fatigue correction factor F_{en} for a combination of transients is calculated by the following equation using the environmental fatigue correction factors $F_{en,A}$ and $F_{en,B}$ calculated for two transients A and B:

F_{en} for a combination of transients

$$F_{en} = \frac{F_{en,A}\times\varepsilon_A + F_{en,B}\times\varepsilon_B}{\varepsilon_A+\varepsilon_B} \tag{6}$$

5) Temperature

6) Strain rate

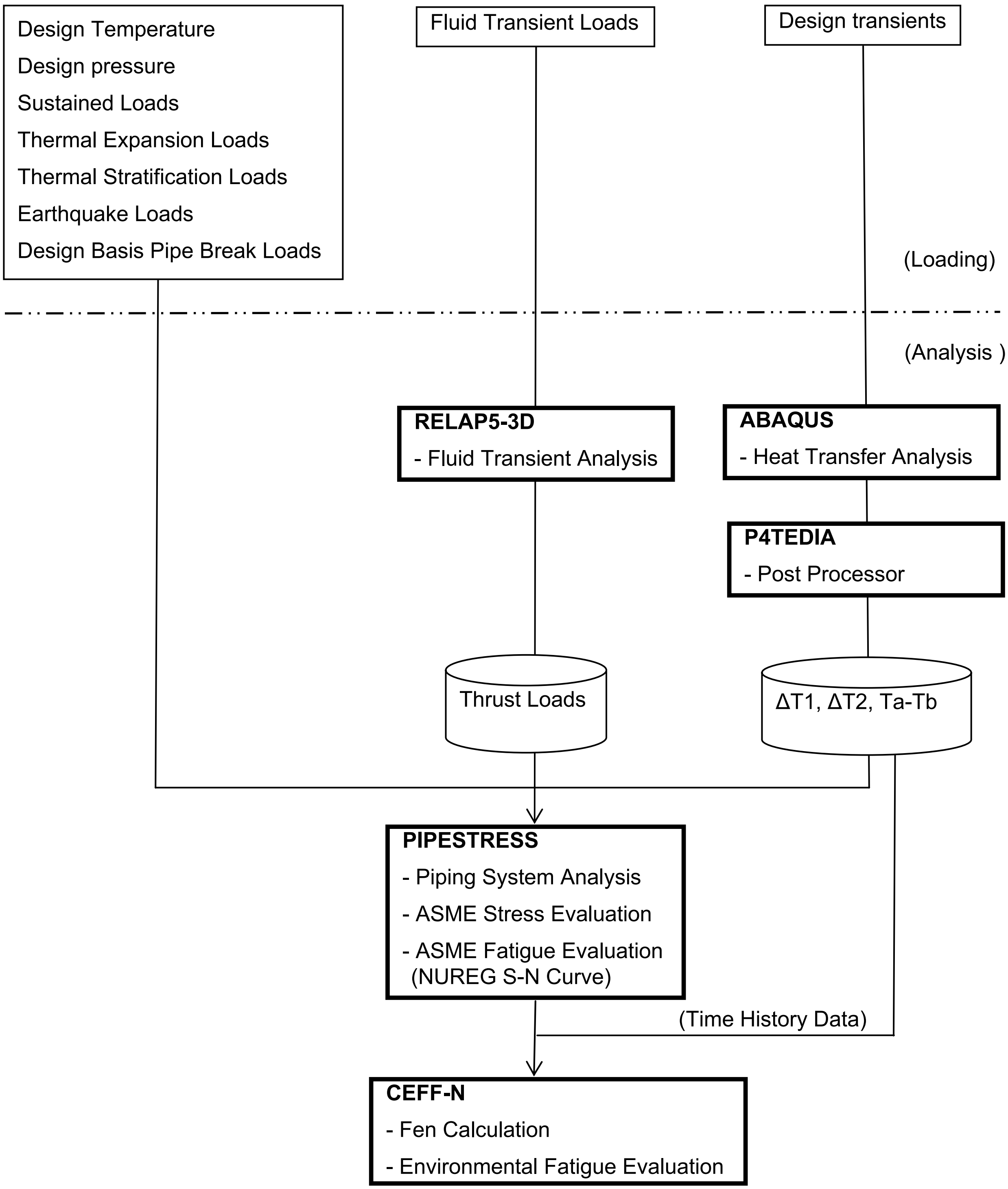


Figure 6.3-1 Environmental Fatigue Analysis Approach

Figure 6.3-2 Portion for calculating strain rate (1)

Figure 6.3-3 (1/2) Portion for calculating strain rate (2)

Figure 6.3-3(2/2) Portion for calculating strain rate (2)

7.0 COMPUTER CODE USED IN CALCULATION

Table 7-1 below provides a brief description of each of the computer programs used.

Table 7.0-1 Computer Program Description

No.	Program Name	Version	Description
1	PIPESTRESS	3.6.0	PIPESTRESS is a computer program for the analysis of piping systems. This program is used for the analysis of ASME Code, Section , Class 1, 2, 3 and ASME B31.1 piping systems under various load conditions.
2	ABAQUS	6.7-1	ABAQUS is a general-purpose finite element computer program that performs a wide range of linear and nonlinear engineering simulations. This program is used for temperature distribution analysis and thermal stress analysis according to piping geometries and design transients such as fluid temperature and coefficient of heat transfer.
3	P4TEDIA	1.3	P4TEDIA is an in-house program to obtain temperature difference between in-side and out-side of pipe ΔT_1, ΔT_2 and temperature difference at structural discontinuous point T_a-T_b. This program uses the thermal distribution analysis results generated by ABAQUS.
4	CEFF-N	1.0	CEFF-N is an in-house program. This program is used for calculating environmental usage factor.

All these computer programs were verified and validated in compliance with the MHI quality assurance program. The computer programs were validated using one of the methods described below. Verification tests demonstrate the capability of the computer program to produce valid results for the test problems encompassing the range of permitted usage defined by the program documentation.

- Hand calculations
- Known solution for similar or standard problem
- Acceptable experimental test results
- Published analytical results
- Results from other similar verified programs

8.0 ENVIRONMENTAL FATIGUE ANALYSIS RESULTS

This section summarizes the environmental fatigue evaluation results for the class 1 branch piping.

Maximum F_{en} is 14.514 for austenitic stainless steels for T $\geqq$ 325 ^{o}C and $\dot{\varepsilon} <$ 0.0004%/s. Therefore, the environmental fatigue analysis was performed for all points of the class 1 branch piping in the case when cumulative usage factor based on the NUREG new fatigue curve was equal or greater than 0.0689 (=1/14.514). All the calculated environmental usage factor are listed in Table 8-1. In this table, only the maximum NUREG (air) cumulative usage factor is listed for each class 1 branch piping in the case when its cumulative usage factor is less than 0.0689.

The details of the most severe environmental fatigue analysis results for each piping are shown in figures and tables listed in Table 8-2.

Table 8.0-1(1/3) The Results of Environmental Fatigue Evaluation for Class 1 Branch Piping

Piping	Point	Location	NUREG (air) U		NUREG (LWR) U_{en}	
			Case1 1)	Case2 1)	Case1 1)	Case2 1)
RC01 Pressurizer Surge Line						

Table 8.0-1(2/3) The Results of Environmental Fatigue Evaluation for Class 1 Branch Piping

Piping	Point	Location	NUREG (air) U	NUREG (LWR) U_{en}
RC02 Pressurizer Spray Line				
RC03 Pressurizer Safety Depressurization Valve Line				
RC04 Pressurizer Safety Valve Line				
RH01 RHR Suction Loop A Line				
RH02 RHR Suction Loop B Line				
RH05 RHR Return Loop A Line				
RH06 RHR Return Loop B Line				
SI01 Accumulator Loop A Line				
SI02 Accumulator Loop B Line				

Table 8.0-1(3/3) The Results of Environmental Fatigue Evaluation for Class 1 Branch Piping

Piping	Point	Location	NUREG (air) U	NUREG (LWR) U_{en}
SI05 DVI A Line				
SI06 DVI B Line				
CS01 CVCS Charging Line				
CS02 CVCS Let Down Line				
CS04 Seal Injection A Line				
CS05 Seal Injection B Line				
CS06 Seal Injection C Line				
CS07 Seal Injection D Line				

Note:
1) The requirement for environmental fatigue is satisfied, because NUREG(air) cumulative usage factor is less than 0.0689.

Table 8.0-2 The detail of analysis results for most severe point

Piping	NUREG (air) U	NUREG (LWR) U_{en}	Most Sever point	Detail of Environmental Usage Factor		typical data for F_{eni} calculation
				NUREG [1)] (air) U	NUREG [2)] (LWR) U_{en}	
RC01 Pressurizer Surge Line (Case1)			Figure 8.1-1	Table 8.1-1	Table 8.1-2	Figure 8.1-2
RC02 Pressurizer Spray Line			Figure 8.2-1	Table 8.2-1	Table 8.2-2	Figure 8.2-2
RC03 Pressurizer Safety Depressurization Valve Line			Figure 8.3-1	Table 8.3-1	Table8.3-2	Figure 8.3-2
RC04 Pressurizer Safety Valve Line			Figure 8.4-1	Table 8.4-1	Table8.4-2	Figure 8.4-2
RH01 RHR Suction Loop A Line			Figure 8.5-1	Table 8.5-1	-	-
RH02 RHR Suction Loop B Line			Figure 8.6-1	Table 8.6-1	-	-
RH05 RHR Return Loop A Line			Figure 8.7-1	Table 8.7-1	-	-
RH06 RHR Return Loop B Line			Figure 8.8-1	Table 8.8-1	-	-
SI01 Accumulator Loop A Line			Figure 8.9-1	Table 8.9-1	-	-
SI02 Accumulator Loop B Line			Figure 8.10-1	Table 8.10-1	-	-
SI05 DVI A Line			Figure 8.11-1	Table8.11-1	-	-
SI06 DVI B Line			Figure 8.12-1	Table 8.12-1	-	-
CS01 CVCS Charging Line			Figure 8.13-1	Table 8.13-1	Table 8.13-2	Figure 8.13-2
CS02 CVCS Let Down Line			Figure 8.14-1	Table 8.14-1	Table 8.14-2	Figure 8.14-2
CS04 CVCS Seal Injection A Line			Figure 8.15-1	Table 8.15-1	-	-
CS05 CVCS Seal Injection B Line			Figure 8.16-1	Table 8.16-1	-	-
CS06 CVCS Seal Injection C Line			Figure 8.17-1	Table 8.17-1	-	-
CS07 CVCS Seal Injection D Line			Figure 8.18-1	Table 8.18-1	-	-

Note:

1) Table 8.1-1 to Table 8.18-1 show the usage factors in air based on the NUREG/CR-6909 fatigue design curve on the most severe point for each piping. The Table lists the stress cycle (transient pair) Salt, number of repetitions that occur for stress cycle “I”(ni), allowable number of cycle for stress cycle “I”(Ni), and partial usage factor in air for stress cycle “I” based on NUREG/CR-6909 fatigue design curve, and cumulative usage factor (U).

2) Table 8.1-2 to Table 8 4-2, Table 8.13-2 and Table 8.14-2 show the environmental usage factors on the most severe point for each piping. The Table lists the stress cycle (transient pair) Sp, Salt, each stress of Sp(pressure, moment, ΔT_1, T_a-T_b, ΔT_2), dominant stress of Sp, partial usage factor in air for stress cycle “I” based on the NUREG/CR-6909 fatigue design curve, environmental fatigue correction factor (F_{eni}), partial environmental usage factor (U_{eni}), and environmental cumulative usage factor (U_{en}).

3) Figure 8.1-2 to Figure 8.4-2, Figure 8.13-2 and Figure 8.14-2 show the typical data for F_{eni} calculation, such as time history of strain, Strain rate and metal temperature.

4) The environmental fatigue requirement is satisfied, because cumulative usage factor based on the NUREG new fatigue curve is less than 0.0689.

8.1 RC01 (Pressurizer Surge Line)

The detail of environmental fatigue analysis results for Pressurizer Surge line is shown in the following tables and figures.

Figure 8.1-1 Most sever point for RC01 Pressurizer Surge Line

Table 8.1-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC01 Pressurizer Surge Line (Point 1000) (case1) (1/4)

Load set[1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Table 8.1-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC01 Pressurizer Surge Line (Point 1000) (case1) (2/4)

Load set[1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Table 8.1-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC01 Pressurizer Surge Line (Point 1000) (case1) (3/4)

Load set[1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Table 8.1-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC01 Pressurizer Surge Line (Point 1000) (case1) (4/4)

Load set[1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-1 of APPENDIX 1.

Table 8.1-2 Environmental Usage Factor
RC01 Pressurizer Surge Line (Point 1000) (case1) (1/4)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Table 8.1-2 Environmental Usage Factor
RC01 Pressurizer Surge Line (Point 1000) (case1) (2/4)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Table 8.1-2 Environmental Usage Factor
RC01 Pressurizer Surge Line (Point 1000) (case1) (3/4)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Table 8.1-2 Environmental Usage Factor
RC01 Pressurizer Surge Line (Point 1000) (case1) (4/4)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking "(*)", the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.1-2(1/5) Time history of strain, strain rate and metal temperature for RC01 Pressurizer Surge Line

Figure 8.1-2(2/5) Time history of strain, strain rate and metal temperature for RC01 Pressurizer Surge Line

Figure 8.1-2(3/5) Time history of strain, strain rate and metal temperature for

RC01 Pressurizer Surge Line

Figure 8.1-2(4/5) Time history of strain, strain rate and metal temperature for

RC01 Pressurizer Surge Line

Figure 8.1-2(5/5) Time history of strain, strain rate and metal temperature for RC01 Pressurizer Surge Line

8.2 RC02 (Pressurizer Spray Line)

The detail of environmental fatigue analysis results for Pressurizer Spray line is shown in the following tables and figures.

Figure 8.2-1(1/5) Most sever point for RC02 Pressurizer Spray Line

Figure 8.2-1(2/5) Most sever point for RC02 Pressurizer Spray Line

Figure 8.2-1(3/5) Most sever point for RC02 Pressurizer Spray Line

Figure 8.2-1(4/5) Most sever point for RC02 Pressurizer Spray Line

Figure 8.2-1(5/5) Most sever point for RC02 Pressurizer Spray Line

Table 8.2-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC02 Pressurizer Spray Line (Point 4000) (1/2)

Load Set [1]		Salt (psi)	ni	NURE(air) Ni	NURE(air) Ui
i [2]	j [2]				

Table 8.2-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC02 Pressurizer Spray Line (Point 4000) (2/2)

Load Set 1)		Salt (psi)	ni	NURE(air) Ni	NURE(air) Ui
i 2)	j 2)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-2 of APPENDIX 1.

Table 8.2-2 Environmental Usage Factor
RC02 Pressurizer Spray Line (Point 4000) (1/2)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Table 8.2-2 Environmental Usage Factor
RC02 Pressurizer Spray Line (Point 4000) (2/2)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking “(*)”, the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.2-2 Time history of strain, strain rate and metal temperature for

RC02 Pressurizer Spray Line

8.3 RC03 (Pressurizer Safety Depressurization Valve Line)

The detail of environmental fatigue analysis results for Pressurizer Safety Depressurization Valve line is shown in the following tables and figures.

Figure 8.3-1(1/3) Most sever point for RC03 Pressurizer Safety Depressurization Valve Line

Figure 8.3-1(2/3) Most sever point for RC03 Pressurizer Safety Depressurization Valve Line

Figure 8.3-1(3/3) Most sever point for RC03 Pressurizer Safety Depressurization Valve Line

Table 8.3-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC03 Pressurizer Safety Depressurization Valve Line (Point 2018)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i 2)	j 2)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-3 of APPENDIX 1.

Table 8.3-2 Environmental Usage Factor
RC03 Pressurizer Safety Depressurization Valve (Point 2018)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking “(*)”, the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.3-2 Time history of strain, strain rate and metal temperature for

RC03 Pressurizer Safety Depressurization Valve Line

8.4 RC04 (Pressurizer Safety Valve Line)

The detail of environmental fatigue analysis results for Pressurizer Safety Valve line is shown in the following tables and figures.

Figure 8.4-1 Most sever point for RC04 Pressurizer Safety Valve Line

Table 8.4-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RC04 Pressurizer Safety Valve Line (Point 1024)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-4 of APPENDIX 1.

Table 8.4-2 Environmental Usage Factor
RC04 Pressurizer Safety Valve Line (Point 1024)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Dominant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking "(*)", the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.4-2 Time history of strain, strain rate and metal temperature for

RC04 Pressurizer Safety Valve Line

8.5 RH01 (RHR Suction Loop A Line)

The detail of environmental fatigue analysis results for RHR suction loop A line is shown in the following tables and figures.

Figure 8.5-1(1/2) Most sever point for RH01 RHR Suction Loop A Line

Figure 8.5-1(2/2) Most sever point for RH01 RHR Suction Loop A Line

Table 8.5-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RH01 RHR Suction Loop A Line (Point 3000)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-5 of APPENDIX 1.

8.6 RH02 (RHR Suction Loop B Line)

The detail of environmental fatigue analysis results for RHR suction loop B line is shown in the following tables and figures.

Figure 8.6-1(1/2) Most sever point for RH02 RHR Suction Loop B Line

Figure 8.6-1(2/2) Most sever point for RH02 RHR Suction Loop B Line

Table 8.6-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RH02 RHR Suction Loop B Line (Point 3000)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(LWR) Ui
i 2)	j 2)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-6 of APPENDIX 1.

8.7 RH05 (RHR Return Loop A Line)

The detail of environmental fatigue analysis results for RHR return loop A line is shown in the following tables and figures.

Figure 8.7-1(1/2) Most sever point for RH05 RHR Return Loop A Line

Figure 8.7-1(2/2) Most sever point for RH05 RHR Return Loop A Line

Table 8.7-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RH05 RHR Return Loop A Line (Point 2007)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-7 of APPENDIX 1.

8.8 RH06 (RHR Return Loop B Line)

The detail of environmental fatigue analysis results for RHR return loop B line is shown in the following tables and figures.

Figure 8.8-1(1/2) Most sever point for RH06 RHR Return Loop B Line

Figure 8.8-1(2/2) Most sever point for RH06 RHR Return Loop A Line

Table 8.8-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for RH06 RHR Return Loop B Line (Point 2007)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-7 of APPENDIX 1.

8.9 SI01 (Accumulator Loop A Line)

The detail of environmental fatigue analysis results for Accumulator loop A line is shown in the following tables and figures.

Figure 8.9-1 Most sever point for SI01 Accumulator Loop A Line

Table 8.9-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for SI01 Accumulator Loop A Line (Point 1009)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-8 of APPENDIX 1.

8.10 SI02 (Accumulator Loop B Line)

The detail of environmental fatigue analysis results for Accumulator loop B line is shown in the following tables and figures.

Figure 8.10-1 Most sever point for SI02 Accumulator Loop B Line

Table 8.10-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for SI02 Accumulator Loop B Line (Point 1009)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-8 of APPENDIX 1.

8.11 SI05 (DVI A Line)

The detail of environmental fatigue analysis results for DVI A line is shown in the following tables and figures.

Figure 8.11-1 Most sever point for SI05 DVI A Line

Table 8.11-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for SI05 DVI A Line (Point 1027)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i 2)	j 2)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-9 of APPENDIX 1.

8.12 SI06 (DVI B Line)

The detail of environmental fatigue analysis results for DVI B line is shown in the following tables and figures.

Figure 8.12-1 Most sever point for SI06 DVI B Line

Table 8.12-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for SI06 DVI B Line (Point 1027)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-9 of APPENDIX 1.

8.13 CS01 (CVCS Charging Line)

The detail of environmental fatigue analysis results for CVCS charging line is shown in the following tables and figures.

Figure 8.13-1 Most sever point for CS01 CVCS Charging Line

Table 8.13-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS01 CVCS Charging Line (Point 2000) (1/3)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i 2)	j 2)				

Table 8.13-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS01 CVCS Charging Line (Point 2000) (2/3)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i 2)	j 2)				

Table 8.13-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS01 CVCS Charging Line (Point 2000) (3/3)

Load Set 1)		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i 2)	j 2)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-10 of APPENDIX 1.

Table 8.13-2 Environmental Usage Factor
CS01 CVCS Charging Line (Point 2000) (1/2)

Load Set [1]		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} [2]
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Table 8.13-2 Environmental Usage Factor
CS01 CVCS Charging Line (Point 2000) (2/2)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:

1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking “(*)”, the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.13-2 Time history of strain, strain rate and metal temperature for

CS01 CVCS Charging Line

8.14 CS02 (CVCS Let Down Line)

The detail of environmental fatigue analysis results for CVCS let down line is shown in the following tables and figures.

Figure 8.14-1(1/3) Most sever point for CS02 CVCS Let Down Line

Figure 8.14-1(2/3) Most sever point for CS02 CVCS Let Down Line

Figure 8.14-1(3/3) Most sever point for CS02 CVCS Let Down Line

Table 8.14-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS02 CVCS Let Down Line (Point 1042)

Load Set [1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-11 of APPENDIX 1.

Table 8.14-2 Environmental Usage Factor
CS02 Let Down Line (Point 1042)

Load Set 1)		Salt (psi)	Sp (psi)	Each Stress of Sp					Domin-ant Stress	NUREG (air) Ui	F_{eni}	NUREG (LWR) U_{eni} 2)
i	J			P (psi)	M (psi)	ΔT1 (psi)	ΔT2 (psi)	Ta-Tb (psi)				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) For marking “(*)”, the time-history of the strain, strain rate and metal temperature are shown in the following figures.

Figure 8.14-2(1/6) Time history of strain, strain rate and metal temperature for CS02 CVCS Let Down Line

Figure 8.14-2(2/6) Time history of strain, strain rate and metal temperature for

CS02 CVCS Let Down Line

Figure 8.14-2(3/6) Time history of strain, strain rate and metal temperature for CS02 CVCS Let Down Line

Figure 8.14-2(4/6) Time history of strain, strain rate and metal temperature for

CS02 CVCS Let Down Line

Figure 8.14-2(5/6) Time history of strain, strain rate and metal temperature for CS02 CVCS Let Down Line

Figure 8.14-2(6/6) Time history of strain, strain rate and metal temperature for

CS02 CVCS Let Down Line

8.15 CS04 (Seal Injection A Line)

The detail of environmental fatigue analysis results for CVCS seal Injection A line is shown in the following tables and figures.

Figure 8.15-1 Most sever point for CS04 CVCS Seal Injection A Line

Table 8.15-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS04 CVCS Seal Injection A Line (Point 1075)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-12 of APPENDIX 1.

8.16 CS05 (Seal Injection B Line)

The detail of environmental fatigue analysis results for CVCS seal Injection B line is shown in the following tables and figures.

Figure 8.16-1 Most sever point for CS05 CVCS Seal Injection B Line

Table 8.16-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS05 CVCS Seal Injection B Line (Point 2000)

Load Set [1)]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2)]	j [2)]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-12 of APPENDIX 1.

8.17 CS06 (Seal Injection C Line)

The detail of environmental fatigue analysis results for CVCS seal Injection C line is shown in the following tables and figures.

Figure 8.17-1 Most sever point for CS06 CVCS Seal Injection C Line

Table 8.17-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS06 CVCS Seal Injection C Line (Point 1060)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-12 of APPENDIX 1.

8.18 CS07 (Seal Injection D Line)

The detail of environmental fatigue analysis results for CVCS seal Injection D line is shown in the following tables and figures.

Figure 8.18-1 Most sever point for CS07 CVCS Seal Injection D Line

Table 8.18-1 Usage Factor based on NUREG/CR-6909 Design Fatigue Curve for CS07 CVCS Seal Injection D Line (Point 2000)

Load Set [1]		Salt (psi)	ni	NUREG(air) Ni	NUREG(air) Ui
i [2]	j [2]				

Note:
1) All other load sets produce zero Ui with the NUREG design fatigue curve in air.
2) Load Set number i and j mean Load No. of design transient shown in Table A1-12 of APPENDIX 1.

9.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section III NB-3600 1992 Edition through 1992 Addenda

2. U.S. Nuclear Regulatory Commission Regulatory Guide 1.207 “Guidelines for evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components due to the effects of the light-water Reactor Environment for New Reactors” March 2007

3. NUREG/CR-6909,”Effect of LWR Coolant Environments on Fatigue Life of Reactor , Materials” (Final Report), ANL-06/08, U.S. Nuclear Regulatory Commission, Washington, DC, February 2007

4. “Code for Nuclear Power Generating Facilities, Environmental Fatigue Evaluation Method for Nuclear Power Plants.” JSME S NF1, 2006, March 2006

5. N0-EE12001 Revision 2 “Class 1 Equipment Design Transient”

6. “Summary of Stress Analysis Results for the US-APWR Reactor Coolant Loop Branch Piping” MUAP-09011-P Revision 1

7. Design Control Document for US-APWR Chapter 3 Design MUAP-DC005 Rev.1 August, 2008

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APPENDIX 1 DESIGN TRANSIENTS

Table A1-1 Pressurizer surge line design transients (1/7)

Level A			
Mark	Transients	Occurrence	Load No.
I-a	Plant heat-up & cooldown	120	1
		120	2
	Plant heat-up1-insurge	120	4
		120	6
	Plant heat-up1-outsurge	120	3
		120	5
	Plant heat-up2-insurge	120	8
		120	10
	Plant heat-up2-outsurge	120	7
		120	9
	Plant heat-up3-insurge	120	12
		120	14
	Plant heat-up3-outsurge	120	11
		120	13
	Plant heat-up4-insurge	120	16
		120	18
	Plant heat-up4-outsurge	120	15
		120	17
	Plant heat-up5-insurge	120	20
		120	22
	Plant heat-up5-outsurge	120	19
		120	21
	Plant heat-up6-insurge	120	24
		120	26
	Plant heat-up6-outsurge	120	23
		120	25
I-b-1	Plant Cooldown1-insurge	120	28
		120	30
	Plant Cooldown1-outsurge	120	27
		120	29
	Plant Cooldown2-insurge	120	32
		120	34
	Plant Cooldown2-outsurge	120	31
		120	33
	Plant Cooldown3-insurge	120	36
		120	38
	Plant Cooldown3-outsurge	120	35
		120	37
	Plant Cooldown4-insurge	120	40
		120	42
	Plant Cooldown4-outsurge	120	39
		120	41
	Plant Cooldown5-insurge	120	44
		120	46
	Plant Cooldown5-outsurge	120	43
		120	45

Table A1-1 Pressurizer surge line design transients (2/7)

Level A			
Mark	Transients	Occurrence	Load No.
I-b-1	Plant Cooldown6-insurge	120	48
		120	50
	Plant Cooldown6-outsurge	120	47
		120	49
I-b-2	Plant Cooldown7-insurge	120	52
		120	54
	Plant Cooldown7-outsurge	120	51
		120	53
	Plant Cooldown8-insurge	120	56
		120	58
	Plant Cooldown8-outsurge	120	55
		120	57
	Plant Cooldown9-insurge	120	60
		120	62
	Plant Cooldown9-outsurge	120	59
		120	61
	Plant Cooldown10-insurge	120	64
		120	66
	Plant Cooldown10-outsurge	120	63
		120	65
	Plant Cooldown11-insurge	120	68
		120	70
	Plant Cooldown11-outsurge	120	67
		120	69
	Plant Cooldown12-insurge	120	72
		120	74
	Plant Cooldown12-outsurge	120	71
		120	73
I-c-1	Ramp load increase between 15% and 100% of full power		
	1st-insurge	600	76
		600	78
	1st-outsurge	600	75
		600	79
	2st-insurge	600	76
		600	80
	2st-outsurge	600	77
		600	79

Table A1-1 Pressurizer surge line design transients (3/7)

Level A			
Mark	Transients	Occurrence	Load No.
I-c-2	Ramp load increase between 50% and 100% of full power		
	1st-insurge	19200	82
		19200	84
	1st-outsurge	19200	81
		19200	85
	2st-insurge	19200	82
		19200	86
	2st-outsurge	19200	83
		19200	85
I-d-1	Ramp load decrease between 15% and 100% of full power		
	1st-insurge	600	88
		600	90
	1st-outsurge	600	87
		600	93
	2st-insurge	600	88
		600	92
	2st-outsurge	600	89
		600	93
	3th-insurge	600	88
		600	94
	3th-outsurge	600	91
		600	93
I-d-2	Ramp load decrease between 50% and 100% of full power		
	1st-insurge	19200	96
		19200	98
	1st-outsurge	19200	95
		19200	99
	2st-insurge	19200	96
		19200	100
	2st-outsurge	19200	97
		19200	99
I-e	Step load increase of 10% of full power		
	insurge	600	102
		600	104
	outsurge	600	101
		600	103
I-f	Step load decrease of 10% of full power		
	insurge	600	106
		600	108
	outsurge	600	105
		600	107

Table A1-1 Pressurizer surge line design transients (4/7)

Level A			
Mark	Transients	Occurrence	Load No.
I-g	Large step load decrease with turbine bypass		
	1st-insurge	60	110
		60	112
	1st-outsurge	60	109
		60	121
	2st-insurge	60	110
		60	114
	2st-outsurge	60	111
		60	121
	3th-insurge	60	110
		60	116
	3th-outsurge	60	113
		60	121
	4th-insurge	60	110
		60	118
	4th-outsurge	60	115
		60	121
	5th-insurge	60	110
		60	120
	5th-outsurge	60	117
		60	121
	6th-insurge	60	110
		60	122
	6th-outsurge	60	119
		60	121
I-h	Steady-state fluctuation and load regulation		
	insurge	1000000 [2]	124
		1000000 [2]	126
	outsurge	1000000 [2]	123
		1000000 [2]	125
I-i	Main feedwater cycling		
	insurge	2100	128
		2100	130
	outsurge	2100	127
		2100	129
I-j	Refueling	60	131
		60	132
I-k	Ramp load increase between 0% and 15% of full power	600	133
		600	134
I-l	Ramp load decrease between 0% and 15% of full power	600	135
		600	136

Table A1-1 Pressurizer surge line design transients (5/7)

Level A			
Mark	Transients	Occurrence	Load No.
I-m I-n	RCP startup & shutdown	3000	137
		3000	138
I-o	Core lifetime extension	60	139
		60	140
I-p	Primary leakage test	120	141
		120	142
I-q	Turbine roll test	10	143
		10	144
I-r	Boron concentration equalization	39600	145
		39600	146

Table A1-1 Pressurizer surge line design transients (6/7)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load		
	insurge	60	148
		60	150
	outsurge	60	147
		60	149
II-b	Loss of offsite power		
	1st-insurge	60	152
		60	154
	1st-outsurge	60	151
		60	155
	2nd -insurge	60	152
		60	156
	2nd -outsurge	60	153
		60	155
II-c	Partial loss of reactor coolant flow		
	insurge	30	158
		30	160
	outsurge	30	157
		30	159
II-d	Reactor trip from full power		
	i) With no inadvertent cooldown	60	161
		60	162
	ii) With cooldown and no safety injection	30	163
		30	164
	iii) With cooldown and safety injection		
	insurge	10	166
		10	168
	outsurge	10	165
		10	167
II-e	Inadvertent RCS depressurization		
	1st-insurge	30	170
		30	172
	1st-outsurge	30	169
		30	173
	2st-insurge	30	170
		30	174
	2st-outsurge	30	171
		30	173
II-f	Control rod drop	30	175
		30	176

Table A1-1 Pressurizer surge line design transients (7/7)

Level B			
Mark	Transients	Occurrence	Load No.
II-g	Inadvertent safeguards actuation		
	insurge	30	178
		30	180
	outsurge	30	177
		30	179
II-h	Emergency feedwater cycling		
	insurge	700	182
		700	184
	outsurge	700	181
		700	183
II-i	Cold over-pressure		
	insurge	30	187
		30	185
	outsurge	30	186
		30	188
II-l	Partial loss of emergency feedwater		
	1st-insurge	30	190
		30	192
	1st-outsurge	30	189
		30	193
	2nd -insurge	30	190
		30	194
	2nd -outsurge	30	191
		30	193
Earthquake Loads		2(150) [1]	195
		2(150) [1]	196

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.
Note2. The number of 1000000 is for “Steady-state” and the number of 1600000 is for “Load Regulation”.

Table A1-2 Pressurizer spray line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a	Plant heat-up & cooldown	120	1
		120	2
	Plant heat-up	720	3
		720	4
I-b-1	Plant cooldown (200F/h,2235~400psig)	720	5
		720	6
I-b-2	Plant cooldown (200F/h,lower than 400psig)	600	7
		600	8
I-b-1	Plant cooldown (auxiliary spray)	120	9
		120	10
I-c-1	Ramp load increase between 15% and 100% of full power	600	11
		600	12
I-c-2	Ramp load increase between 50% and 100% of full power	19200	13
		19200	14
I-d-1	Ramp load decrease between 15% and 100% of full power	1200	15
		1200	16
I-d-2	Ramp load decrease between 50% and 100% of full power	38400	17
		38400	18
I-e	Step load increase of 10% of full power	600	19
		600	20
I-f	Step load decrease of 10% of full power	600	21
		600	22
I-g	Large step load decrease with turbine bypass	60	23
		60	24
I-h	Steady-state fluctuation and load regulation	1000000	25
		1000000	26
I-i	Main feedwater cycling	2100	27
		2100	28
I-j	Refueling	60	29
		60	30
I-k	Ramp load increase between 0% and 15% of full power	600	31
		600	32
I-l	Ramp load decrease between 0% and 15% of full power	600	33
		600	34
I-m I-n	RCP startup & shutdown	3000	35
		3000	36
I-o	Core lifetime extension	60	37
		60	38
I-p	Primary leakage test	120	39
		120	40
I-q	Turbine roll test	10	41
		10	42
I-r	Boron concentration equalization	39600	43
		39600	44

Table A1-2 Pressurizer spray line design transients (2/2)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	45
		60	46
II-b	Loss of offsite power	60	47
		60	48
II-c	Partial loss of reactor coolant flow	30	49
		30	50
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	51
		60	52
	ii) With cooldown and no safety injection	30	53
		30	54
	iii) With cooldown and safety injection	10	55
		10	56
II-e	Inadvertent RCS depressurization i)Umbrella case	15	57
		15	58
	ii)Inadvertent auxiliary spray	15	59
		15	60
II-f	Control rod drop	30	61
		30	62
II-g	Inadvertent safeguards actuation	30	63
		30	64
II-h	Emergency feedwater cycling	700	65
		700	66
II-i	Cold over-pressure	30	67
		30	68
II-l	Partial loss of emergency feedwater	30	69
		30	70
Earthquake Loads		2(150) [1]	71
		2(150) [1]	72

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-3 Pressurizer safety depressurization valve line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-b-1	Plant heat-up & cooldown (200F/h, 2235~400psig)	120	1
		120	2
I-b-2	Plant heat-up & cooldown (200F/h, lower than 400psig)	120	3
		120	4
I-c-1	Ramp load increase between 15% and 100% of full power	600	5
		600	6
I-c-2	Ramp load increase between 50% and 100% of full power	19200	7
		19200	8
I-d-1	Ramp load decrease between 15% and 100% of full power	600	9
		600	10
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	11
		19200	12
I-e	Step load increase of 10% of full power	600	13
		600	14
I-f	Step load decrease of 10% of full power	600	15
		600	16
I-g	Large step load decrease with turbine bypass	60	17
		60	18
I-h	Steady-state fluctuation and load regulation	1000000	19
		1000000	20
I-i	Main feedwater cycling	2100	21
		2100	22
I-m I-n	RCP startup & shutdown	3000	23
		3000	24
I-p	Primary leakage test	120	25
		120	26
I-q	Turbine roll test	10	27
		10	28
I-r	Boron concentration equalization	39600	29
		39600	30

Table A1-3 Pressurizer safety depressurization valve line design transients (2/2)

Mark	Transients	Occurrence	Load No.
Level B			
II-a	Loss of load	60	31
		60	32
II-b	Loss of offsite power	60	33
		60	34
II-c	Partial loss of reactor coolant flow	30	35
		30	36
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	37
		60	38
	ii) With cooldown and no safety injection	30	39
		30	40
	iii) With cooldown and safety injection	10	41
		10	42
II-e	Inadvertent RCS depressurization Umbrella case	30	43
		30	44
II-f	Control rod drop	30	45
		30	46
II-g	Inadvertent safeguards actuation	30	47
		30	48
II-h	Emergency feedwater cycling	700	49
		700	50
II-i	Cold over-pressure	30	51
		30	52
II-l	Partial loss of emergency feedwater	30	53
		30	54
Specific transient of branch pipe			
-	Pressurizer safety depressurization valve actuation	60	55
		60	56
Earthquake Loads		2(150) [1]	59
		2(150) [1]	60

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-4 Pressurizer safety valve line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-b-1	Plant heat-up & cooldown (200F/h, 2235~400psig)	120	1
		120	2
I-b-2	Plant heat-up & cooldown (200F/h, lower than 400psig)	120	3
		120	4
I-c-1	Ramp load increase between 15% and 100% of full power	600	5
		600	6
I-c-2	Ramp load increase between 50% and 100% of full power	19200	7
		19200	8
I-d-1	Ramp load decrease between 15% and 100% of full power	600	9
		600	10
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	11
		19200	12
I-e	Step load increase of 10% of full power	600	13
		600	14
I-f	Step load decrease of 10% of full power	600	15
		600	16
I-g	Large step load decrease with turbine bypass	60	17
		60	18
I-h	Steady-state fluctuation and load regulation	1000000	19
		1000000	20
I-i	Main feedwater cycling	2100	21
		2100	22
I-m I-n	RCP startup & shutdown	3000	23
		3000	24
I-p	Primary leakage test	120	25
		120	26
I-q	Turbine roll test	10	27
		10	28
I-r	Boron concentration equalization	39600	29
		39600	30

Table A1-4 Pressurizer safety valve line design transients (2/2)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	31
		60	32
II-b	Loss of offsite power	60	33
		60	34
II-c	Partial loss of reactor coolant flow	30	35
		30	36
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	37
		60	38
	ii) With cooldown and no safety injection	30	39
		30	40
	iii) With cooldown and safety injection	10	41
		10	42
II-e	Inadvertent RCS depressurization Umbrella case	30	43
		30	44
II-f	Control rod drop	30	45
		30	46
II-g	Inadvertent safeguards actuation	30	47
		30	48
II-h	Emergency feedwater cycling	700	49
		700	50
II-i	Cold over-pressure	30	51
		30	52
II-l	Partial loss of emergency feedwater	30	53
		30	54
Specific transient of branch pipe			
-	Pressurizer safety valve actuation	60	55
		60	56
Earthquake Loads		2(150) [1]	59
		2(150) [1]	60

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-5 RHRS Suction loop A line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-5 RHRS suction loop A line design transients (2/2)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58
Specific transient of branch pipe			
a) b)	Plant heat-up & cooldown	120	59
		120	60
-	Safe shutdown 1	1	61
		1	62
	Safe shutdown 2~6	5	63
		5	64
Earthquake Loads		2(150) [1]	65
		2(150) [1]	66

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-6 RHRS suction loop B line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-6 RHRS suction loop B line design transients (2/2)

Mark	Transients	Occurrence	Load No.
Level B			
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58
Specific transient of branch pipe			
a) b)	Plant heat-up & cooldown	120	59
		120	60
Earthquake Loads		2(150) [1]	61
		2(150) [1]	62

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-7 RHR return line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	
		60	
I-k	Ramp load increase between 0% and 15% of full power	600	21
		600	22
I-l	Ramp load decrease between 0% and 15% of full power	600	23
		600	24
I-m I-n	RCP startup & shutdown	3000	25
		3000	26
I-o	Core lifetime extension	60	27
		60	28
I-p	Primary leakage test	120	29
		120	30
I-q	Turbine roll test	10	31
		10	32

Table A1-7 RHR return line design transients (2/2)

Mark	Transients	Occurrence	Load No.
Level B			
II-a	Loss of load	60	33
		60	34
II-b	Loss of offsite power	60	35
		60	36
II-c	Partial loss of reactor coolant flow	30	37
		30	38
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	39
		60	40
	ii) With cooldown and no safety injection	30	41
		30	42
	iii) With cooldown and safety injection	10	43
		10	44
II-e	Inadvertent RCS depressurization	30	45
		30	46
II-f	Control rod drop	30	47
		30	48
II-g	Inadvertent safeguards actuation	30	49
		30	50
II-h	Emergency feedwater cycling	700	51
		700	52
II-i	Cold over-pressure	30	53
		30	54
II-l	Partial loss of emergency feedwater	30	55
		30	56
Specific transient of branch pipe			
a) c)	Plant heat-up & cooldown 1	120	57
		120	58
	Plant heat-up & cooldown 2	120	59
		120	60
b)	Refueling	60	61
		60	62
Earthquake Loads		2(150) [1]	63
		2(150) [1]	64

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-8 Accumulator line design transient (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-8 Accumulator line design transient (2/2)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58
Specific transient of branch pipe			
a)	Inadvertent actuation of the accumulator tank	5	59
		5	60
d)	Inadvertent RCS depressurization	30	61
		30	62
Earthquake Loads		2(150) [1]	63
		2(150) [1]	64

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-9 DVI line design transients (1/3)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-9 DVI line design transients (2/3)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58

Table A1-9 DVI line design transients (3/3)

Specific transient of branch pipe			
Mark	Transients	Occurrence	Load No.
a)	Reactor trip from full power with cooldown and safety injection	10	59
		10	60
b)	Inadvertent RCS depressurization	30	61
		30	62
c)	Inadvertent safeguards actuation	30	63
		30	64
d)	Safe shutdown 1	1	65
		1	66
	Safe shutdown 2~6	5	67
		5	68
	Safe shutdown 7	1	69
		1	70
	Safe shutdown 8	1	71
		1	72
Earthquake Loads		2(150) [1]	73
		2(150) [1]	74

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-10 CVCS charging line design transients (1/3)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power (Charging flow 50% step decrease and return)	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power (Charging flow 50% step decrease and return)	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power (Charging flow 50% step increase and return)	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power (Charging flow 50% step increase and return)	19200	9
		19200	10
I-e	Step load increase of 10% of full power (Charging flow 50% step decrease and return)	600	11
		600	12
I-f	Step load decrease of 10% of full power (Charging flow 50% step increase and return)	600	13
		600	14
I-g	Large step load decrease with turbine bypass (Charging flow 50% step increase and return)	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling (Charging flow 50% step increase and return)	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-10 CVCS charging line design transients (2/3)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load (Charging flow 50% step increase and return)	60	35
		60	36
II-b	Loss of offsite power (Charging flow 50% step increase and return)	60	37
		60	38
II-c	Partial loss of reactor coolant flow (Charging flow 50% step increase and return)	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown (Charging flow 50% step increase and return)	60	41
		60	42
	ii) With cooldown and no safety injection Letdown line shut off and re-initiated	30	43
		30	44
	ii) With cooldown and no safety injection (Charging flow 50% step increase and return)	30	45
		30	46
	iii) With cooldown and safety injection Letdown line shut off and re-initiated	10	47
		10	48
	iii) With cooldown and safety injection Charging line shut off and re-initiated b) SI 1	10	49
		10	50
	iii) With cooldown and safety injection Charging line shut off and re-initiated b) SI 2	10	51
		10	52
	iii) With cooldown and safety injection (Charging flow 50% step increase and return)	10	53
		10	54
II-e	Inadvertent RCS depressurization Charging line shut off and re-initiated b) SI 1	30	55
		30	56
	Inadvertent RCS depressurization Charging line shut off and re-initiated b) SI 2	30	57
		30	58
	Inadvertent RCS depressurization (Charging flow 50% step increase and return)	30	59
		30	60
II-f	Control rod dropLetdown line shut off and re-initiated	30	61
		30	62
	Control rod drop (Charging flow 50% step increase and return)	30	63
		30	64
II-g	Inadvertent safeguards actuation Charging line shut off and re-initiated b) SI 1	30	65
		30	66

Table A1-10 CVCS charging line design transients (3/3)

Mark	Transients	Occurrence	Load No.
Level B			
II-g	Inadvertent safeguards actuation Charging line shut off and re-initiated b) SI 2	30	67
		30	68
	Inadvertent safeguards actuation (Charging flow 50% step increase and return)	30	69
		30	70
II-h	Emergency feedwater cycling (Charging flow 50% step increase and return)	700	71
		700	72
II-i	Cold over-pressure	30	73
		30	74
II-l	Partial loss of emergency feedwater	30	75
		30	76
Specific transient of branch pipe			
1.B a)	Charging line shut off and re-initiated a) Maintenance 1	30	77
		30	78
	Charging line shut off and re-initiated a) Maintenance 2	30	79
		30	80
	Charging line shut off and re-initiated a) Maintenance 3	30	81
		30	82
2.C	Letdown flow 50% step decrease and return 1	2900	83
		2900	84
	Letdown flow 50% step decrease and return 2	2900	85
		2900	86
2.D	Letdown flow 100% step increase and return 1	19800	87
		19800	88
	Letdown flow 100% step increase and return 2	19800	89
		19800	90
Earthquake Loads		2(150) [1]	91
		2(150) [1]	92

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-11 CVCS let down line design transients (1/3)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-11 CVCS let down line design transients (2/3)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58

Table A1-11 CVCS let down line design transients (3/3)

Specific transient of branch pipe			
Mark	Transients	Occurrence	Load No.
a) b)	Plant heat-up & cooldown	120	59
		120	60
c)	Letdown line shut off and re-initiated (maintenance)	30	61
		30	62
d)	Letdown line shut off and re-initiated (SI) With cooldown and no safety injection	30	63
		30	64
	Letdown line shut off and re-initiated (SI) With cooldown and safety injection	10	65
		10	66
	Letdown line shut off and re-initiated (SI) Control rod drop	30	67
		30	68
e)	RCS drain	120	69
		120	70
Earthquake Loads		2(150) [1]	71
		2(150) [1]	72

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.

Table A1-12 CVCS seal injection line design transients (1/2)

Level A			
Mark	Transients	Occurrence	Load No.
I-a I-b	Plant heat-up & cooldown	120	1
		120	2
I-c-1	Ramp load increase between 15% and 100% of full power	600	3
		600	4
I-c-2	Ramp load increase between 50% and 100% of full power	19200	5
		19200	6
I-d-1	Ramp load decrease between 15% and 100% of full power	600	7
		600	8
I-d-2	Ramp load decrease between 50% and 100% of full power	19200	9
		19200	10
I-e	Step load increase of 10% of full power	600	11
		600	12
I-f	Step load decrease of 10% of full power	600	13
		600	14
I-g	Large step load decrease with turbine bypass	60	15
		60	16
I-h	Steady-state fluctuation and load regulation	1000000	17
		1000000	18
I-i	Main feedwater cycling	2100	19
		2100	20
I-j	Refueling	60	21
		60	22
I-k	Ramp load increase between 0% and 15% of full power	600	23
		600	24
I-l	Ramp load decrease between 0% and 15% of full power	600	25
		600	26
I-m I-n	RCP startup & shutdown	3000	27
		3000	28
I-o	Core lifetime extension	60	29
		60	30
I-p	Primary leakage test	120	31
		120	32
I-q	Turbine roll test	10	33
		10	34

Table A1-12 CVCS seal injection line design transients (2/2)

Level B			
Mark	Transients	Occurrence	Load No.
II-a	Loss of load	60	35
		60	36
II-b	Loss of offsite power	60	37
		60	38
II-c	Partial loss of reactor coolant flow	30	39
		30	40
II-d	Reactor trip from full power i) With no inadvertent cooldown	60	41
		60	42
	ii) With cooldown and no safety injection	30	43
		30	44
	iii) With cooldown and safety injection	10	45
		10	46
II-e	Inadvertent RCS depressurization	30	47
		30	48
II-f	Control rod drop	30	49
		30	50
II-g	Inadvertent safeguards actuation	30	51
		30	52
II-h	Emergency feedwater cycling	700	53
		700	54
II-i	Cold over-pressure	30	55
		30	56
II-l	Partial loss of emergency feedwater	30	57
		30	58
Earthquake Loads		2(150) [1]	59
		2(150) [1]	60

Note1. (150) indicate the number of dynamic cycle for each occurrence of Earthquake.