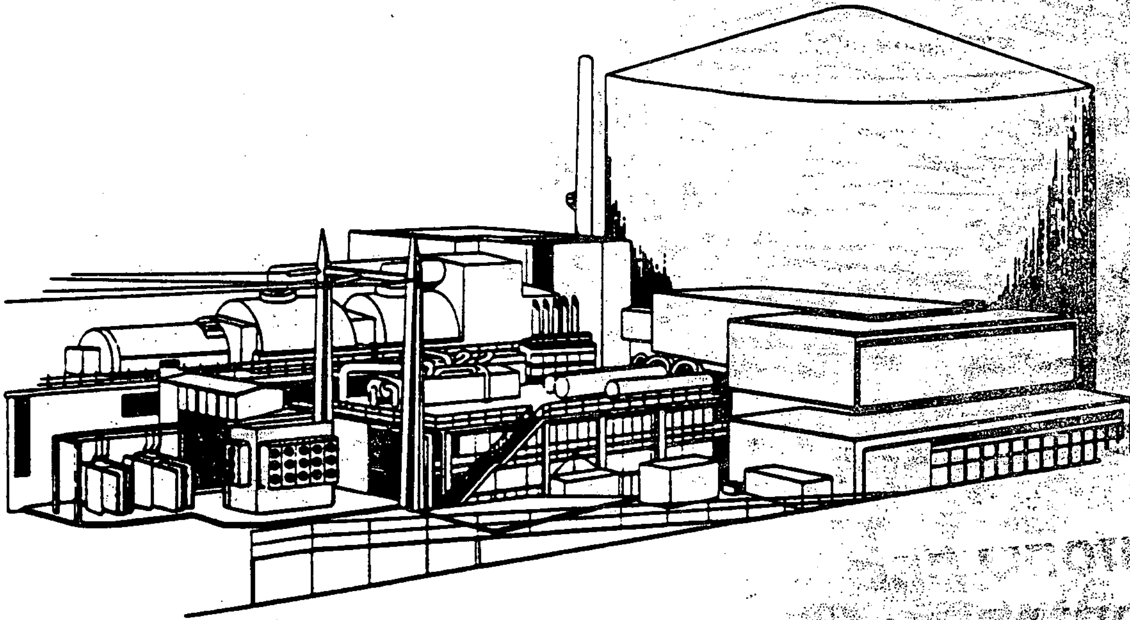
High Energy Line Break Analysis

Inside and Outside Containment



San Onofre
Nuclear Generating Station
Unit 1

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1.0 INTRODUCTION

This report describes the scope, criteria, methodology, assumptions, and results for the evaluation of high energy line breaks (HELB) both inside and outside containment at San Onofre Nuclear Generating Station Unit 1 (SONGS-1). It is submitted to resolve Systematic Evaluation Program (SEP) Topics III-5.A, "Effects of Pipe Break on Structures, Systems, and Components Inside Containment" and III-5.B, "Pipe Break Outside Containment." The objective of SEP Topics III-5.A and III-5.B is to assure that high energy pipe breaks will not cause the loss of systems, structures, and components required for safe shutdown of the plant.

1.1 Background

SONGS-1 was designed in the 1960s, prior to the existence of any requirements or guidelines for HELB analysis. The original design did not consider train separation and other design features now utilized in newer plants to preclude the effects of postulated HELBs. Consequently, the number of potential HELB interactions which must be evaluated for SONGS-1 is large. As evidenced in the following chronological summary, Southern California Edison (SCE) has expended a significant effort to demonstrate SONGS-1 compliance with the HELB standards in a manner which is both reasonable and practical.

1973 STUDY

The Atomic Energy Commission (AEC) first requested an analysis of the effects of a rupture of the high energy piping located <u>outside</u> the containment in December, 1972. In response to this request, SCE submitted a study to the AEC in December, 1973 (Reference 1). The 1973 report along with the associated addenda submitted in November, 1974, and April, 1975, analyzed pipe segments outside containment with service temperatures exceeding 200°F and/or service pressures above 275 psig. Those lines exceeding <u>both</u> temperature and pressure limits were analyzed for full pipe break effects, while those exceeding <u>only</u> <u>one</u> of these criteria were analyzed for jet impingement effects. A Safety Evaluation Report (SER) was issued by the NRC affirming the results of the 1973 study.

Several modifications resulted from the 1973 study and an augmented inservice inspection (ISI) program was established for certain main steam, feedwater, and extraction steam piping. The augmented ISI program was incorporated into SONGS-1 Technical Specification 4.10 (Reference 5), and is in the current specifications.

1983 STUDIES

The analysis of high energy systems was expanded in Standard Review Plan (SRP) 3.6.1, Revision 1, dated July 1981, to include an evaluation of full break effects for any pipe segments which met <u>either</u> the temperature <u>or</u> pressure values cited. A supplemental study on the effects of a pipe break outside containment was submitted to the NRC in March, 1983, and an amended version in October, 1983 (Reference 2). That study analyzed those piping lines which met the current criteria and were not considered in the original 1973 report. The analysis was performed as part of the ongoing SEP and was intended to determine the extent to which the SONGS-1 design met current regulatory criteria. The evaluation of electrical interactions was deferred until modifications required by 10 CFR 50 Appendix R were implemented. As a result of this study, approximately one hundred interactions requiring further analysis were identified.

High energy line breaks inside the SONGS-1 containment were evaluated in a report submitted to NRC in October, 1983 (Reference 3). This report was similar to the outside containment report in that it also was intended to determine the extent to which SONGS-1 design met current regulatory criteria. Again, electrical interactions were not considered due to projected modifications required by 10 CFR 50 Appendix R. The report indicated that the leak-before-break (LBB) approach would be used to evaluate large high energy lines inside containment. This was required because modifications to alleviate postulated pipe break effects would be very extensive.

1985 STUDY

Draft NUREG-0829, "Integrated Plant Safety Assessment, Systematic Evaluation Program," (Reference 4) dated April, 1985, was published by the NRC to document unresolved issues related to the SEP at SONGS-1 (Final Report dated December 1986). It included a summary of the results of the two HELB analyses (Topics III-5.A and III-5.B) and recommended further analysis.

Following the issuance of NUREG-0829 in 1985, SCE performed a scoping study to develop a plan to resolve outstanding issues related to high energy pipe break effects at SONGS-1. Significant modifications to the plant required by Appendix R, NUREG 0737, and Return-to-Service (RTS)/Long-Term-Service (LTS) seismic programs potentially impacted the previous studies. Based on the results of the scoping study, it was decided that the 1973 report would be revalidated and included in an updated report. Criteria were established and technical instructions were written. The list of high energy lines was reverified and documented. Lines were excluded from further analysis based on criteria in the SRP (Sections 3.6.1 and 3.6.2). Potential damage zones, known as "zones-of-influence" (ZOIs), were defined. The ZOIs were used during plant walkdowns to determine potential HELB interactions with targets.

The LBB approach was applied to several high energy lines inside containment where physical modifications were impractical. The augmented ISI program, which was originally established in 1975, was reviewed against recent LTS seismic evaluation pipe stress results and confirmed to still be applicable.

Results of that study were submitted to the NRC January 31, 1989. The study indicated that the majority of the plant's high energy lines would not adversely affect plant shutdown capabilities. However, results of the study were inconclusive since a number of the postulated breaks resulted in unacceptable interactions or were left unresolved. Although the results contained in that study are no longer valid, data collected from that study were used as a basis for our current HELB evaluation.

1990 PRA FEASIBILITY STUDY

A feasibility study was conducted for resolution of the potential HELB interactions using probability risk assessment (PRA) techniques. Based on the favorable results of the PRA feasibility study, in 1990 (references 17 and 18) we proposed to resolve this issue using PRA for HELB interactions related to safe shutdown systems and deterministic methodology for structural interactions.

On April 17, 1991, SCE personnel met with members of the NRC staff to present a general review of our proposed approach. As noted in the meeting, the PRA approach has been used many times in the past to resolve other SONGS-1 SEP issues. Therefore, use of the PRA approach to resolve the HELB SEP Topics is consistent with our previous practice for SONGS-1. In view of the fact that SONGS-1 was designed prior to the existence of HELB standards/guidelines, PRA is a reasonable and practical approach to evaluating the system related HELB interactions for SONGS-1.

1.2 Summary of Results

GENERAL

This report summarizes the accumulative results of all high energy line break analyses performed for SONGS-1 for piping inside and outside the containment. The results of the systems and structural evaluation to address SEP Topics III-5.A and III-5.B for SONGS-1 are presented. A total of 239 out of 770 high energy lines were excluded from further consideration using SRP criteria. The remaining high energy lines were assessed using various alternate assessment methods such as LBB, and augmented ISI.

HELB interactions resulting from pipe whip and jet impingement have been characterized as falling into two categories:

1) SYSTEMS RELATED--Interactions that affect system piping, equipment, or components required to achieve a safe shutdown, and

2) STRUCTURAL--Interactions that affect structural members/components.

Structural interactions were evaluated using deterministic methodology, while system related interactions were evaluated by calculating the increase in risk of core damage associated with the HELB interactions using PRA methodology.

LEAK-BEFORE-BREAK

The LBB approach was used to resolve 19 high energy piping lines. Ten of these lines were evaluated as part of this effort and nine were evaluated as part of the asymmetric LOCA loads issue (Reference 40).

INSERVICE INSPECTION

Twenty-five piping segments were resolved by application of ISI as covered by Technical Specification 4.10, "Augmented Inservice Inspection of high Energy Lines Outside Containment". Of the 25 lines, three were resolved by application of the ISI program outside containment, while the portions of those lines located inside containment were resolved by the LBB approach.

PRA RESULTS FOR SYSTEMS INTERACTIONS

More than 2500 system interactions were identified and approximately 500 high energy lines were evaluated for systems interaction effects using PRA methodology. The total risk of core damage due to system related HELB interactions was calculated to be 1.03E-5. This is considered to be a low risk, and represents approximately 5% of the total risk of core damage due to internally initiated events (estimated to be 2E-4).

Although 1.03E-5 is a low risk, we have elected to implement a design change which will lower the HELB risk by an additional 82%. The design change will protect the recirculation pump motor cables from a potential pipe break, thereby reducing the calculated HELB risk to an SEP acceptable value of 1.87E-6 per year. This reduced value constitutes less than 1% of the total risk of core damage due to internally initiated events, and is considered to be an insignificant increase in the total core damage risk. The design change will be implemented during the Cycle 13 refueling outage.

STRUCTURAL DETERMINISTIC EVALUATION RESULTS

Five hundred and six (506) structural interactions were identified and evaluated using deterministic methodology. Structural targets were initially evaluated using deterministic screening process where elastic and limited ductile ($\mu \leq 3$) capacities for various structural member types were developed and compared to the conservative pipe rupture loading cases. More refined screening considered specific jet impingement and pipe whip load geometry and member connection details. As a result of this screening process, 397 structural interactions were determined to be acceptable. The remaining 108 structural interactions were reduced to 21 using further refined deterministic evaluation, stress calculations, walkdowns, zones-of-influence, and the 10D criteria. The resulting 21 structural interactions which could not be eliminated by these methods were analyzed using allowable ductility ratios. Based on this analysis, 19 of the 21 structural interactions met the acceptance criteria. The remaining two, which affected one essential structural steel column, are scheduled for modification during the Cycle 13 refueling outage.

A summary of the resolution of high energy lines is included in the following tables.

Table 1-1

PRA Results Summary

Core Damage Frequency	Core Damage Frequency With Modification
8.46E-6 per year Inside Containment	3.22E-8 per year
1.84E-6 per year Outside Containment	1.84E-6 per year
1.03E-5 per year Total Risk	1.87E-6 per year

Table 1-2

High Energy Line Break Analysis Results Summary

Analysis Method	Evaluated	Not Meeting Criteria
Systems Interactions	> 2500 Interactions	0
Probabilistic Risk Assessment (PRA)	> 500 Lines	0
Leak-Before-Break	19 Lines(2)	1 Location on(1) 1 Line
Augmented ISI	30 Lines(2)	5 (See Table 4-2)
Structural Interactions	506	2(3)

Notes : (1) The one location which did not meet the leak detectability criteria is considered acceptable since the calculated pipe stress is below the 0.8 $(1.2S_h + S_a)$ allowable pipe break stress limit that required intermediate break postulation.

(2) Three (3) of the lines were resolved by both of the LBB and Augmented ISI. The inside containment portion was resolved by LBB, and outside containment by Augmented ISI.

(3) Affected structural column (K2) in the Turbine Building is scheduled for modification during the Cycle 13 refueling outage.

2.0 CRITERIA

This high energy line analysis is based primarily on the criteria outlined in NRC Standard Review Plan, Sections 3.6.1 and 3.6.2 (References 6 & 7). Specific deviations from that criteria are noted in this report.

2.1 High Energy Line Definition

High energy piping at SONGS-1 has been identified consistent with the following definition provided in Reference 7 (SRP 3.6.2):

> Fluid systems that, during normal plant conditions, are either in operation or maintained pressurized under conditions where either or both of the following are met:
>
> a. maximum operating temperature exceeds 200°F, and/or
>
> b. maximum operating pressure exceeds 275 psig.

Piping segments whose nominal diameter was equal to or smaller than one inch have been excluded from the HELBA study (Reference 7).

2.2 Exclusion Criteria

Sections 3.6.1 and 3.6.2 of the Standard Review Plan provide criteria for excluding pipe segments from break postulation. Section B.2.e of SRP 3.6.2 Branch Technical Position MEB 3-1 states that "breaks do not need to be postulated in the piping of those fluid systems that qualify as high energy fluid systems only for short operational periods" where "an operational period is considered short if the fraction of time that the system operates within the pressure-temperature conditions specified for high-energy fluid system is about 2 percent of the time that the system operates as a moderate energy system."

Appendix A of Branch Technical Position (BTP) ASS 3-1 of SRP 3.6.1 defines a high energy fluid system as one that "during normal plant conditions (further defined as reactor startup, operation at power, hot standby or reactor cooldown to cold shutdown) is either in operation or maintained pressurized under conditions where either or both of the conditions specified in [2.1] are met."

In accordance with SRP 3.6.1 BTP ASS 3-1 paragraph B.3.a, a system or pipe line segment not meeting the above definition does not need to have pipe breaks postulated in accordance with BTP NES 3-1 for high energy pipes.

Therefore, break postulation is not required in a pipe segment if:

- The line is only pressurized during accident or transient (upset) conditions since these are not normal plant conditions.

- The line is used infrequently during the course of power operation, (e.g., stem stop valve bypass lines) and, therefore would meet the 2 percent of system operating time criteria.

- The line is a limited reservoir high energy line and does not have sufficient stored energy to cause damaging interactions when broken. The basis for considering a specific line as a limited high energy reservoir is documented in the calculations.

2.3 Break Postulation Criteria

Pipe break locations and types were postulated in accordance with the guidance contained in the NRC staff's safety evaluation report (Reference 8), with exceptions and modifications as described below.

2.3.1 Location of Postulated Breaks

Breaks on high energy lines were postulated using either of the following methods:

Fully-Mechanistic Approach (FMA)

For SONGS-1 Long Term Service (LTS) seismic reevaluation, piping was analyzed using a Class 2/3 approach. Break locations were postulated at the following locations:

- At terminal ends.

- At all intermediate locations between terminal ends, where the primary plus secondary stresses as calculated in accordance with LTS stress criterion, exceeds 0.8 (1.2 S_h+S_A) (Reference 4 & 9). The seismic stresses (due to 0.67g Modified Housner Seismic Event) used in the primary stress check were reduced by 50%. The 50% reduction was applied to adjust the seismic stresses due to Modified Housner Seismic Event, which is a faulted condition, to correspond to the upset seismic conditions upon which the break location stress check is based.

FMA was used to determine break locations for lines with systems or structural interactions and for which stress analyses were performed. Break locations were selected by reviewing calculations based on the stress results.

In accordance with the recommendations of NUREG-1061, Volume 3 (Reference 10), "arbitrary" intermediate breaks were not postulated for those lines which were resolved using the FMA approach (Reference 11).

Simplified Mechanistic Approach (SMA)

For high-energy lines in which stress analyses were not performed, break locations were postulated using the SMA approach at the terminal ends of the run and at each intermediate location of potential high stress and fatigue such as Pipe fittings (elbows, tees, reducers, etc.), valves, and welded attachments.

2.3.2 Break Types

Two break types were postulated at the break locations. Circumferential breaks were postulated at all break locations in piping runs with nominal pipe diameter greater than 1-inch. Longitudinal breaks were postulated at all break locations in piping runs with nominal pipe sizes greater than or equal to 4 inches. In accordance with Reference 8 guidance, the break opening was assumed to be circular for both circumferential and longitudinal breaks and to have a cross-sectional area equal to the effective flow area of the pipe at the break location.

2.4 Leak-Before-Break Evaluation Criteria

2.4.1 General Criteria

The LBB approach was applied to selected lines where the relocation of equipment or other modifications to mitigate the consequences of postulated pipe breaks was impractical due to plant arrangement or other considerations. Therefore, fracture mechanics evaluation of the piping was performed to determine if unstable ruptures could occur in piping that contained large undetected flaws.

The criteria used for the LBB evaluation were provided by the NRC staff in the attachment to Reference 8, "Guidance for Resolution of High Energy Break Locations Where Remedial Modifications are Impractical." In addition, specific technical guidance and recommendations from the most recent NUREG 1061 (Reference 10) were used. In several cases, exceptions to the established criteria were required to demonstrate the leak-before-break conditions. The criteria used, and the exceptions taken, are described below.

2.4.2 Detectability Requirements

Leak detection capability to detect through-wall cracks of a length of twice the wall thickness (2t) for normal (Level A) operating conditions was demonstrated. Both circumferential and longitudinal cracks were considered for all postulated breaks or locations using the methods for estimation of crack opening areas described in Reference 14. Surface roughness of the crack was considered. Cracks longer than 2t were evaluated where necessary to demonstrate detectability.

2.4.3 Integrity Requirements

Circumferential or longitudinal through-wall cracks of four times the wall thickness (4t) in length subjected to normal plus maximum seismic loading conditions were shown to not exhibit substantial monotonic loading crack growth. Alternatively, if a crack lengths was shown to be detectable it could be evaluated under seismic loading conditions. Stability was evaluated using the plastic zone corrected linear-elastic fracture mechanics methods provided in Reference 14. The applied stress-intensity factor, K, was shown to be below the material fracture toughness, K_{IC}.

Prevention of general plastic instability was demonstrated for the postulated cracks by comparing the normal plus maximum seismic moment to the plastic moment capacity of the cracked pipe section. (Plastic instability does not occur if the applied moment is below the plastic moment capacity.)

Based upon the recommendation of NUREG-1061 that large-deformation loading is not a realistic design basis, loads in excess of Level D design loads were not considered in the LBB evaluation.

Conservative fracture resistance properties for the piping materials, both weldment and base metal, were used in the analyses. Material properties were determined considering the normal operating temperatures of the piping.

The jet impingement due to flow through the crack under seismic conditions was evaluated to show whether the jet will impair safe shutdown systems using the component damage criteria (Reference 30).

2.4.4 Subcritical Crack Development

Consideration was given to the types of subcritical cracks which may develop at all locations associated with this type of analysis and whether there was a positive tendency to develop through-wall cracks.

2.4.5 Inservice Inspection

For lines with an explicit leak-before-break evaluation which demonstrates the ability to tolerate large, detectable, through-wall flaws, existing Inservice Inspection Program and/or leak detection system was acceptable for providing early detection of possible cracks.

2.5 Augmented ISI Criteria

The Augmented ISI Program was established for the main steam, main feedwater, and certain extraction steam lines outside containment where protection from the consequences of postulated pipe breaks were not provided. This rigorous inspection program was designed to assure the continued integrity of these piping system over their service lifetime.

If a break location was found enveloped by the Augmented ISI Program, the break was considered resolved and further evaluation was not performed. The inservice inspection at each of the welds identified in the Augmented ISI Program was performed in compliance with the AEC and in accordance with the applicable requirements of ASME Boiler and Pressure Vessel Code, Section XI, titled "Inservice Inspection of Nuclear Power Plant Components."

Review of the current Augmented ISI Program identified one additional piping weld on each of the three main feedwater lines which should have been included in the program. These welds are located at the 3" auxiliary feedwater line (AFW) branch connection to the 10" main feedwater (MFW) header, and should have been categorized as part of the main feedwater piping pressure boundary. The welds will be added to the Augmented ISI Program.

2.6 Probabilistic Risk Assessment

The acceptance criteria for qualifying system interactions from the effects of HELBs were based on Probabilistic Risk Assessment. Use of PRA techniques to resolve system interactions issue is consistent with SEP philosophy. The SEP program utilized PRA techniques to identify and resolve plant features and characteristics that differed from current design requirements, which potentially could result in higher accident risks than would be expected for more recently constructed plants. SONGS-1 HELB PRA evaluation adopted the same approach as well as considering all failure modes (i.e., single failures and multiple failures) that could disable system functions. Also considered in the PRA analysis models were the effects of maintenance activities, human actions, and the potential for common cause failures.

PRA methodology was applied to resolved system interaction targets such as cable tray and conduits; piping, supports, and penetrations; and electrical components including pump and valve motors, etc. PRA Methodology is described in detail in Section 3.5.

2.7 Structural Target Qualification

Jet impingement and pipe whip interactions with essential structural members were identified by walkdown and evaluated using deterministic methodology. Essential structural members support components that are determined through systems analysis to be required for a particular pipe rupture. Major structural steel members (columns and girders) in the turbine area which are required to ensure the integrity of the structural framing are considered essential. Seismic bracing of the turbine area primary structure is not considered essential since the HELB event is not considered to be concurrent with a seismic event. The ability of the turbine deck to maintain its structural integrity after the failure of a single support beam was shown generically (Reference 33). Consequently, interactions with turbine deck support beams were not individually evaluated.

Interactions with all structural steel inside containment (except for non-essential steel, such as platforms) were evaluated.

Jet impingement force was considered insufficient to cause structural damage if:

1. analysis of the interaction geometry and ruptured pipe fluid conditions demonstrated that the impingement pressure would be less than 5 psi, or
2. the pipe break points were located more than 10 times the pipe diameters away from the target.

2.7.1 General Acceptance Criteria

The acceptance criteria for structural steel members under jet impingement loads are defined below.

Girders

The acceptance criteria for girders were based on the AISC Specification, Part 1 (Reference 12):

$1.6S \geq R$

where:

S = The required section strength based on elastic design methods and the allowable stresses defined in Part 1 of Reference 12.

R = Total resultant applied loads.

For example,

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.6$$

where:

f_a, f_{bx}, f_{by} = axial, major axis bending, and minor axis bending stresses, respectively, in the member due to the total resultant applied loads.

F_a, F_{bx}, F_{by} = axial, major axis bending, and minor axis bending allowable stresses, respectively, based on elastic design methods and allowables defined in Part 1 of the AISC Specification (Reference 12).

Columns

The criteria for structural columns were the AISC Specification, 8th Edition, Part 2 (Reference 12), with biaxial bending considered as follows.

When considering major and minor axes bending moments and the axial load to determine the ultimate capacity of the steel columns, the interaction equation as specified in Reference 13 was used.

$$\frac{P}{P_y} + \frac{1}{1.18}\,\frac{M_x}{M_{px}} + \frac{1}{1.67}\,\frac{M_y}{M_{py}} \le 1.0$$

where:

P = Applied axial load (kips)

P_y = F_y x A = Yield stress x section area [kips]

M_x = Applied moment, major axis [kip-inches]

M_y = Applied moment, minor axis [kip-inches]

M_{px} = Z_x x F_y = Plastic moment capacity, major axis [kip-inches]

M_{py} = Z_y x F_y = Plastic moment capacity, minor axis [kip-inches]

Connections

The acceptance criteria for bolted and moment connections was:

$1.6S \geq R$

where S and R are defined previously in this section.

Pipe Whip Loads on Girders

Girders were acceptable with no further evaluation required when evaluated using elastic analysis, if:

$$1.6S \geq R$$

where S and R are as defined for jet impingement evaluation.

When the elastic criteria were not satisfied, girders were evaluated for inelastic behavior. Qualification criteria were based on ductility ratios. Inelastic girders were acceptable provided the ductility ratio is less than 10 or the values stated in Section 2.7.2.

Connections

The criteria used for jet impingement target evaluation were applied to whip loading.

Pipe Whip Loads on Columns

The criteria and load definition used for jet impingement target evaluation were acceptable for pipe whip as well.

If inelastic behavior was determined, the same approach as for girders was used.

Connections

The criteria used for jet impingement target evaluation were applied to pipe whip loading.

Criteria for Pipe whip Load Definition

The pipe whip load was defined based upon the kinetic energy imparted to the pipe by the blowdown subsequent to pipe rupture as determined by an unrestrained whip analysis.

The kinetic energy must be less than the strain energy absorbing capability of the structural member. The strain energy capacity was defined through an acceptable ductility ratio limit. Assuming elastic behavior, an equivalent load (R) was determined by equating the kinetic energy and strain energy, and using the appropriate boundary conditions. This equivalent load (R) was imposed on the beam, together with the static loading and member critical forces and moments (P, M_x, M_y) were determined. Using the interaction equation, the ductility ratios were determined. If this ductility ratio was less than the allowable, the member was qualified.

2.7.2 Inelastic Analysis

This section defines the additional acceptance criteria for evaluating structural members affected by High Energy Line Break (HELB) loads using inelastic analyses. Load combinations including dead loads, live loads, normal operating loads and HELB loads were evaluated. Potential seismic loads were not considered to occur simultaneously with HELB loads. Items which were initially impacted by the high energy line break forces were not considered to cause secondary missiles.

Acceptance Criteria

The acceptance criteria followed the guidance of NUREG-0800, Section 3.5.3, for overall damage prediction, with the following deviations for cases having a ductility ratio greater than one:

1. Ductilities for reinforced concrete are as indicated below which is per BC-TOP-9A and supplemented by ACI 349.

   Flexure:

Beams and one-way slabs	$[0.10/(p-p')] \leq 10$ or 30*
Slabs with two-way reinforcing	$[0.10/(p-p')] \leq 10$ or 30*

   * Ductility ratio limit of up to 30 can be used when the angular rotation is limited to $0.0065\ (d/c) < 0.07$ radians.

   where,

   p and p' are the tension and compression reinforcing steel ratios respectively

   d - effective depth of sections

   c - distance from extreme compression fiber to neutral axis at ultimate strength

   Beams and slabs where shear controls design:

Shear carried by concrete only	1.3
Shear carried by concrete and stirrups	1.6

2. Structural steel ductility ratios for secondary members. Secondary members are defined as members not required to support slabs, or maintain the integrity of a structure.

a.	Compression due to flexure	20
b.	Tension due to flexure	20
c.	Shear	20
d.	Compression members not required for stability of building structures	20

3.0 METHODOLOGY

3.1 High Energy Line Identification

The purpose was to identify all pipe line segments at SONGS-1 which met the definition of a high energy line as described in Section 2.1 of this report. The task used the SONGS-1 Piping and instrumentation Diagrams (P&IDs) and the SONGS-1 Master Line List, Reference 15, as the principal input documents in developing the list and was confirmed by physically siting the line as part of the walkdown target identification effort (Reference 21).

3.1.1 Assumptions

The fundamental assumption was that:

- The valve status as shown on the Piping and instrumentation Diagrams (P&IDs) reflects the normal full power operation configuration.

3.1.2 Methodology

The SONGS-1 Master Line List was reviewed and lines with operating conditions meeting the definition of a high energy line were identified (see section 2.1).

Next, based on the information in the Master Line List, a review of the P&IDs was performed to identify piping connected to high energy pipe segments which were not isolated by normally closed valves. If these pipe segments were identifiable as having unique line identification, they were added to the HELBA Line List in Reference 24. If they were not uniquely identified, then they were included in the analysis of the line to which they were attached.

Some plant systems such as the plant air systems, the liquid nitrogen system, the condenser vacuum system, and fire protection system did not meet high energy criteria and therefore were excluded. The list of systems containing high energy lines and the list of high energy lines are contained in Table 3-1 and Appendix A, respectively. The list of systems excluded from the HELBA study are tabulated in Table 3-2.

3.2 Break Postulation Exclusion Review

The purpose of this task was to document whether a high energy line could be excluded from break postulation. Exclusion was based on various criteria from Section 2.2.

Using the HELB Line List from Reference 24, exclusion review forms were prepared. Each high energy line listed was entered on an exclusion review form along with its service function.

Next, a review was performed, using the criteria defined in Section 2.2, and the evaluation form was marked to indicate whether break postulation is required. In cases where none of the criteria was exactly applicable or where additional explanation was required, the basis was given in the evaluation column adjacent to the line.

The result of the exclusion review was a revised HELB Line List, with those lines which did not require break postulation being identified. Appendix A identified those lines that were excluded by this review.

3.3 Walkdown of High Energy Line for Pipe Break Interaction Targets

All high energy lines other than those which met the exclusion criteria or which were evaluated in the leak-before-break (LBB) and augmented Inservice Inspection (ISI) programs were the subject of pipe rupture interaction walkdowns. The walkdown program considered both pipe whip and jet impingement types of interactions between the source pipe and the other plant components (targets).

3.3.1 Assumptions

Several conservative assumptions were made in order to simplify the pipe rupture interaction walkdown and target identification effort.

- The Simplified Mechanistic Approach (SMA) was used for postulating break locations in the pipe segment being walked down. This approach postulated breaks at each fitting and weld attachment in the pipe segment (Criteria 2.3).

- In order to avoid the identifying, documenting, and reviewing of acceptable pipe-to-pipe pipewhip interactions, a screening matrix was developed based on all target piping having a wall thickness equal to or greater than schedule 40 piping. The screening matrix is based on Standard Review Plan Section 3.6.1 which states, "The energy level in a whipping pipe may be considered as insufficient to rupture an impacted pipe of equal or greater nominal pipe size and equal or heavier wall thickness." The matrix identifies interactions which could induce failure of adjacent pipes due to whip impact. Screening matrices were prepared for source (impactor) pipe schedules of 40, 60, 80, and 160. If the line being impacted by pipewhip was smaller than schedule 40S then the target pipe was always identified. Some safe shutdown pipe had different wall thickness than schedule 40 and above. These pipe segments were listed in the walkdown procedure and all interactions with these pipe segments were recorded. In this way, only those pipe-to-pipe interactions which may be potential problems were identified during the target identification walkdowns.

- The zone-of-influence for jet impingement interactions was defined for nominal pipe diameters and system operating pressures. The zone of influence was based on a 5.0 psig cutoff pressure at the zone's boundaries. The pipe whip interaction zone of influence was defined as a radial 180° arc about a hinge being formed at the second elbow back from the break.

3.3.2 Methodology

For each line to be walked down, a walkdown package was prepared. The package consisted of a checklist, walkdown target identification forms, any isometric drawings of the source pipe, P&ID(s) marked to show the source pipe, and pipe layout and area general arrangement drawings.

An "as-found" isometric sketch of the line being considered was prepared and all break locations dictated by the SMA approach were marked on it and sequentially numbered.

During the walkdown of a line, any and all interactions that occurred within the zone of influence were evaluated and, unless they were acceptable pipe-to-pipe pipewhip interactions as defined by the screening matrices described above, were recorded. If the pipe to pipe pipewhip interaction involved "non-SSD" piping or involved multiple targets, then special annotation was provided in the walkdown package. If no interaction existed along a given line, the word "none" was written under the Hardware Affected column of the Walkdown Data Sheet.

For each break location on the line's isometric sketch, the walkdown package contained a statement of whether a pipe whip was postulated at the break location, any pipe whip targets (impactees), and what eventually stopped the pipe whip.

The walkdown package also itemized all jet impingement targets. Targets physically located together were described as one target in general terms as long as they were all part of the same system. Targets impinged upon by more than one break on the same line were listed only under the first break node number on the walkdown isometric sketch for which they were a target. Pipe supports and structural members were considered as potential targets and were also recorded as part of the walkdown.

TABLE 3-1

SONGS Unit 1 Plant Systems Containing High Energy Lines

- Auxiliary Feedwater (AFW)
- Condensate (CND)
- Containment Spray and Recirculation (CRS)
- Condenser Vents and Drains (CVD)
- Feedwater Sampling (FSS)
- 1st, 2nd, 3rd Point Feedwater Heaters (FNH)
- Feedwater (FNS)
- Letdown Demineralizer (LDS)
- Main Steam (MSS)
- Pressurizer and Pressurizer Relief Tank (PZR)
- Reactor Coolant Pump Seal Water (RCP)
- Reactor Coolant (RCS)
- Residual Heat Removal (RHR)
- Radwaste Liquid Collection (RLC)
- Radwaste Liquid Processing (RWL)
- Secondary Chemical Feed (SCF)
- Safety Injection (SIS)
- Turbine (TBN)
- High Pressure Turbine (THP)
- Low Pressure Turbine (TLP)
- Volume Control and Charging (VCC)

TABLE 3-2
SONGS Unit 1 Plant Systems Not Containing Lines in the High Energy Line Break (HELB) Program

This table lists the plant systems which are part of the master line list (Reference 15) and meet at least one of the requirements to be a High Energy Line but were not considered in the HELB study. The reasons for the exclusion of these systems are listed in Reference 24:

- Boric Acid System (BAS)
- Component Cooling Water (CCW)
- Condenser Air Removal System (CNA)
- Diesel #1 Combustion Air Intake - Exhaust System (DCS)
- Diesel #2 Combustion Air Intake - Exhaust System (DCN)
- Diesel #1 Starting Air System (DSS)
- Diesel #1 Starting Air System (DSN)
- Fire Protection Water System (FPW)
- Fire Protection Foam and Spray System (FPS)
- Generator Seal Oil System (GSO)
- Instrument Air System (IAS)
- Liquid Nitrogen System (LNI)
- Turbine Plant Cooling System (PCS)
- Radwaste Drains (RWD)
- Service and Domestic Water System (SDW)
- Spent Fuel Pool Cooling System (SFP)
- Secondary Station Pumps and Drain Sump (SSD)
- Sphere Test System (STS)
- Turbine Plant Cooling Water System (TCW)
- Turbine Lube Oil System (TLO)

3.4 Review of Recent Design Change Packages (DCP)

Because the plant has been modified since the time that the detailed walkdowns were performed (1985), it was necessary to review all recent design changes to determine if any new significant HELB interactions were created. It was postulated that new HELB locations could have been created by the addition of new high energy piping or the relocation of existing piping. New targets might have been added if the design change added new high energy line or relocated a component (including its power and control cables) of a required mitigating system. If potentially new break locations or targets were added, then the impacts of these changes were reviewed to determine if new systems or structural interactions were created to assure that the plant can be shutdown during a HELB event.

3.5 PRA Methodology

Modern nuclear power plants incorporate HELB protection requirements into the initial plant design. However, older plants, such as San Onofre Unit 1, were not required to consider line break effects during the initial plant layout and design.

Each possible high energy line break location could potentially cause a plant transient and, possibly, a loss of one or more mitigating system trains. If the required mitigating systems cannot function, either due to failures caused by the HELB itself or due to random equipment failures or operator errors, then a core damage event can occur. The total core damage risk due to HELBs can be expressed as follows:

Risk = Σ (Probability of pipe break i) * (Conditional core damage likelihood given break i occurs)

where i = 1 to N (the total number of high energy line break locations).

The conditional core damage likelihood is calculated based upon the plant transient/accident resulting from the line break and the systems/trains disabled as a result of the break.

At SONGS-1, 770 potential high energy lines and over 4000 break locations were identified. Fortunately, many break locations have similar plant transient responses and similar system disabling effects. It was therefore possible to define a small number of representative cases (approximately 15) that were used as surrogates for all high energy lines. The core damage risk results for each case was then summed with the calculated risks from the other cases to obtain an estimate of the core damage risk of all the high energy lines.

The plant was considered to successfully accommodate a HELB if the plant can be brought to a stable shutdown condition (i.e., hot standby conditions) without serious core damage. No arbitrary time limits were imposed in the PRA evaluation for arriving at cold shutdown conditions. (If the plant can achieve a stable shutdown in the short term, it was assumed that the plant staff can effect adequate repairs and/or system realignments in the long term to allow the plant to safely reach cold shutdown conditions). Failures of mitigating systems were considered in a probabilistic fashion (i.e., worst single failures were not arbitrarily assumed). In other words, the PRA models consider the possible failure of all components (either singly or in various combinations) based upon the likelihood of each failure's occurrence.

The methodology involved a multiple phase approach. The initial phases identified the relevant pipe break categories to be evaluated. Subsequent phases calculated the core damage risk. Each of the key phases is described below:

<u>Census of Existing Line Break Calculations</u>

High energy line breaks excluded from PRA review:

- Lines credited to the Augmented ISI program.
- Lines analyzed to meet leak-before-break criteria

The frequency of pipe rupture in these lines was expected to be significantly lower than the rupture frequency for other plant piping.

Two hundred thirty nine (239) high energy lines were excluded from review since these lines did not meet high energy line criteria for more than 2% of the system operating time.

Approximately 500 remaining lines were then grouped based upon common factors such as:

- The transient event resulting from the break; and
- The specific accident mitigating system trains damaged as a direct result of pipe whip or jet impingement.

Approximately 200 of these lines were determined to result in no significant plant transients (and resulted in no damage to safety systems). These lines were not considered further since their risk contribution would be expected to be insignificant. About 150 lines were also identified that resulted in plant transients, however, the line breaks did not disable any required mitigating equipment. These lines were not considered further because these breaks did not result in "Systems Interactions" (i.e., the plant design is the best that can be achieved for these breaks). The risk from these lines would also be expected to be relatively low since all the plant's safety systems are available to respond to the event.

The remaining lines (approximately 170 lines) were then grouped into 15 distinct categories for PRA analysis.

Determination of Pipe Rupture Frequency

In order to calculate the frequency of pipe rupture for a given line, the methodology presented in a recent EPRI study (Reference 47) was used. The study encompassed a thorough review of U.S. nuclear plant pipe break experience and presents empirical relationships for the calculation of frequencies. The methodology includes consideration of system and plant types, pipe size and material, and the number of discontinuities (e.g., tees, reducers, in-line components, etc.) in the piping.

For a given PRA class of piping (based upon break effect and systems disabled, as described previously), each pipe within the class could have a significantly different rupture frequency due to differences in the factors described above. The rupture frequency for each group of pipes was calculated in one of the following ways:

- The rupture frequency for each line was calculated separately and the results were summed over all of the lines to determine the frequency of any rupture in the group; or

- A "worst case" line was selected (based upon its configuration, size, materials, etc.) and a rupture frequency was calculated. This frequency was then used as a "surrogate" value for all of the other lines in the group.

PRA Evaluation

Appendix C of this report presents a discussion of the event tree models developed for the analysis and PRA data sources used to perform the PRA evaluation. Event tree models were constructed for each of the 15 pipe break classes (Reference 62, Appendix A). Fault tree models were constructed for approximately eleven plant systems (both front-line and support systems). These models included consideration of maintenance activities and errors, and operator actions. Common cause failures were also considered for all major classes of components. However, the common cause evaluation was performed using the results of the fault tree models (i.e., the common cause failures do not explicitly appear in the fault trees). Probabilistic data was assembled from a set of NRC-published sources and industry sources.

For each event tree, fault tree models were solved, taking into account those system trains that were potentially disabled by the line break event. Each event tree was then solved to determine the overall core damage risk from that particular class. The total "HELB systems interaction risk" was then computed as the sum of the risks from each pipe class.

High Energy Line Break PRA Models

In order to evaluate the risk of each HELB system interaction, detailed plant models must be prepared and used to perform the PRA calculations. This section describes the key aspects of the plant model.

Because the particular line breaks of concern can result in a number of different transients, a large number of plant systems may be required to mitigate the consequences of the line break. These systems include both the plant's "front-line" systems (such as feedwater, safety injection, etc.) and the support systems (e.g., component cooling water, AC power) needed to assist the front-line systems. Section 3.5.1 through 3.5.5 describes five of the key front-line systems required for HELB mitigation.

Key Systems Needed to Ensure Plant Safety

The high energy line breaks that were evaluated could result in the initiation of LOCAs, steam line or feedwater line breaks, or losses of feedwater. The key safety functions required to mitigate these events include reactivity control, steam generator makeup, and RCS makeup and cooling.

Failures of the reactivity control function (i.e., the control rods and the Reactor Protection System) were not evaluated in detail for this since their functionality would be unaffected by the HELBs under evaluation and the reactivity control system exhibits a very high reliability due to its diversity and fail-safe design.

Steam generator makeup is provided by the main feedwater and auxiliary feedwater systems. RCS makeup and cooling is provided by the safety injection system, the charging system, and the recirculation system. Each of these five systems is described in further detail below. Included in each description are some of the key assumptions adopted for the development of the system models.

3.5.1 Safety Injection System

Safety Function

The SI System is one of three safety systems designed to mitigate the consequences of a design basis LOCA and other less severe loss of reactor coolant inventory events. The other two safety systems are the Recirculation System and the Containment SpraySystem. The SI System is designed to provide sufficient borated makeup water to the RCS in an inventory threatening event until the Recirculation System is initiated. The Safety Injection System has the following main function:

- Mitigate core damage resulting from overheating following a loss of coolant accident by (i) immediately injecting borated water (negative reactivity insertion) to the core and by (ii) subsequently recirculating the borated primary coolant through the core for long-term post-LOCA cooling.

In addition, the SI system is used to inject borated water to provide necessary negative reactivity insertion during a rapid cooldown of the primary coolant system following a secondary side steam line break.

System Configuration

Figure 3-1 presents a simplified diagram of the SI System. The SI System is comprised of two redundant and independent trains of equipment, each of which is capable of providing adequate makeup to the RCS in inventory threatening events. Each train is comprised of a safety injection pump (booster pump) and a main feedwater pump in series and is provided with independent power sources and actuation signals. The source of safety injection water is always the refueling water storage tank (RWST), from which water is provided via independent, redundant suction flow paths to each SI pump.

The discharge flow path from each SI train is first to a common header and then into the containment through three separate lines. Each line is connected to a corresponding RCS loop. Between the SI pump and main feedwater pump in each train is a valve which is normally closed and opens on an SI signal. The valves in the discharge flow path are normally closed to provide isolation between the RCS and SI System during normal operation. The main feedwater pumps can be utilized in both the Main Feedwater and SI Systems. When a SI signal is received, valves on the discharge and suction change position to realign the main feedwater pumps from the Main Feedwater System to the SI System.

Each SI pump can be manually controlled from the control room. The pumps will start automatically on a Safety Injection Signal (SIS). Once started by an SIS, the pumps can be manually stopped or automatically tripped at the RWST 20% level. The pumps are automatically tripped on overcurrent or undervoltage as well. Each feedwater pump can be manually started and stopped from the Control Room or automatically started by an SI signal.

Each SI train is provided with a minimum flow recirculation line leading from the discharge of each main feedwater pump back to the RWST. An SI signal to the

feedwater pumps will align the pumps for the SI mode and will open SI minimum flow valves, while closing normal feedwater minimum flow valves that control the minimum flow from the feedwater pump discharged to the condenser. Each pump in the SI System is provided with a check valve on the pump discharge. The check valves ensure that backflow from the common header through a failed train to the RWST will not occur.

Upon the receipt of an SI signal, a number of valves in each train must change position to align the system for injection. The valves which must close include: the pneumatic/hydraulic valves on suction and discharge of the main feedwater pumps which isolate the pumps from the Main Feedwater System, and the feedwater control valves in the normal minimum flow lines. In addition, downstream main feedwater discharge valves to the steam generators along with their flow control valves receive close signals. This prevents potential diversion of SI to the steam generators. The feedwater low flow regulating valves and the normal regulating valves also receive an SIS signal to close.

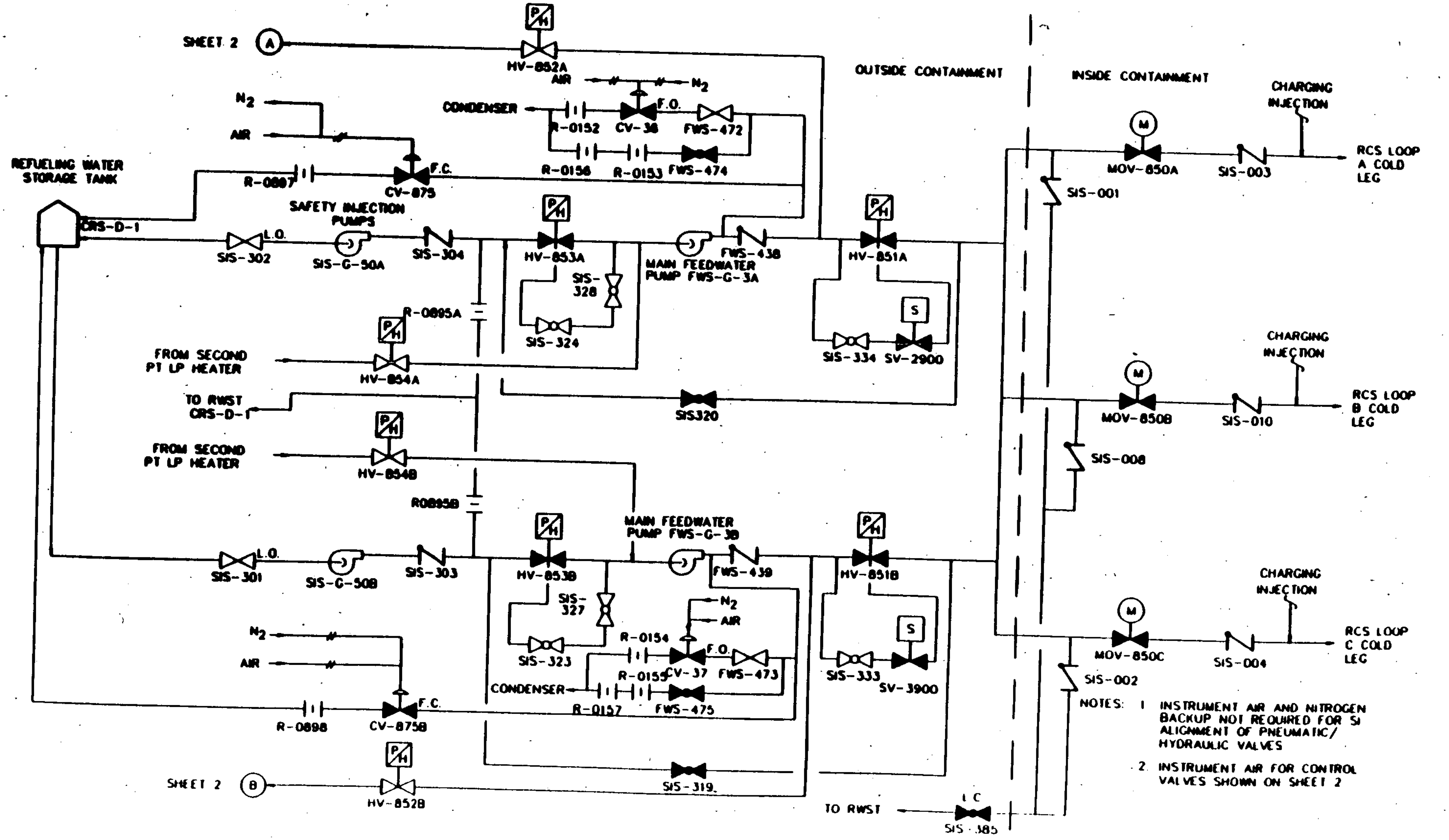
The valves which must open on an SIS to align the SI System for injection include: the pneumatic/hydraulic valves on the suction and discharge of the main feedwater pumps, which isolate the pumps from the SI System during normal operation, the solenoid valves on the lines around the pneumatic/hydraulic valves (which help equalize pressure across the valve disk to ensure opening), the valves on the SI minimum flow recirculation line to the RWST, and the three motor-operated RCS injection line isolation valves located inside containment.

System Operation

A Safety Injection Signal (SIS) is initiated either by two out of three high containment pressure signals or by two out of three low pressurizer pressure signals. Upon receipt of an SIS, the main feedwater pumps are automatically tripped and then restarted after an 11 second time delay. The condensate suction valves and condensate discharge valves close, and the SI suction valves and SI discharge valves open. The SI pumps start, and the SI to RCS isolation valves open. Borated water is then pumped from the RWST to the three RCS cold leg injection lines at a rate dependent on the RCS pressure. The SI System is designed to withstand one single active failure and still perform its design function. Single active failures include failure of a pump to start, failure of a pneumatic/hydraulic valve to reposition, and failure of an SI to RCS isolation valve to open. When the level of the RWST falls below 20%, the operators perform a switchover to cold leg recirculation.

Figure 3-1
Sheet 1

SAN ONOFRE UNIT 1 SAFETY INJECTION SYSTEM

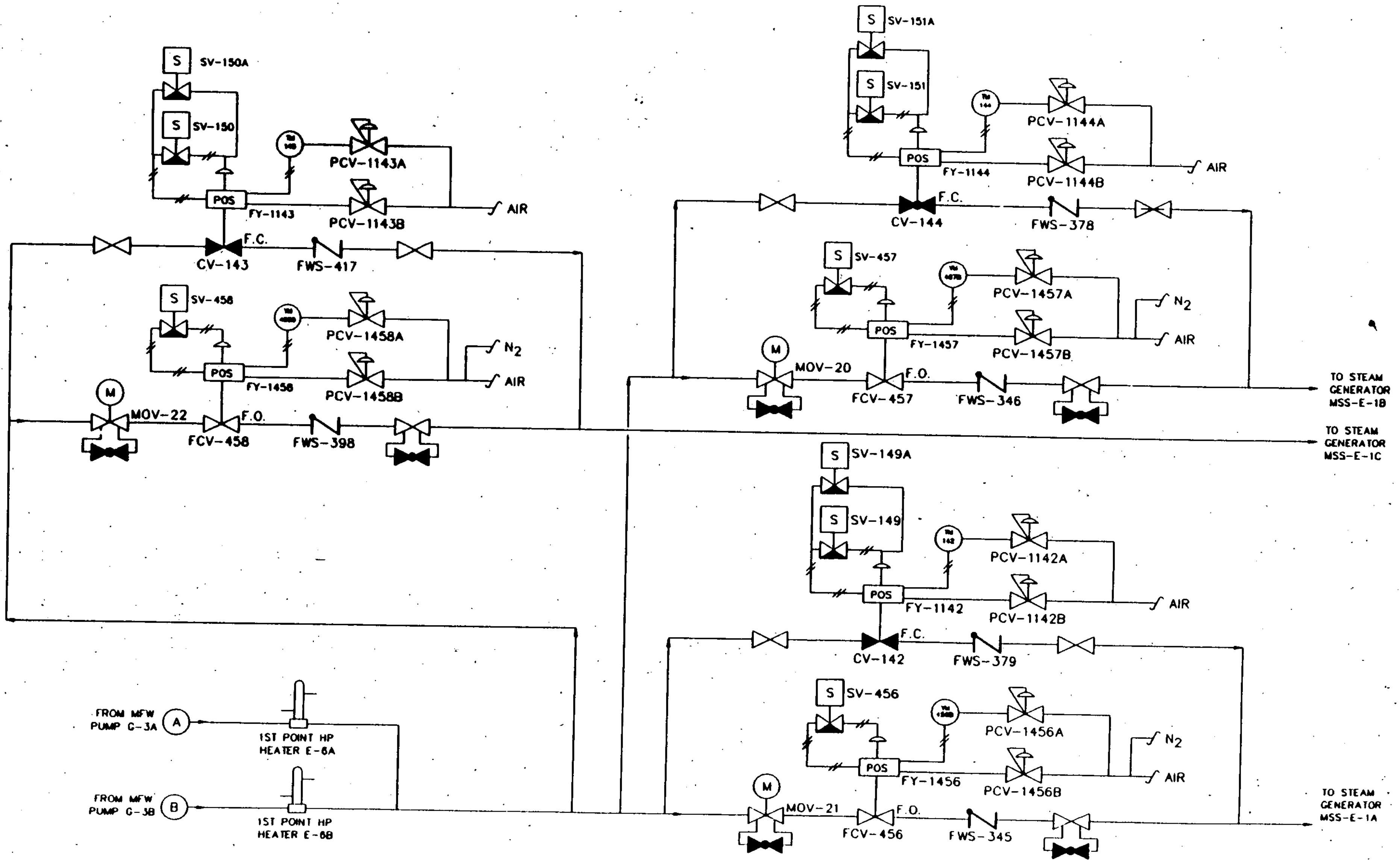


NOTES: 1 INSTRUMENT AIR AND NITROGEN BACKUP NOT REQUIRED FOR SI ALIGNMENT OF PNEUMATIC/HYDRAULIC VALVES

2 INSTRUMENT AIR FOR CONTROL VALVES SHOWN ON SHEET 2

Figure 3-1
Sheet 2

SAN ONOFRE UNIT 1 SAFETY INJECTION SYSTEM



Success Criteria

Following a small break LOCA, at least one train of the SI System is required to function successfully.

For SI train "x" to function successfully during a small LOCA, the following must occur:

1. The SI System must be actuated automatically or manually within several minutes of the break (prior to core uncovery).

2. SI pump "x" must start and continue to run for up to 24 hours.

3. The associated main feedwater pump "x" (in SI alignment) must stop, restart, and continue to run for up to 24 hours.

4. The SI minimum flow recirculation lines from the operating SI pump and feedwater pump back to the RWST must open.

5. Both MFW pump normal minimum flow paths to the condenser must close. Diversion of SI flow to the secondary system contributes to loss of injection flow and/or inadequate coolant in the containment sump to support recirculation. However, overfill of the steam generators from SI diversion is not a concern for core cooling

6. The following train "x" valves must change position:

    a. Feedwater pump feedwater suction and discharge (pneumatic/hydraulic) valves close.

    b. Feedwater pump SI suction and discharge (pneumatic/hydraulic) valves open.

    c. At least one of the three possible SI injection lines must open into a RCS cold leg not associated with the break. (Note: It is conservatively assumed that the RCS leak occurs in a cold leg and that each of the three cold legs has a 33% chance of being ruptured.)

7. The RWST and the flow path to SI pump "x" must be functional.

8. The train associated support systems and power supplies must operate for 24 hours.

Fault Tree Modeling Assumptions

The assumptions utilized in the development of the fault tree are listed below:

1. Diversion flow paths in excess of 2" equivalent diameter are conservatively assumed to prevent sufficient injection water from reaching the reactor vessel.

2. Non-proceduralized operator recovery from failed SI components is not modeled. This is conservative for a small LOCA, since the time to core uncovery is long and non-proceduralized actions would be implemented. However, the inclusion of the Charging System as a backup to the SI System results in recovery actions having less significance.

3. Entry of feedwater into the reactor vessel and subsequent boron dilution is not considered due to low probability.

4. In order for the main feedwater pump pneumatic/hydraulic discharge valves to open, the respective main feedwater pump must stop, and the associated equalizing valve must open. However, for HV-853A and B, the trees will assume no effect if their equalizing valves do not open and/or the MFW pumps fail to trip.

5. The SI System is assumed to suffer flow diversion due to a single break in any one of the three injection lines or associated cold legs with a probability of 0.33.

6. The failure to close a bypass line around a main feedwater pump following testing is assumed to result in excessive recirculation around the pump and a loss of associated train injection capability. However, the line is not assumed to fail from the high pressure discharge of the pump and thus is not considered a diversion flow path for the other SI injection train.

3.5.2 Charging System (Injection Mode)

Safety Function

The Charging System is a part of the Chemical and Volume Control System (CVCS). In normal conditions, the Charging System provides RCS makeup and flow to the Reactor Coolant Pump Seal Water System. In their injection mode, in the event of a LOCA, the charging pumps are aligned for injection to the RCS.

The Charging System has the following main functions:

1. Provide a means of injecting borated water from the Boric Acid System, and provide primary makeup for RCS dilution.

2. Maintain the proper coolant inventory in the RCS during all phases of operations.

3. Provide the seal water circuit for the reactor coolant pumps.

In addition, the charging system is used to inject corrosion inhibiting chemicals and reduce the amount of corrosion and fission product impurities in the RCS. It can also be used to fill and pressure test the RCS. For accident analysis, the injection mode at the charging system is the main focus.

System Configuration

Figure 3-2 presents a simplified P&ID of the Charging System. The Charging System is comprised of a single flow path with two trains of pumps and other active components, such that the failure of any single active component will not disable the system. The normal charging path is from the volume control tank (VCT) to one operating charging pump. The source of charging water in the injection mode is from the reactor water storage tank (RWST). The suction alignment to the charging pump automatically switches from the VCT to the RWST on a safety injection signal (SIS). Flow passes from the RWST through motor-operated valves, check valves and manual isolation valves to a common suction header. The suction header splits into two lines feeding each charging pump. Check valves are provided on the discharge of each charging pump, and manual isolation valves are provided on the suction and discharge of each charging pump. The discharge flow from each charging pump flows into a common header and splits into three injection lines, each feeding an RCS cold leg and an RCP seal supply filter. Each charging pump has its own miniflow line which transmits a portion of its discharge back to the charging pump suction header. The operating charging pump discharges through a check valve and manual isolation valve to a common header, and then via a flow control valve to the regenerative heat exchanger where it is heated prior to entering the RCS loop A through control valve CV-304.

A charging pump automatically starts on any one of the following signals: low charging header pressure, running pump lockout relay energized (non-running pump starts), and SIS (preferred pump starts if previously stopped).

A charging pump can trip on any one of the following signals: manual, undervoltage, overcurrent, SIS concurrent with loss of power, or SIS if the pump is the non-preferred pump. On each RCS injection line, a normally closed gate valve is provided to isolate the charging injection line from the RCS during normal operation. The opening circuit on each valve operator is disabled during normal operation and is enabled by an SIS actuation.

System Operation

During normal operation, the Charging System provides RCS makeup and RCP seal water injection. One charging pump is normally running while the other is in standby. Also, one charging pump (not necessarily the one in standby) is locked out from starting or running in the event of an SIS actuation.

In the event of an SIS actuation, several automatic actions occur:

1. The suction to the charging pump switches from the VCT to the RWST.

2. Charging Pump in Train "B", which is not locked out, is given a start signal (unless already running).

3. Charging pump in Train "A", which is locked out, is stopped (if running) and cannot be started without resetting the lockout.

4. Enabling the open circuit for RCS injection isolation valves on an SIS actuation.

These automatic actions provide for charging injection from the RWST through the normal makeup path to RCS loop A at the normal flow rate. Manual operator action is required to align the Charging System for its maximum injection flow capability. These manual actions include:

1. Opening of isolation valves to bypass the seal supply filter.

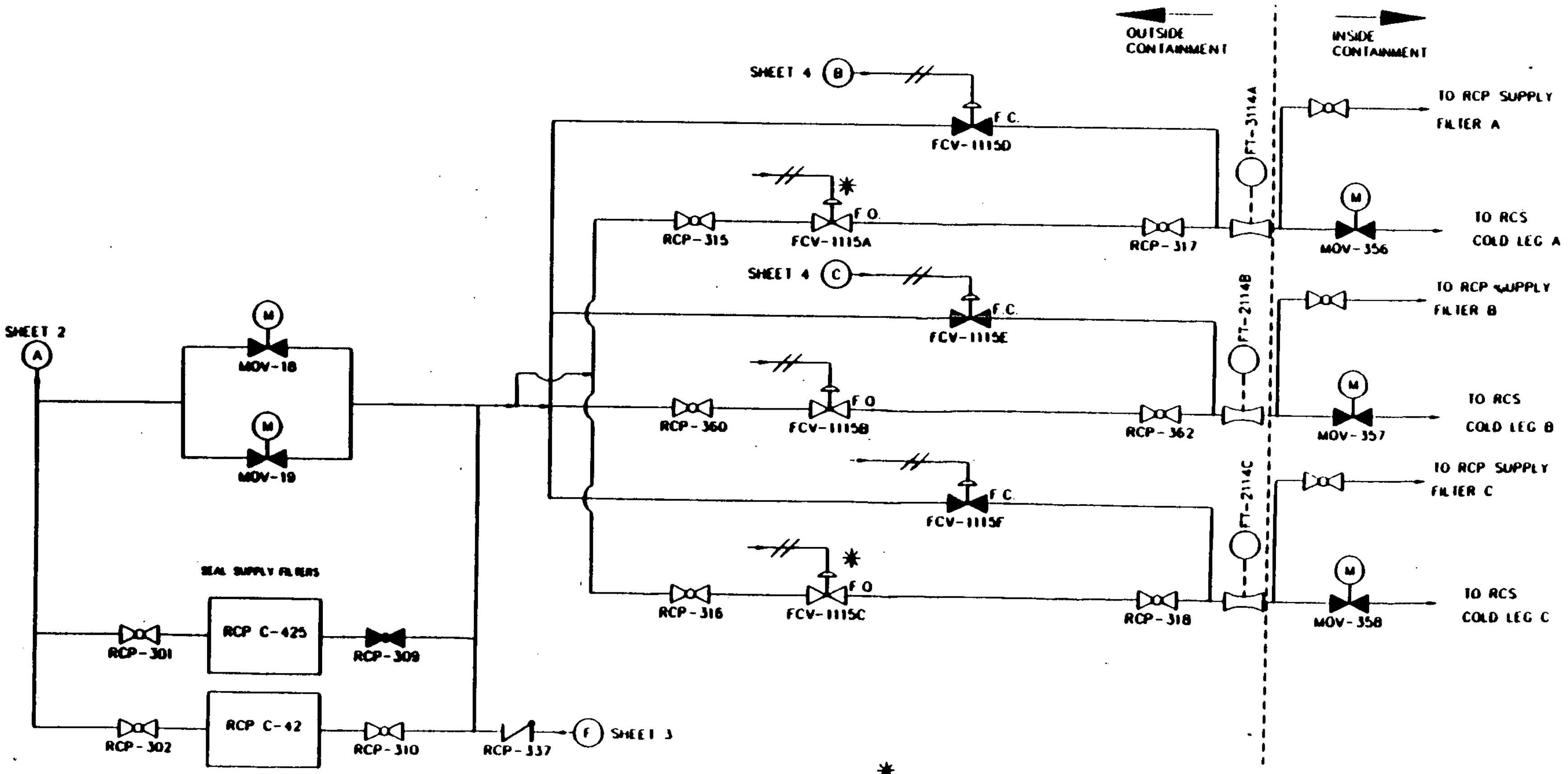
2. Opening of isolation valves connecting each charging injection line with its associated RCS loop.

3. Operating the controllers for flow control valves on each charging injection line.

In the event of a small break LOCA, the Charging System will automatically increase injection flow to maintain pressurizer level. When either a low-low level alarm is

Figure 3-2
Sheet 1

SAN ONOFRE UNIT 1 CHARGING AND RECIRCULATION SYSTEMS



* LOW FLOW CAPACITY VALVES

Figure 3-2
Sheet 2

SAN ONOFRE UNIT 1 CHARGING AND RECIRCULATION SYSTEMS

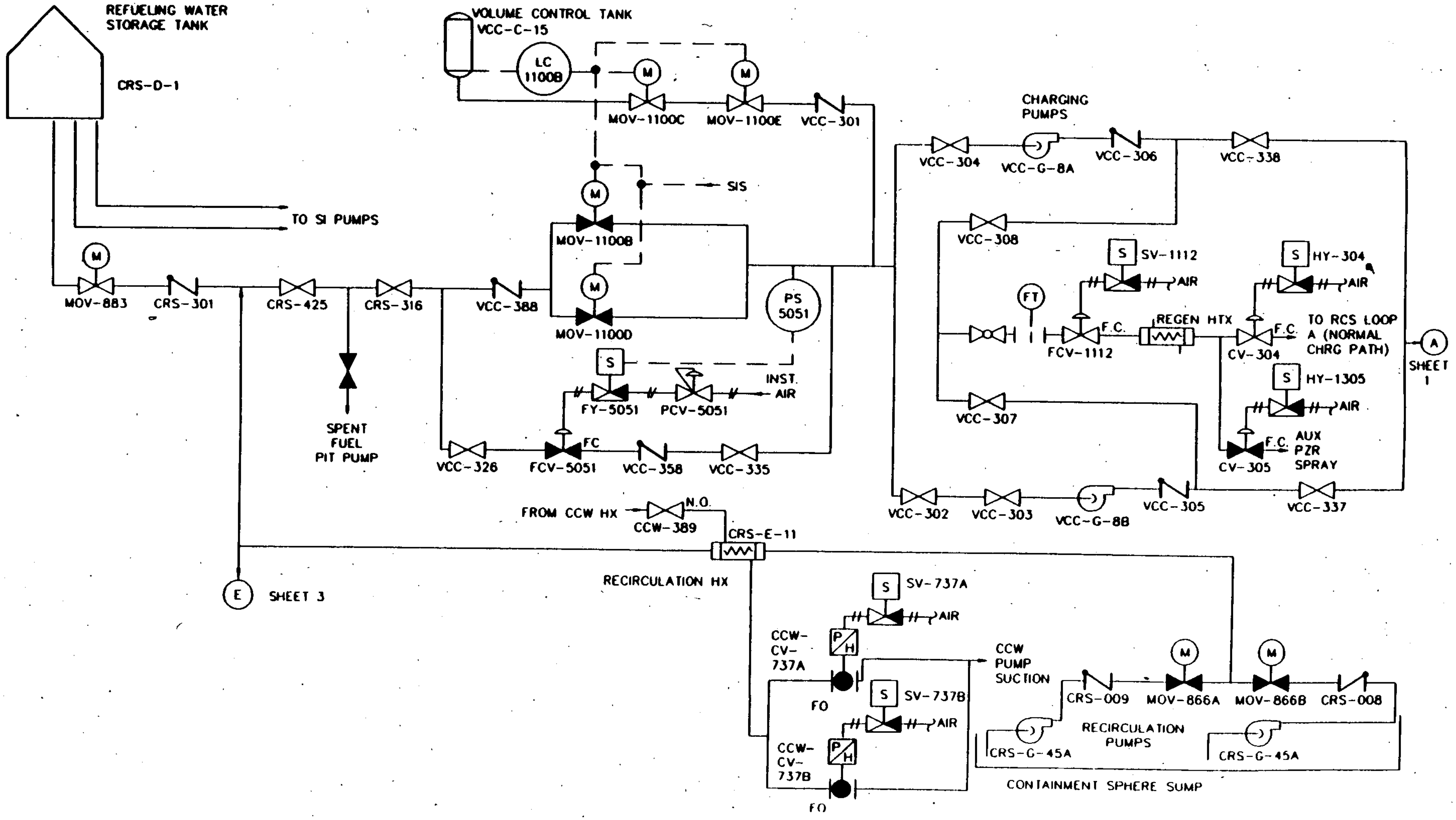
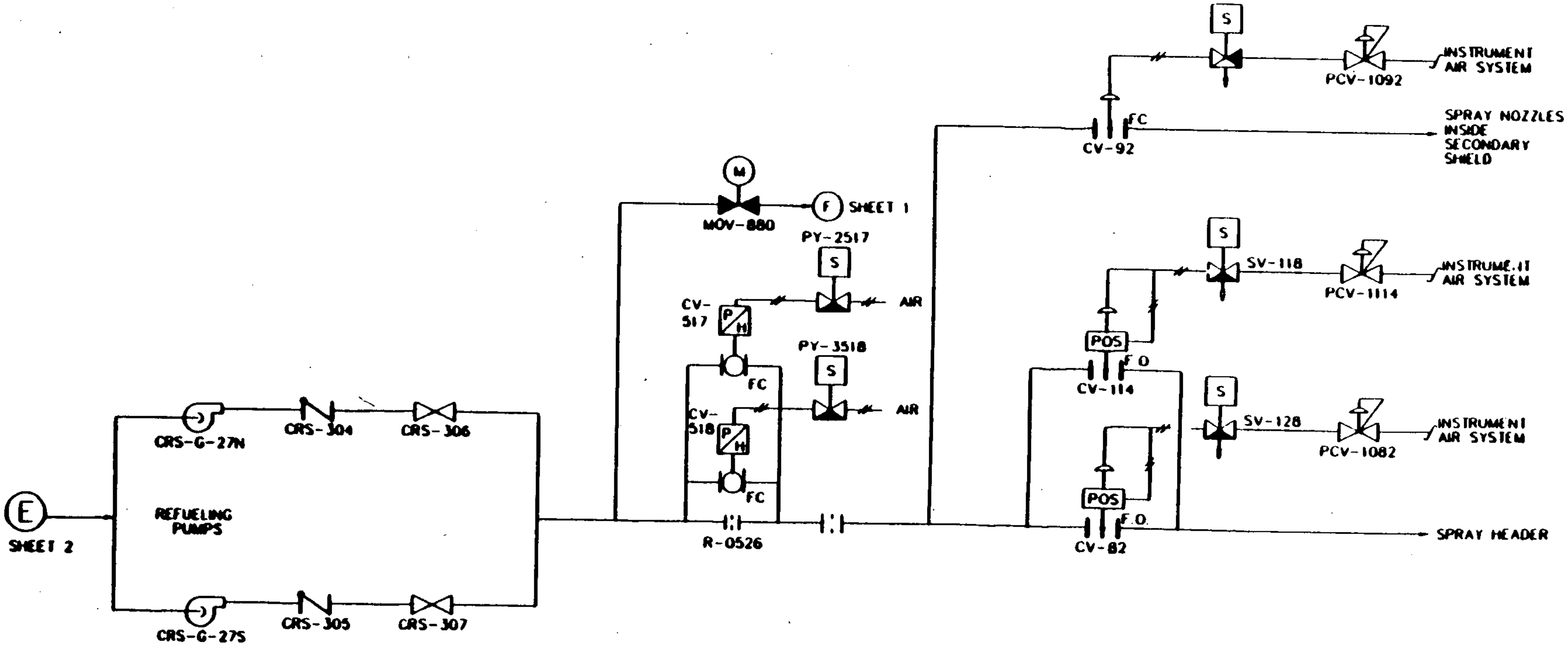


Figure 3-2
Sheet 3

SAN ONOFRE UNIT 1 CHARGING AND RECIRCULATION SYSTEMS



received on the VCT or an SIS actuation occurs manually or automatically the suction to the charging pumps will align to the RWST, the locked out charging pump will stop if running and the preferred charging pump will start, and the injection line to RCS cold leg will be enabled. Injection flow will then pass through the normal makeup path to RCS cold leg A until the operators open the isolation valves and permit cold leg injection to each RCS cold leg. Operator action will result in the Charging System providing a maximum flow of 300 gpm into the intact RCS cold legs.

The Charging System will continue to operate in the injection mode until the RWST inventory drops below 21% at some time prior to 24 hours. Recirculation cooling would then be initiated.

Success Criteria

For a small break LOCA, the Charging System may function to back up a failed Safety Injection System to prevent significant fuel damage. In order to do this, the Charging System must deliver at least 200 gpm into the reactor core. For this to happen, the following must occur:

1. At least one charging pump must start and run for 24 hours.
2. At least one of the parallel seal supply filter bypass valves must open.
3. At least two of the three possible cold leg injection lines must open into a non-ruptured RCS cold leg.
4. Control room operators must follow the instructions to obtain sufficient flow and to prevent excessive flow leading to pump runout and subsequent damage.
5. At least one of the three charging pump suction valves must open.
6. One of the two VCT isolation valves must close.
7. The RWST and the flow path to the charging pumps must be functional.
8. Support systems and power supplies must operate for 24 hours.

Modeling Assumptions

The assumptions utilized in the development of the fault tree are listed below:

1. The normal charging pump line-up is assumed to be:

   a) Charging Pump G-8A (Train "B") running, and

   b) Charging Pump G-8B (Train "A") in standby.

2. Standby Charging Pump G-8B may be out of service for maintenance for a period of 72 hours according to Technical Specifications.

3. Failure of VCT isolation valves MOV-1100C and MOV-1100E to close will prevent the Charging System from functioning as a backup to the Safety Injection System. Entrainment of VCT cover gas in the operating charging pump will result in the non-recoverable failure of the pump due to cavitation. Operators will not start the standby charging pump unless MOV-1100C or MOV-1100E has been verified closed.

4. Credit was not taken for the Fan Cooler on Charging Pump G-8B due to its marginal under-sizing.

5. The charging pump mini-flow through the Seal Water Heat Exchanger is assumed to have no adverse impact.

6. The air supply to FCV-5051 is conservatively modeled by neglecting the 30-minute backup nitrogen in the accumulator.

7. The DSD diesel is modeled as an alternate power source to Charging Pump G-8A.

8. Credit is not taken for the injection capability of the normal charging flow path through the regenerative heat exchanger or the hot leg injection path.

9. Any RCS break resulting in a LOCA is assumed to be located in one of the RCS cold legs such that any SI or charging flow being successfully injected into that leg would be entirely lost through spillage.

10. Diversion of charging flow to the normal charging flow path is neglected.

11. Instrument air lines are modeled only if failure of instrument air will result in valve failures in a non-safe position.

12. Flow diversion from Charging Pump G-8B through stuck open check valve VCC-306 with subsequent backflow through failed Charging Pump G-8A is not considered.

3.5.3 Recirculation System

Safety Function

The Post-LOCA Recirculation System is a part of the Recirculation System utilized for the removal of decay heat from the reactor following a LOCA event after the SI System has been secured. The Recirculation System has the following main function:

- Provide long term core cooling using spilled reactor coolant following a loss of coolant accident.

The system utilizes the containment sump recirculation pumps, recirculation heat exchanger, charging pumps, and cold leg injection lines for long term recirculation and cooling of the reactor.

System Configuration

The system consists of two recirculation sump pumps, sump discharge control valves, the recirculation heat exchanger, and the charging system including the charging pumps (see Figure 3-2). The normal recirculation flow path begins in the containment sump. Flow is discharged from each recirculation sump pump through a discharge valve into a common line and on to the recirculation heat exchanger. The recirculation water passing through the recirculation heat exchanger tubes is cooled by CCW on the shell side. From the recirculation heat exchanger flow, it passes to the Charging System where it is injected back into the RCS via the cold leg injection lines.

Other alternate recirculation flow paths exist which can be utilized in the event of a failure of the primary flow path. These include:

Alternate Cold Leg Injection: This flow path also uses the recirculation pumps through the recirculation heat exchanger to the refueling pumps suction. Flow then travels into the normal cold leg injection line downstream of the seal injection filter bypass valves. This alignment is used when normal cold leg injection is unavailable.

Normal Hot Leg Injection: The flow path uses the recirculation pumps and heat exchanger. From here, flow is directed to the charging pumps, then through the auxiliary spray valve into the pressurizer, and on into the loop B hot leg.

Alternate Hot Leg Injection: This flow path uses the recirculation pumps and recirculation heat exchanger. Flow is directed to the refueling pumps and then to the letdown system manual valve. From here, injection flow travels through the Residual Heat Removal System in <u>reverse direction</u>. Flow enters the bypass line of the east RHR pump, and is directed into reactor coolant loop hot leg C.

Each recirculation sump pump, in conjunction with a charging pump or refueling pump, is capable of delivering sufficient water to keep the core covered after safety injection is terminated. Each pump is controlled via a control switch in the control room. There are no automatic actions or trips associated with the pumps, and no automatic recirculation system actions which occur upon a switchover to the recirculation cooling mode. All system component alignments are performed remote-manually from the control room. Flow is the only parameter measured on the Recirculation System. Two flow elements and two flow transmitters provide signals to the control room.

System Operation

Cold leg recirculation is initiated manually by the operators. When RWST level reaches 20%, an automatic 2 out of 3 level signal trip stops the safety injection pumps and main feedwater pumps. This provides time for the operators to align and initiate the Recirculation System. When the RWST level reaches 12%, the operators initiate cold leg recirculation by: (1) starting both recirculation pumps, (2) throttling injection flow, (3) ensuring that component cooling water (CCW) and Saltwater cooling (SWC) are available, (4) opening CCW discharge valves from the recirculation heat exchanger, (5) closing containment spray isolation valves, (6) opening recirculation pump discharge valves and (7) isolating the RWST. When the Containment Spray System is used in conjunction with recirculation, the spray control valves must be closed. Approximately 19 hours after a loss-of-coolant accident occurs, the system is aligned for hot leg recirculation. The Recirculation System is normally maintained in standby readiness.

Success Criteria

For a small break LOCA, successful operation of the Recirculation System requires delivery of at least 150 gpm into the reactor core starting from termination of the Safety Injection System and continuing for 30 days. For this to happen, the following must occur:

- At least one charging pump must start and run for 30 days.

- At least one of the parallel seal supply filter bypass valves must open.

- At least one of the three possible cold leg injection lines must open into a non-ruptured RCS cold leg.

- Control Room operators must follow the instructions to obtain sufficient flow and to prevent excessive flow leading to pump runout and subsequent damage. Operator response time is critical.

- At least one of the three charging pump suction valves must open.

- At least one of the two Recirculation Pumps must start and run for 30 days.

- The discharge valve on the operating Recirculation Pump must open.

- The Recirculation Heat Exchanger must operate for 30 days.

- Support systems and power supplies must operate for 30 days.

Modeling Assumptions

The assumptions utilized in the development of the fault tree are listed below:

1. The normal charging pump line-up is assumed to be:

   (a) Charging Pump in Train "B" is running, and

   (b) Charging Pump in Train "A" is in stand-by

2. The standby Charging Pump may be out of service for maintenance for a period of 72 hours according to Technical Specifications.

3. Failure of VCT isolation valves MOV-1100C and MOV-1100E to close will result in the entrainment of VCT cover gas in the operating charging pump and non-recoverable failure of the pump due to cavitation. Failure of the VCT isolation valves to close will result in the entrainment of VCT cover gas in the standby charging pump <u>only if</u> the operator fails to correctly follow procedural instructions to start the recirculation pumps prior to starting the standby charging pump. (The discharge of the recirculation pumps will back-seat the VCT discharge check valve and prevent further entry of gas.)

4. Credit was not taken for the Fan Cooler E-909 on Charging Pump G-8B due to its marginal undersizing.

5. The charging pump mini-flow through the Seal Water Heat Exchanger is assumed to have no adverse impact.

6. The air supply to FCV-5051 is conservatively modeled by neglecting the 30-minute backup nitrogen in the accumulator.

7. The DSD diesel is modeled as an alternate power source to charging pump in Train "A".

8. Credit is not taken for the injection capability of the normal charging flow path through the regenerative heat exchanger, the normal hot leg injection flow path, or the alternate hot leg injection flow path.

9. Any RCS break resulting in a LOCA is assumed to be located in one of the RCS cold legs such that any SI or charging flow being successfully injected into that leg would be entirely lost through spillage.

10. Diversion of charging flow to the normal charging flow path is neglected.

11. The probability of undetected diversion of charging pump discharge back to the RWST via an open mini-flow path is considered negligible.

12. Instrument air lines are modeled only if failure of instrument air will result in valve failures in a non-safe position.

13. Flow diversion from Charging Pump G-8B through stuck open check valve VCC-306 with subsequent backflow through failed Charging Pump G-8A is not considered.

14. No credit is taken for closure of CV-92, CV-114, and CV-82 to backup failed Containment Spray Isolation valves CV-517 and CV-518.

3.5.4 Auxiliary Feedwater System

Safety Function

The Auxiliary Feedwater (AFW) System is a safety related system which provides feedwater to the steam generators in the event the Main Feedwater System is unavailable. The AFW System has two main functions.

1. To provide feedwater to the steam generators during abnormal or emergency conditions which result in a loss of main feedwater.

2. To provide feedwater to the steam generators during

normal startup, normal shutdown, and hot standby conditions.

In addition, the AFW system can be used to fill and vent the Main Feedwater System, and to fill the steam generators while in Modes 5 or 6.

System Configuration

Figure 3-3 presents a simplified P&ID of the AFW System. The AFW System takes suction on the auxiliary feedwater storage tank and provides feedwater to the steam generators via two independent and redundant feedwater trains. The "A" train utilizes a motor-driven pump and a turbine-driven pump, while the "B" train utilizes only a motor-driven pump. The condensate storage tank (CST) is also available for use as an AFW source.

The flow from each AFW pump branches out into three lines such that either train of AFW can feed any steam generator. The Auxiliary Feedwater System can be connected to the Main Feedwater System via manual operator action. For each AFW pump there is a minimum flow recirculation line back to the AFW storage tank. Train "B" motor driven pump serves as the dedicated safe shutdown (DSD) pump, and can be powered and manually controlled from the DSD system. The pump trips only on timed and instantaneous overcurrent. The train "A" motor driven pump trips on low suction pressure, overcurrent or loss of power. The train "A" steam driven pump is powered from the west main steam header, and can be started in 3.5 minutes. This pump trips on low suction pressure and turbine overspeed.

Independent and redundant flow control valves are used to control the AFW flow to each steam generator. Similarly, independent and redundant instrumentation is used to monitor steam generator levels and generate actuation signals for individual AFW components. The instrumentation and component configuration is designed to allow any AFW train to provide water to each of the three steam generators.

System Operation

During normal operation, the AFW system is in automatic mode. An AFWAS signal automatically initiates Train "B" flow. Train "A" is used in case Train "B" fails or is insufficient. In the standby mode, the suction of all three AFW pumps is aligned to the AFW storage tank, and all three discharge flows from each pump are aligned to the steam generators. The pump discharge valves and the auxiliary feedwater regulating valves are closed and all other valves open. The AFWAS signal opens the discharge valve of the Train "B" pump (or the Train "A" pumps if needed), and the auxiliary feedwater regulating valves. Each pump and its discharge valves, as well as the auxiliary feedwater regulating valves can also be manually controlled from the control room.

The AFW G-10W pump is normally controlled from the main control room at the Auxiliary Feedwater Panel. With Train "B" in "AUTO" mode, the AFW G-10W pump will be started upon receipt of an initiation signal from Train "B" of the Auxiliary Feedwater Actuation System. The pump may also be started in the "AUTO" mode by operation of the "AFWS INITIATE-TRAIN B" switch at the Auxiliary Feedwater Panel.

Success Criteria

Following a small LOCA, steam line break, feedwater line break, or loss of main feedwater, at least one AFW train is required to function successfully for 24 hours. In order to function successfully, the train has to satisfy the following:

1. An AFWAS "X" must actuate either manually or automatically.

2. AFW pump "X" must start and run for 24 hours.

3. Either the AFW storage tank or the condensate storage tank and its flow path to the AFW pump must be functional.

4. The discharge from one AFW pump must be delivered to at least one steam generator.

5. The AFW pump discharge valve from the operating pump must open, and one of the six AFW flow control valves must open and remain properly positioned for 24 hours.

6. The AFW support systems and power supplies must operate for 24 hours.

Fault Tree Modeling Assumptions

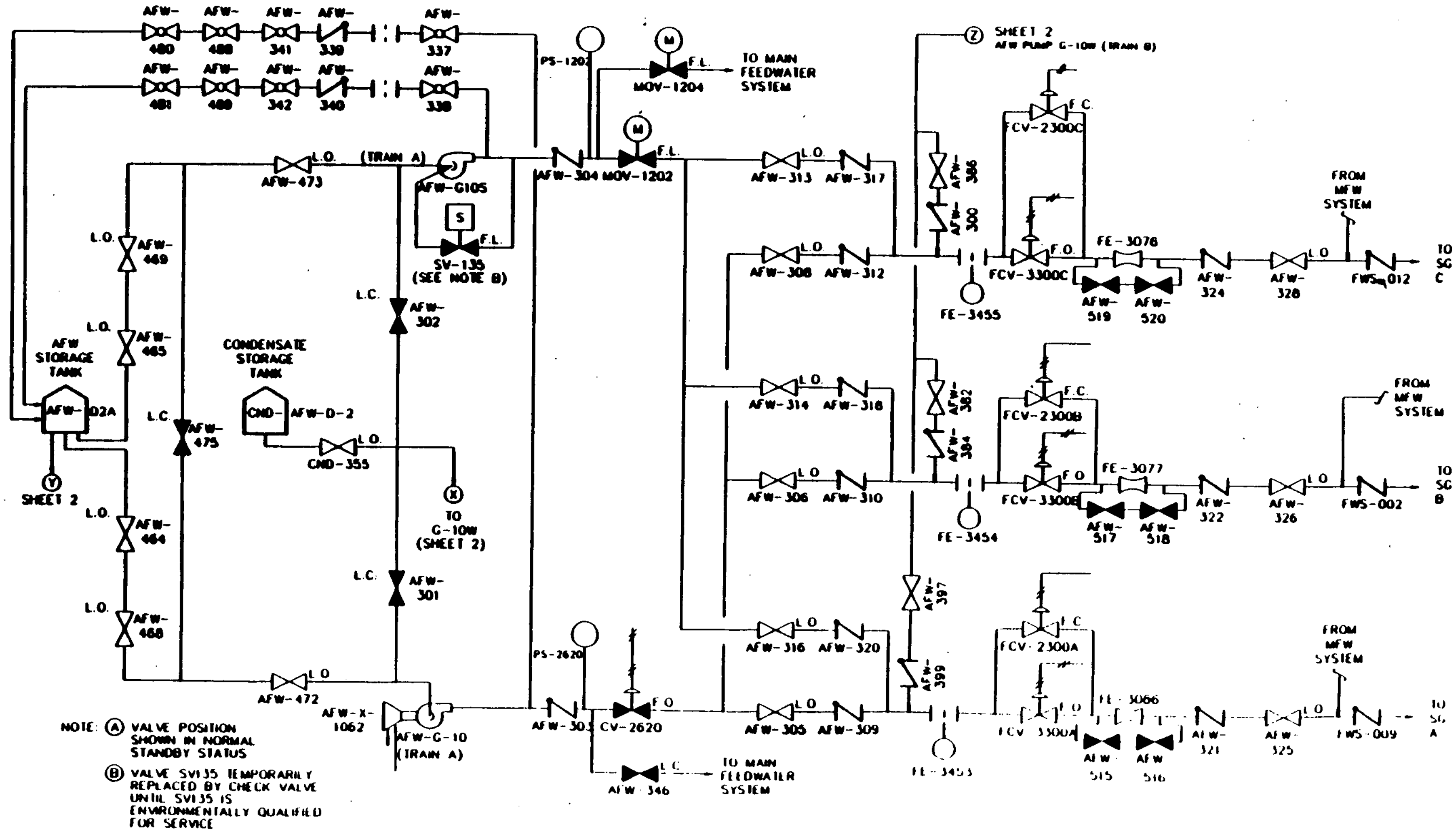
The assumptions used in development of the fault tree are listed below:

1. Flow diversion to the Main Feedwater System is included in the fault tree as a single event; however, multiple check valve failures are involved.

2. Flow diversion from Train "A" AFW System to Train "B" is not modeled, since multiple check valve failures are involved and because isolation valve CV-3110 is normally closed when the system is not operating.

Figure 3-3
Sheet 1

SAN ONOFRE UNIT 1 AUXILIARY FEEDWATER SYSTEM TRAIN "A"

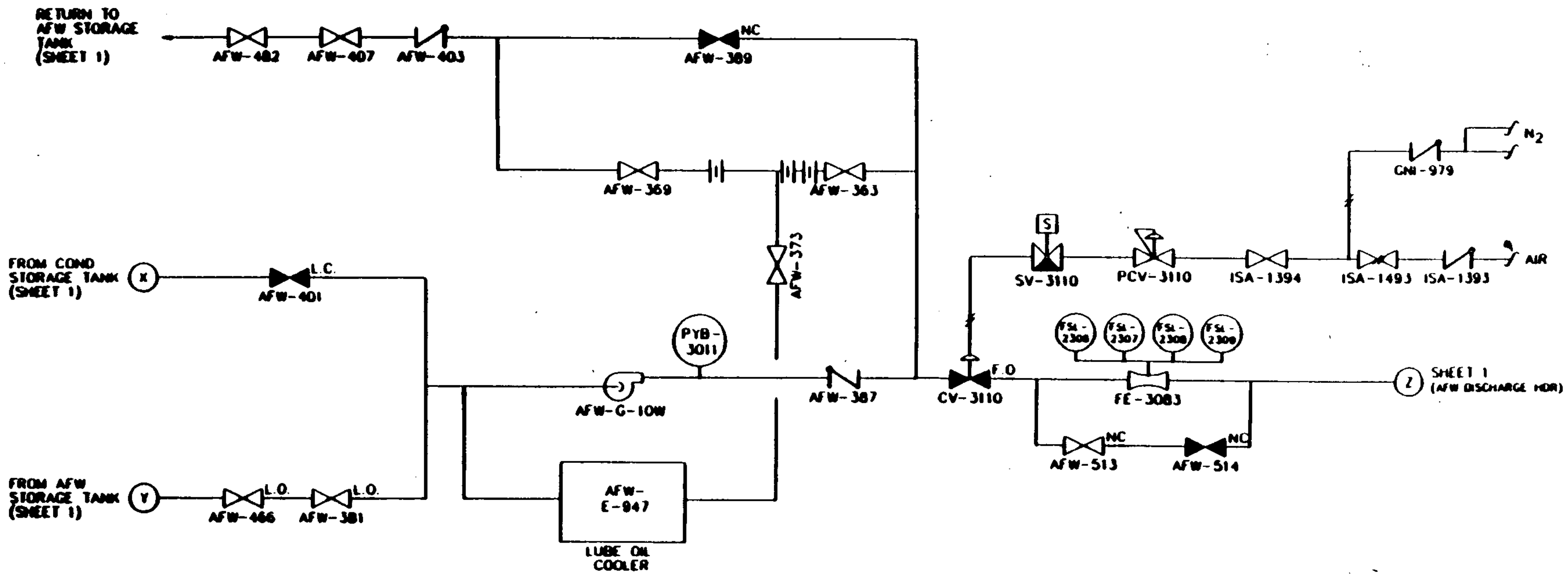


NOTE: Ⓐ VALVE POSITION SHOWN IN NORMAL STANDBY STATUS

Ⓑ VALVE SV135 TEMPORARILY REPLACED BY CHECK VALVE UNTIL SV135 IS ENVIRONMENTALLY QUALIFIED FOR SERVICE

Figure 3-3
Sheet 2

SAN ONOFRE UNIT 1 AUXILIARY FEEDWATER SYSTEM TRAIN "B"



3. The failure of motor-driven AFW Pumps to start or run is not assumed to be recoverable. While the failure of the turbine-driven AFW pump to run is also not recoverable, failures of this pump to start due to overspeed trips can be recovered.

4. Electrical failures of the flow controllers are conservatively assumed to occur such that their respective Flow Control Valves (FCVs) will close, regardless of whether the FCV is a Fail Open or Fail Closed valve.

5. Backup sources of water to the suction of the AFW pumps (e.g., fire water, reservoir) are not considered.

6. Overfilling of a steam generator and flooding of a main steam line with feedwater is not assumed to create a core cooling problem except for the steam lines feeding the turbine-driven AFW pump turbine. The turbine-driven AFW pump is assumed to fail if steam generator overfill occurs.

7. Overheating of AFW pumps due to failures of mini-flow recirculation paths is not modeled, since dead-heading of pumps cannot occur without injection path failure.

8. Service water cooling to the turbine-driven AFW Pump is not modeled, because it is not required for the operation of the pump.

3.5.5 Main Feedwater and Emergency Condensate Feed System

System Function

The Main Feedwater System has the following primary function:

1. To transfer dearated condensate from the condenser hot wells through two parallel trains of feedwater heaters to the steam generators as the normal source of steam generator secondary makeup water.

In addition, the main feedwater pumps are also utilized as part of the plant's Safety Injection System. Upon receipt of an SIS, the feedwater pumps are isolated from the Main Feedwater System and are aligned to the safety injection flow paths.

System Configuration

Figure 3-4 presents a simplified P&ID of the Main Feedwater and Condensate System.

The main feedwater system takes its suction from the main condenser. Four condensate pumps discharge to a common header, after which there are two feedwater trains. Each train consists of a series of heaters, a feedwater pump, and pneumatic hydraulic valves at the suction and at the discharge of the pump. The two feedwater trains discharge to a common header, from which the three steam generators are supplied their feedwater through independent flow paths. Each of the three flow paths also allows bypass flow along an additional flow path.

There are also pneumatic/hydraulic valves at the suction and at the discharge of each feedwater pump, which can be opened upon SI signal, to connect the pumps to the safety injection system.

The main feedwater pumps are motor-driven, for the purpose of their dual use. The system does not have automatically actuated main feedwater isolation valves.

System Operation

The Main Feedwater System can provide flow to the steam generators provided that an SIS actuation has not occurred and the feedwater pumps have not realigned to the SI System. Also all power needs to be available to run the main feedwater pumps and condensate pumps. Existing piping also allows bypassing the main feedwater pumps and using the condensate pumps to directly feed the steam generators through the feedwater heaters.

Success Criteria

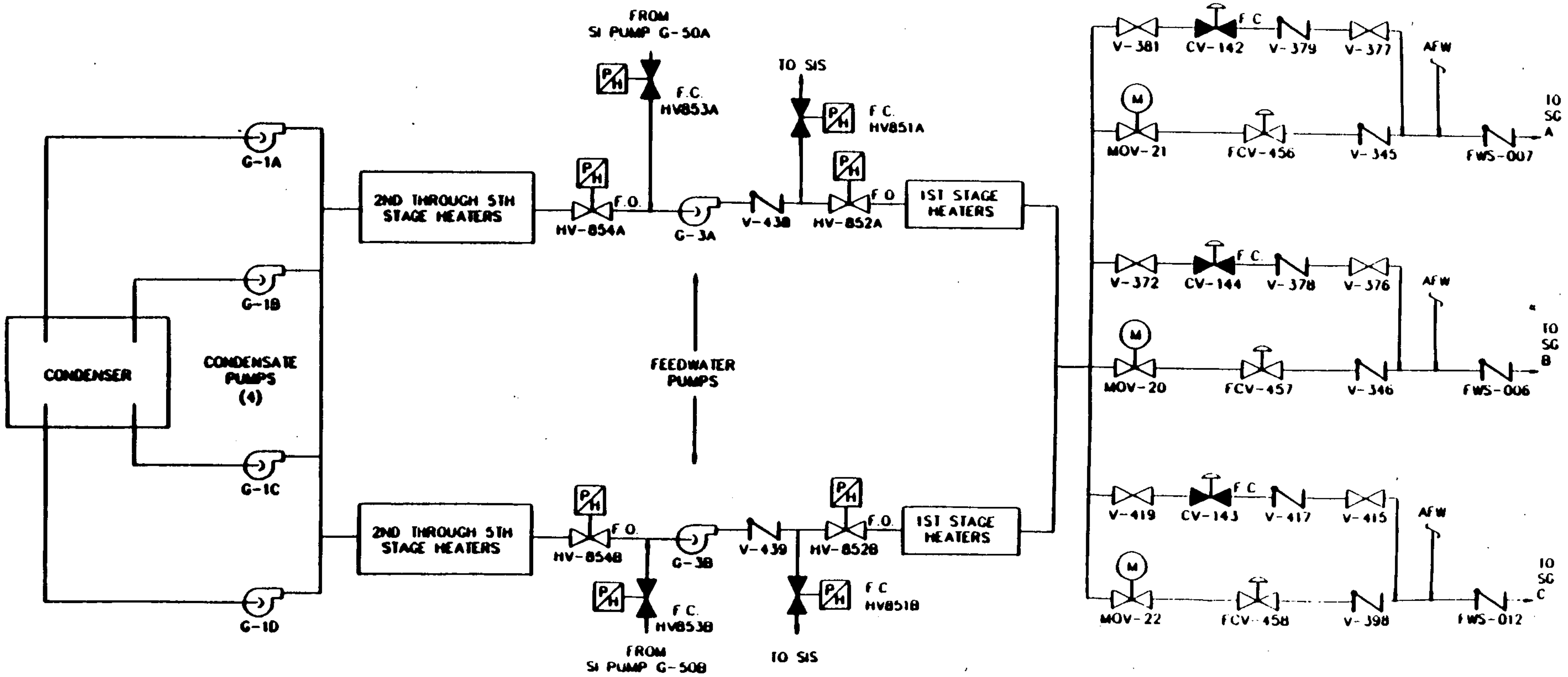
Following LOCA and steam line break events, the main feedwater pumps will realign to the SI System as a result of an SI actuation. Therefore, the Main Feedwater System will be unavailable.

Following a loss of main feedwater event, it is assumed that main feedwater could be recovered prior to the time the steam generators boil dry (approximately 30 minutes). Following the loss of main feedwater, success is defined in the recovery of one feedwater train consisting of:

1. One condensate pump restarting and running for 24 hours.
2. One feedwater pump restarting and running for 24 hours.
3. One feedwater control valve to a steam generator functions.

Figure 3-4

SAN ONOFRE UNIT 1 CONDENSATE/FEEDWATER SYSTEM



Fault Tree Modeling Assumptions

The assumptions used in the construction of the fault tree are listed below:

1. Only 1 feedwater pump is required to run in order to supply sufficient makeup to the steam generators following a reactor trip. Only one of the four condensate pumps is assumed necessary to provide adequate water supply for the feedwater pumps under shutdown conditions.

2. The failure of manual valves in the feedwater path is neglected. These manual valves are normally open.

3. Failures of feedwater heaters or heater drain pumps are not included in the model.

4. The reactor trips upon a steam flow/feed flow mismatch signal allowing the initial steam generator with inventory to be at or near its normal full power value.

3.6 Structural Target Interactions Evaluation

3.6.1 Jet Impingement Geometry

For component targets which were evaluated for qualification under jet impingement loads, walkdowns were performed to provide detailed geometry of the interaction. The target qualification walkdown and analysis of jet impingement effects were based on the following jet modeling assumptions:

1. A discharging jet from a steam, steam-water mixture or subcooled flashing water line was assumed to expand at 10° half-angles. Subcooled nonflashing water jets were assumed to be nonexpanding.

2. The jet was assumed to proceed along a straight path from the exit plane. Gravity effects were neglected.

3. Jet source located more than 10 times the pipe diameter from any structural targets was assumed not to produce sufficient pressure to cause significant damage (10D criteria).

4. The pressure of the fluid jet was assumed to be uniformly distributed over any cross-section normal to the axis of the jet.

5. Shadowing of a target by intervening structures was considered. Reformation or deflection of the blocked portion of the jet was not considered.

6 For low pressure lines, the effects of pipe whip were not considered (i.e. the pipe was not considered capable of whipping) if the existing supports were qualified for the HELB reaction loads.

7 The break opening was assumed to reach full size instantaneously after break initiation.

3.6.2 Jet Impingement Load Definition

The jet thrust from the ruptured pipe was defined by:

$$P_{jet} = C_T \; P_o \; A$$

where:
P_{jet} - jet thrust
C_T - thrust coefficient
P_o - initial pressure
A - pipe break area

The value of C_T depends on the fluid conditions and the friction losses between the reservoir and the break location (Reference 41). For frictionless flow of steam, saturated water, or steam-water mixtures, C_T will be 1.26. For frictionless flow of subcooled flashing water, C_T will be between 1.26 and 2.0. For subcooled non-flashing water, C_T will be 2.0.

3.6.3 Qualification Analysis

Analysis was performed in order to determine if essential structures are qualified under the application of jet impingement forces. This section describes methodologies used for determining jet impingement forces and for evaluating target response.

The jet impingement force acting on the target was obtained from the following equation:

$$F_{imp} = K_O \; T_{jet} \; \frac{A_{tar}}{A_{jet}}$$

where:
F_{imp} = impingement force on target
K_0 = the target shape factor
T_{jet} = jet thrust
A_{tar} = the projected area of the impinged portion of the target on to a plane which is perpendicular to the axis of the jet

A_{jet} = the cross sectional area of the jet perpendicular to the jet axis at the target location

Structural analysis methods for determining the response of the target from jet impingement loads considered the dynamic characteristics of the loading.

Equivalent static analysis was used for component and structural evaluations. This type of analysis modeled the impingement force as a static load with a magnitude equal to the jet impingement force multiplied by a dynamic load factor, as follows:

$$F_s = DLF\ (F_{imp})$$

where:

F_s - equivalent static impingement force
DLF - dynamic load factor
F_{imp} - jet impingement force

A DLF of 2.0 was conservatively used unless a lower value was justified by analysis.

3.6.4 Target Qualification of Structures

Girders and columns in the turbine building were evaluated using a two-step methodology, consisting of (1) an initial screening and (2) walkdown and detailed evaluation.

The structural steel girders and columns were evaluated for the occurrence of the jet impingement load in combination with the dead loads.

For the initial screening, a lower bound capacity for each structural member was developed. Both the member and end connection were evaluated using several conservative assumptions.

The full jet thrust load was assumed to act at the point which results in maximum stresses. The load was assumed to cause minor axis bending of the member. Conservative end restraint assumptions were made to maximize stresses in the member and any bracing members, attachments to concrete slab, torsional assemblies, and reinforcements to members were neglected in this initial screening.

If the members and connections met the structural acceptance criteria, the member was qualified. This approach was used to screen out interactions where the impingement load was much lower than the member capacity.

For members which failed the initial screening, a walkdown was performed to allow a more specific evaluation of the interaction. A detailed evaluation was then performed considering several factors. The impingement load was reduced considering the fraction of the total jet which impinged on the target and shadowing by intervening structures. The angle at which the blowdown load impinges on the member was determined and the increased capacity obtained when the load is partially resisted in the major axis was included. The actual location of impact of the load on the member was considered. Reinforcements on the member (e.g., modified section, stiffened end restraints, attachment to concrete slab, or torsional assemblies) were considered.

Members which did not qualify after reviewing the above steps were identified as requiring additional detailed analysis per methodology based on inelastic criteria.

3.6.5 Methodology Based on Inelastic Criteria

This section describes the additional structural analysis methodologies employed to determine design forces and ductilities at critical locations of the structure. The structural analyses were performed by both manual and computer methods.

As discussed in ANSI/ANS-58.2-1980, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," (Reference 41), Section 6.3, when a postulated ruptured pipe results in a whipping pipe, two design considerations shall be evaluated:

1. The dynamic event of the pipe whipping into nearby structures or components. The piping will acquire kinetic energy as it moves across a gap toward an impact with nearby structures or components. The evaluation demonstrated that the total energy acquired would be dissipated in the piping, restraints, and supporting structure.

2. The steady state condition after pipe motion ceases, but the jet continues to blowdown.

The first loading condition was evaluated by manual analyses as discussed below. The second loading condition was evaluated by computer analyses as discussed in the following paragraph.

Computer analyses were performed for the evaluation of HELBA jet impingement loads. The structure was modeled as an assemblage of finite elements and the analysis was performed using standard finite element methods and STAAD III, which is a general purpose computer program for linear-type finite element analyses. This program used the direct stiffness approach to perform linear elastic analyses of one-, two-, or three-dimensional structural models.

Manual analyses were performed for the evaluation of HELBA pipe whip loads. The structural members evaluated herein were all ductile structural steel and the analyses were performed using standard structural analysis techniques. The analysis uses the energy balance techniques, discussed as follows.

Methodology for Evaluating Pipe Whip Impact on Structural Steel

For any body being acted on by an external force (F) and rotating about a fixed axis (the hinge location of the pipe), the following equation provides the relation between the forces on the rotating body and its angular acceleration.

$$F*r_o = I_m*\alpha$$

where:

F = External force acting on the body
r_o = Distance from axis of rotation to the location of the external force
I_m = Mass moment of inertia = $\Sigma[(m_i)(r_i)^2]$
α = Angular acceleration (radians/sec^2)

Rewriting the above equation:

$$\alpha = \frac{F*r_o}{I_m}$$

The equation for rotation with constant angular acceleration is:

$$\omega^2 = \omega_o^2 + 2*\alpha*\theta$$

where:

ω = Angular velocity (radians/sec)
ω_o = Angular velocity at time 0 (radians/sec)
θ = Angular displacement of a rotating body (radians)

Since ω_o is zero, the equation can be rewritten as:

$$\omega = \sqrt{2*\alpha*\theta}$$

Substituting α into the above equation:

$$\omega = \sqrt{\frac{2*F*r_o*\theta}{I_m}}$$

The total Kinetic Energy (KE) of the rotating pipe is:

$$KE = \frac{I_m*\omega^2}{2}$$

Substituting ω into the above equation:

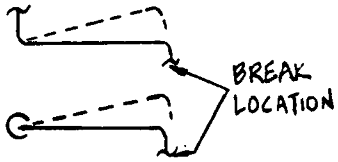
$$KE = F*r_o*\theta$$

Apply a 1.1 factor to the above equation to account for rebound effects (as discussed in "Design for Pipe Break Effects," BN-TOP-2, Rev. 2, Appendix C and ANSI/ANS-58.2-1980, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," subsection 6.3.4).

$$KE = 1.1*F*r_o*\theta$$

There are two types of plastic hinges (shown below) which are formed:

- "Bending type" plastic hinges
- "Twisting type" plastic hinges



The energy absorbed by "bending type" plastic hinges will be developed herein. The energy absorbed by "twisting type" plastic hinges will not be developed since the "twisting type" plastic hinges being evaluated in this calculation have small thrust forces and will not result in ductility ratios which exceed the allowables.

M_p = Plastic moment of the pipe

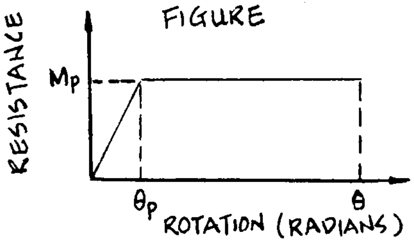
= $(DIF)*F_y*Z$

where: DIF = Dynamic Increase Factor (Refer to Ref. 65, Table 1)

F_y = Yield Strength of the Pipe
Z = $t*d^2$

E_p = Energy absorbed by the pipe hinge
= Area under the curve (See figure at right)
= $M_p[\theta-(\theta_p/2)]$

$$\theta_p = \frac{F_p*L^2}{2*E*I_p}$$



where : F_p = Force required to form a plastic hinge
L = r_o = Moment arm
E = Modulus of elasticity of steel
I_p = Moment of inertia of the pipe
F_p*L = M_p

Thus, θ_p can be rewritten as:

$$\theta_p = \frac{M_p*r_o}{2*E*I_p}$$

E_p can be rewritten as:

$E_p = M_p[\theta-(M_p*r_o)/(4*E*1_p)]$ (for "bending type" plastic hinges only)

$E_p = 0$ (Conservative) (for "twisting type" plastic hinges only)

The strain energy (E_s) to be absorbed by the structural member to stop the pipe:

E_s = (Total KE of the rotating pipe) -
(Energy absorbed by the pipe hinge)

For "bending type" plastic hinges only

$$E_s = 1.1*F*r_o*\theta - M_p\left(\theta - \frac{M_p*r_o}{4*E*I_p}\right)$$

For "twisting type" plastic hinges only

$$E_s = 1.1*F*r_o*\theta$$

For elasto-plastic target response, the ductility ratio (μ) was obtained from BC-TOP-9-A (Reference 67), Revision 2, "Design of Structures for Missile Impact," Equation 3-22.

$$\mu = \frac{E_s}{X_e * R_m} + \frac{1}{2}$$

where: X_e = Yield displacement of the structural member

R_m = Plastic resistance

Substituting for E_s:

- For "bending type" plastic hinges only:

$$\mu = \frac{1.1 * F * r_o * \theta - M_p\left(\theta - \dfrac{M_p * r_o}{4 * E * I_p}\right)}{X_e * R_m} + \frac{1}{2}$$

- For "twisting type" plastic hinges only:

$$\mu = \frac{1.1 * F * r_o * \theta}{X_e * R_m} + \frac{1}{2}$$

For cases with biaxial loads:

- For "bending type" plastic hinges only:

$$\mu = \sqrt{\left[\frac{1.1 * F_{y-y} * r_o * \theta - E_p * \left(\dfrac{F_{y-y}}{F}\right)}{X_{e_{y-y}} * R_{m_{y-y}}}\right]^2 + \left[\frac{1.1 * F_{z-z} * r_o * \theta - E_p * \left(\dfrac{F_{z-z}}{F}\right)}{X_{e_{z-z}} * R_{m_{z-z}}}\right]^2} + \frac{1}{2}$$

- For "twisting type" plastic hinges only:

$$\mu = \sqrt{\left[\frac{1.1 * F_{y-y} * r_o * \theta}{X_{e_{y-y}} * R_{m_{y-y}}}\right]^2 + \left[\frac{1.1 * F_{z-z} * r_o * \theta}{X_{e_{z-z}} * R_{m_{z-z}}}\right]^2} + \frac{1}{2}$$

Assumptions

1. The beams were assumed to be simply supported at their connections. This was appropriate due to their end connections, and since this maximizes the moment in the beam. For continuous girders, moment capacity was accounted for at intermediate column support points. Column bases that were embedded in the concrete foundation were assumed to be fixed, otherwise they were conservatively assumed to be simply supported.

2. The loads and load combinations on the structural steel were based on Reference 65. P_a loads were not applicable since the Turbine Building is an open area such that there was insignificant subcompartment pressurization. T_a loads were not applicable since they do not act concurrently (the time to increase the temperature of the beam was greater than the blowdown time of the jet) with the jet loads or pipe whip loads, and they act only over a local area of the member.

3. All pipe reactions were based upon Return-To- Service (RTS) calculations IPTC-CC-03.14 (Reference 68) and IPTC-CC-03.15 (Reference 69). These R_a loads do not have their seismic loads separated from the total loads; therefore, the total R_a load was conservatively used. The Square Root of the Sum of the Squares (SRSS) method has been utilized for all the pipe reactions on the columns since it is not likely to have all the pipe reactions acting at the same time. For beam evaluations, the pipe reactions were conservatively combined using the Absolute Sum method.

4. All pipelines were assumed as a single line for geometrical calculation purpose. This was conservative since this results in larger angles of pipe rotations than what can actually occur.

5. For pipe whip evaluations, the energy absorbed by crushing of the pipe during impact with structural members conservatively neglected.

3.7 Leak-Before-Break

The methods and procedures applied for the leak-before-break analysis steps are described in this section. The LBB approach was applied to nineteen (19) large diameter high energy line piping inside containment where physical modifications were impractical.

3.7.1 Detectability Determination

Postulated break locations on the pipes were determined using the FMA criteria. Crack detectability was determined and covers all postulated break locations.

Using pipe dimensions, material properties, and operating loads as determined from current piping stress analyses, the CRACK computer program was used to calculate the crack opening area and stress intensity factor, K_I, for a crack with a specified length and orientation (circumferential was found to be the worst case orientation). The crack opening area was then input into the IMLEAK computer program along with the operating conditions to determine the amount of leakage that would occur through the crack. Detectability was demonstrated by establishing a 1 gpm leak rate.

3.7.2 Integrity Evaluation

A linear elastic fracture mechanics analysis, with plastic zone corrections, was used to compute the stress intensity factor, K_I, for the postulated cracks, under normal plus maximum seismic conditions. The CRACK computer program was used. The Level D loads at each postulated break location were obtained from the piping analyses and combined in accordance with the guidance provided by NUREG-1061, Reference 10. When the computed K_I is less than the material fracture toughness K_{IC}, crack stability was assured.

To evaluate global stability of the piping, the limit moment that the uncracked portion of the pipe could carry was calculated and compared to the calculated applied moment. The limit moment was computed in accordance with the guidelines provided in NUREG-1061, Volume 3, Appendix A, Equation A-19 (Reference 10). Acceptability was demonstrated when the ratio of the limit moment to the applied moment remained greater than 1.0.

Lower-bound fracture toughness for the piping materials was based on a review of published test results. Typical weld procedures used on SONGS-1 piping were reviewed and lower bound fracture toughness was determined which covers both the base metal and the weldment.

Similar to the Level A leak rate computation, the crack opening dimensions are obtained from the Level D CRACK computer runs. The crack opening areas, crack geometrics and associated normal operating conditions are input into the IMLEAK program. IMLEAK computes the resulting leak rate and pressure at the exit plane. The resulting Jet under Level D conditions was evaluated for potential damage to safety related structures.

3.7.3 Subcritical Crack Development

The subcritical crack development evaluation demonstrated that partial-through wall cracks are likely to break through the pipe wall and leak before they will progress around the pipe and cause a complete break. The tendency for development of a leak-before-break condition was verified for the two conditions that are of major interest: normal operation and large bending loads in excess of those postulated for seismic loading. Industry service experience and previously performed analyses were reviewed to perform this evaluation.

3.8 Environmental Analysis

Equipment Qualification

Equipment which was required to be operable during and after a postulated pipe break was qualified either by testing or analysis to demonstrate operability in the environmental condition for the equipment location. For qualification of equipment, the plant area and associated environmental profiles (HELB, LOCA, MSLB) were documented in Appendices B and C of the Retrofit General Design Criteria (RGDC, Reference 45). As part of the HELB analysis, the most severe pressure and temperature profiles (References 42 and 43) were calculated for each high energy line breaks. The result profiles were then compared and verified to be bounded by the EQ profiles of the RGDC.

Compartmental Pressurization

Safety related Structures were required to be qualified for the effects of compartmental pressurization due to high energy line breaks. Pressure profiles for various plant area were calculated as part of the EQ Program. Analyses were performed using these pressure profiles to determine the adequacy of the building structures to withstand the imposed pressure loadings.

Flooding analysis

Flooding effects were evaluated based on the following methodology :

1. Identify major sources of flooding for every fluid carrying piping systems.
2. Identify safety related equipment in each respective area.
3. Assume the worst flooding situation from major source of flooding located by area.
4. Evaluate whether current plant design is adequate to accommodate each flooding condition due to pipe break.

4.0 RESULTS

4.1 Leak Before Break (LBB)

Leak-Before-Break Numerical Results

Leak-before-break (LBB) evaluations were performed for nineteen large diameter piping lines inside containment. Ten lines were evaluated as part of HELBA to address the SEP topics III-5.A and nine reactor coolant loop lines were evaluated as part of the resolution of the asymmetric LOCA loads issue. Table 4-1 lists the lines and presents the results of the analyses. The SEP criteria for crack stability and detectability were applied to line MSS-3-20. The other lines were evaluated by showing crack stability for crack sizes large enough to meet the 1 gpm global stability limit.

Detectability Evaluation

For each line, results are presented for one or more break locations, depending upon the number of postulated breaks and the extent to which enveloping conditions were used to evaluate the breaks. The crack size used for the detectability evaluation and the leak rate determined is listed in the third column. A minimum crack length of 2 times the pipe wall thickness was evaluated.

The 1 gpm criteria is met for all lines except MSS-3-20. The postulated break point which did not meet the leak detectability criteria was eliminated based on pipe break stress allowable.

Integrity Evaluation

The crack size evaluated for local stability under normal plus seismic loads and the resulting stress intensity factor is given in the fourth column. For MSS-3-20, a 4 times the pipe wall thickness crack was evaluated and for the other lines, the crack size determined in the detectability evaluation was used.

Lower bound material fracture toughness values are given for each line. The FWS and MSS lines are SA 106 carbon steel and the RCS lines are SA 312 stainless steel. The values given are conservative lower bound values which envelop available test data for both the pipe base metal and the welds.

The material fracture toughness is greater than the applied stress intensity factor for all break locations and local stability of the postulated cracks is demonstrated.

Finally, the ratio of the plastic moment capacity of the pipe, considering the capacity reduction due to the crack postulated for the stability analysis, to the normal plus maximum seismic moment is given in the last column. All ratios are greater than one, demonstrating that global instability of the piping system will not occur.

TABLE 4-1

LEAK BEFORE BREAK RESULTS

Line Number	Break Location	Leak Rate Under Normal Operating Conditions (Size/gpm)	Crack Stability Under Normal and Seismic Conditions (Size/$K_I$ksi$\sqrt{in}$)	Lower Bound Material Fracture Toughness K_{IC} (ksi$\sqrt{in}$)	Net Section Evaluation $M_{LIMIT}/M_{APPLIED}$
FWS-391-10 Inside Containment	D.P. 70	7t/1.00	7t/58.5	168.4	3.23
	D.P. 45	7t/1.00	7t/123.8	168.4	1.80
	D.P. 5	6t/1.00	6t/60.1	168.4	2.86
FWS-392-10 Inside Containment	D.P. 870	7t/1.00	7t/49.2	168.4	3.88
	D.P. 160	7t/1.00	7t/93.8	168.4	2.09
	D.P. 5	6t/1.00	6t/46.3	168.4	3.75
FWS-393-10 Inside Containment	D.P. 650	7.5t/1.00	7t/57.9	168.4	3.33
	D.P. 631	6t/1.00	6t/Not Converging(1)	-	1.24
	D.P. 600	6t/1.00	6t/60.7	168.4	2.83
MSS-3-20	121	2t/0.10	4t/144.6	168.4	1.46
	122W	2t/0.08	4t/138.2	168.4	1.49
	127R	2t/0.07	4t/ 86.3	168.4	1.96
	128C	2t/0.09	4t/132.6	168.4	1.52
	129	2t/0.09	4t/132.6	168.4	1.53
MSS-4-20	130	4.5t/1.12	4.5t/46.2	168.4	3.77
	138	4.5t/1.15	4.5t/45.7	168.4	3.88
MSS-5-20	139	6t/0.92	6t/36.3	168.4	6.69
	147	5t/1.03	5t/32.9	168.4	6.76
MSS-6-24	89L	4.5t/0.98	4.5t/91.7	168.4	2.18
MSS-7-24	24/24L	4.5t/1.04	4.5t/67.2	168.4	3.02
RCS-5002-8	ANCH	2.375t/0.98	2.375t/45.3	158.9	2.29
	192	2.5t/1.05	2.5t/39.3	158.9	2.91
RCS-5013-10	1020	2t/3.02	2t/ 65.6	158.9	2.12
	1080	2t/2.66	2t/ 78.8	158.9	1.86
	1210	2t/3.69	2t/154.0	158.9	1.46

(1) Crack stability demonstrated by hand calculation using EPFM approach.

Subcritical Crack Development Review

For normal operating conditions, there is a large amount of service experience which demonstrates that cracks progress radially though the pipe wall and result in leak-before-break conditions. As indicated in References 40 and 41, incidents of pipe cracking have been documented at a number of PWRs in the United States. These references discuss pipe that is 4 inches or more in diameter, which includes the pipe sizes being considered in this evaluation.

The statistics show data with a wide range of crack sizes and piping systems. The cracks result from various initiation and propagation mechanisms, such as intergranular stress corrosion cracking, thermal fatigue, dynamic loads, and erosion/cavitation. In addition, these various type cracks are exposed to different combinations of stress states, i.e., bending and tension. For all the different conditions that actually occur in service, the cracking data indicate that the likelihood of a significant break is remote and that the dominant behavior for intermediate and large diameter piping is for the crack to grow radially though the wall to produce the leak-before-break condition.

Because accident loadings have a very low rate of occurrence, it is not possible to use service experience to define crack growth. Instead, analyses are used to demonstrate that the leak-before-break condition will be maintained for loads in excess of postulated large accident seismic loads. The study described in Reference 42 defined the ratio of the J-integral in the circumferential-to-radial direction for a partial-through-wall crack in a pipe. The analytic results indicate that the value of J in the radial direction is always greater than the value of J in the circumferential direction for all combinations of depth to wall thickness and circumferential distance around the pipe. Results presented in Reference 42 demonstrate that there is a strong tendency for leak-before-break conditions to exist for loads in excess of large postulated seismic loads.

Based upon a review of documented incidents of cracked piping in RHRs and review of analysis of circumferential cracks, LBB is applicable to the piping considered in this evaluation.

4.2 Augmented Inservice Inspection (ISI)

Table 4.2 summaries the results of the ISI points comparison. The augmented inservice inspection program was established, in lieu of encapsulated pipe sleeves, for welds associated with postulated break points on the main steam and main feedwater lines outside containment. These postulated break points were revalidated due to piping evaluation performed for the RTS/LTS seismic programs. A total of twenty-seven lines (27) contained all the ISI weld points identified in the program. If all the postulated break points at the pipe were enveloped by the augmented ISI program, the pipe break effects were considered resolved and further evaluation was not performed.

TABLE 4-2

AUGMENTED INSERVICE INSPECTION RESULTS

Line Number	Stress Calculation No.	Break Points Enveloped by ISI	Comments
AFW-381A-3"-3ACB	DC-859	Yes	Postulated Breaks Points Enveloped by ISI.
AFW-381B-3"-3ACB	DC-859	Yes	Same as Above
AFW-381C-3"-3ACB	DC-859	Yes	Same as Above
FWS-319-12"-EG	SI-51	Yes	No Intermediate Break Points Postulated. Terminal End Points Enveloped by ISI.
FWS-319-14"-EG	SI-51	Yes	Same as Above.
FWS-320-12"-EG	FW-04	Yes	Same as Above.
FWS-320-14"-EG	FW-04	Yes	Same as Above.
FWS-321-12"-EG	FW-04	Yes	Same as Above.
FWS-321-14"-EG	FW-04	Yes	Same as Above.
FWS-322-12"-EG	FW-04	Yes	Same as Above.
FWS-322-14"-EG	FW-04	Yes	Same as Above.
FWS-323-12"-EG	FW-04	Yes	Same as Above.
FWS-324-12"-EG	FW-04	Yes	Same as Above.
FWS-325-10"-EG	FW-04	No	Postulated Breaks Points not Enveloped by ISI.
FWS-325-18"-EG	FW-04	Yes	No Break Points Postulated.
FWS-326-10"-EG	FW-04	No	Postulated Breaks Points not Enveloped by ISI.

TABLE 4-2 (Continued)

AUGMENTED INSERVICE INSPECTION RESULTS

Line Number	Stress Calculation No.	Break Points Enveloped by ISI	Comments
FWS-329-10"-EG	FW-04	No	Postulated Breaks Points not Enveloped by ISI.
FWS-391-10"-EG Outside Containment	FW-04	Yes	No Intermediate Break Points Postulated. Terminal End Points Enveloped by ISI.
FWS-392-10"-EG Outside Containment	FW-04	Yes	Same as Above
FWS-393-10"-EG Outside Containment	FW-04	Yes	Same as Above
FWS-14104-4"-EG	FW-04	Yes	No Break Points Postulated.
FWS-14109-4"-EG	FW-04	Yes	Same as above.
FWS-14114-4"-EG	FW-04	Yes	Same as above.
MSS-1-24"-EG	MS-01/122	Yes	No Intermediate Break Points Postulated. Terminal End Points Enveloped By ISI.
MSS-2-24"-EG	MS-01/122	Yes	Same as above.
MSS-14-20"-EG	MS-03	Yes	No Break Points Postulated.
MSS-17-8"-EG	MS-02	No	Postulated Breaks Points not Enveloped by ISI.
MSS-18-10"-EG	MS-01/122	Yes	Postulated Breaks Points Enveloped by ISI.
MSS-50-24"-EG	MS-01/122	No	Postulated Breaks Points not Enveloped by ISI.
MSS-51-24"-EG	MS-01/122	Yes	No Break Points Postulated.

4.3 PRA Results

In order to ensure the validity of the data used for the PRA analysis, a screening review of all post-1985 design changes was conducted. Selected walkdowns were also performed to verify current plant layout in several key areas. Over 700 design changes were reviewed and no new HELB/system interaction cases were identified. Since SCE has been utilizing current design standards, wherever practical, for all recent design changes, it is not surprising that no new interaction cases were identified.

Table 4-3 shows the distribution of the high energy lines by plant system name. The majority of these lines are associated with the feedwater, main steam, and turbine systems. The 1985 walkdown study separated these lines into analysis categories.

Table 4-4 illustrates the breakdown of the lines by categories. A significant number of these lines (239 lines) are maintained at high energy conditions less than 2% of the time, and these lines were excluded from further study. Another 37 lines were excluded from further consideration because they were addressed by the SONGS-1 Augmented ISI Program or were shown previously to be dominated by leak-before-break phenomena. These 37 lines include the RCS, main steam lines and feedwater lines inside containment, and portions of the main steam and feedwater lines outside containment. (See Appendix A)

Approximately 500 lines were evaluated for systems interaction effects in the PRA evaluation. Tables 4-5 and 4-6 indicate the piping materials and pressure ratings of the lines considered in that evaluation. Table 4-7 indicates the types of transients that could be induced by the various line breaks. The PRA considered those breaks resulting in LOCAs, steam line or main feedwater line breaks, or losses of feedwater transients. About 200 lines were eliminated from further review because breaks in these lines did not result in any significant transient (i.e., the likelihood of safe shutdown for line breaks of these types would be very high).

Further analysis of the walkdown data indicated that pipe ruptures in about 150 lines would result in one of the significant transient categories, but no damage would occur to safe shutdown equipment. These lines do not pose a HELB systems interaction risk and therefore were excluded from further PRA evaluation. The core damage risks from pipe breaks in these lines would be considered in the normal course of the Individual Plant Examination (IPE) PRA currently being performed by SCE in response to NRC Generic Letter 88-20.

Tables 4-8 and 4-9 present the final results of the categorization of the remaining approximately 170 lines. Each case consists of a representative transient resulting from the HELB and indicates the resulting safe shutdown systems that are disabled by the break. Each case represents from one to twenty eight lines.

4.3.1 Calculation of Pipe Rupture Frequencies

In order to compute the core damage risk for each of the cases described in Tables 4-8 and 4-9, pipe rupture frequencies must be calculated for the lines within the case. The methodology of reference 47 is used to perform the calculations. Over 85 lines were explicitly evaluated for this analysis. Those pipe break cases that were expected to be of higher risk (e.g., multiple safe shutdown systems are impacted) were quantified by calculating the rupture frequency for each individual line. The results were then summed for all of the lines to determine an initiator frequency for the case.

For the cases expected to be of lower risk, a conservative approximation of the rupture frequency for the case was calculated by selecting a "worst case" (in terms of rupture frequency) line for detailed calculation. The frequency for this line was then multiplied by the number of lines in the case to establish an upper bound initiator frequency for the case.

Tables 4-10 and 4-11 summarize the results of the pipe rupture calculations. The individual calculations were performed by considering the piping to fall into three size groups:

½" ≤ Diameter < 2"
2" ≤ Diameter < 6"
6" ≤ Diameter

Failure rates were calculated for each of these piping sizes for four classes of systems using the data contained in the EPRI report:

Main Feedwater and Condensate
Reactor Coolant System
Safety Injection and Recirculation
Other Safety-Related Systems

Each pipe was then categorized based upon the number of pipe segments in each size category and a total rupture frequency was calculated considering the number of segments, piping size and system type. It should be noted that these calculations are somewhat conservative as it is assumed that all breaks result in catastrophic ruptures. The EPRI data indicates that a significant portion of the calculated frequencies is attributable to lesser magnitude breaks, which would result in less severe plant transients and lesser systems interactions effects.

Using the results summarized in Tables 4-8 through 4-11, a series of event tree/fault tree calculations were performed for each of the cases. Each event tree was quantified using the pipe break initiator frequency calculated for its analysis case. The system fault trees were solved for each node, with HELB-impacted trains assumed to be failed. In addition to the systems interactions summarized in Table 4-9, all outside containment breaks were also conservatively assumed to fail the instrument air system, since the system is not environmentally qualified for HELB environments.

Tables 4-12 and 4-13 summarize the calculated results for each of the 15 analysis cases.

4.3.2 Interpretation of Results

The total core damage risk due to HELB systems interactions is calculated to be 1.03E-5 per year. As noted below, after implementation of design modifications to the Recirculation System, the total core damage risk will be reduced to 1.87E-6. Estimates for the SONGS-1 core damage frequency due to other internal initiators have not been completed as part of the IPE effort, but are estimated to be approximately 2E-4 per year (as previously transmitted to the NRC in reference 11). Hence, these HELB interactions constitute about 5% of the total internal initiator risk, approximately 1% after the Recirculation System design modification.

Figure 4-1 graphically presents a comparison of the risks due to HELB interactions inside containment, HELB interactions outside containment, and the estimated risk due to all other internal initiators. As can be seen, most of the HELB risk is due to line breaks inside containment. Figure 4-2 presents a breakdown of the HELB risk results by type of interaction. About 82% of the risk is due to Case B, 12.5% is due to case J, and 2.5% is due to Case O.

Case B represents a set of interactions that result in small LOCAs that could result in failure of both trains of the post-LOCA recirculation cooling system. Recirculation failure occurs as a result of damage to the power cables to recirculation pumps G-45A and G-45B. A design change has been recommended to protect these cables from the effects of line breaks in the vicinity. Section 4.3.1 presents the results of a sensitivity study performed to determine the risk improvement that would result from this design change.

Cases J and O represent a series of pipe breaks that damage both trains of main feedwater and one train of auxiliary feedwater. Safe shutdown can be achieved using either AFW train "B" (Pump G-10W) or RCS "feed and bleed" cooling. It does not appear to be cost-effective to protect additional safe shutdown equipment. Plant modifications would be very costly and would result in only a minor reduction in the overall core damage frequency. The contribution of these sequences to the overall internal initiator core damage risk is less than 0.8%.

The risk from all other pipe break cases is acceptably low and constitutes less than 0.2% of the estimated total core damage risk. It should be also noted that a portion of the calculated risk is, in fact, due to non-system interaction-induced failures. This overstatement of the risk occurs because all of the event tree sequences for each HELB case have been evaluated (rather than including only those that were directly affected by the systems interactions). Hence the actual risk contributions of the systems interactions are less than the values shown in Tables 4-10 and 4-11.

4.3.3 Assessment of Modifications

The HELB assessment identified a vulnerability of the post-LOCA recirculation pumps (G-45A and G-45B) due to cable damage following certain line breaks. Because these breaks result in Small LOCA transients that require the use of the recirculation system to provide long term core cooling, a relatively high risk contribution was obtained from these break scenarios.

These high risk interactions will be eliminated by implementing a permanent design change. This change would protect the recirculation pump cables from jet impingement and pipe whip effects through a combination of cable rerouting and/or installation of jet impingement barriers. The existing plant design could allow both recirculation pumps to be disabled if the pipe break jet were aligned so as to provide the maximum amount of damage. The new design would ensure that pump's cables would be protected from breaks in the critical areas near the pump pit.

4.3.4 Revised PRA Results Following Installation of Modifications

The installation of this design change will have a direct impact upon Case B. This change would possibly also affect cases A, C, and D, but the core damage risk reductions for these cases will be much smaller and are not explicitly evaluated.

The protection of the recirculation pump cables effectively eliminates the HELB systems interaction risk for this class of breaks. The residual risks for this case result from non-HELB induced random failures of the safe shutdown systems.

The Case B event tree was re-solved by removing the HELB induced recirculation system damage. Table 4-14 summarizes the results of this sensitivity analysis. The results of the re-analysis indicate that the core damage risk from this case is decreased from 8.43E-6 per year to 1.52E-7 per year. As noted previously, this residual risk is, in fact, unrelated to HELB systems interactions since all such interactions have been eliminated. Therefore, the inside containment HELB systems interaction risk is reduced to less than 3.22E-8 per year and the total HELB systems interaction risk is reduced to less than 1.87E-6 per year. This remaining risk is acceptable and is comparable to the risks calculated for other SEP issues that have been considered to be adequately resolved by the NRC.

This evaluation has quantified the core damage risks resulting from systems interactions due to HELBs at SONGS-1. The results indicated that the potential for these interactions has contributed a modest increment in the plant's overall core damage risk profile. It should be emphasized that considerable conservatism exists in the data used to quantify this PRA. As a result, the actual HELB systems interaction risk should be considerably lower. These conservatisms include the following:

- For the purposes of the systems interaction analyses, all piping ruptures were assumed to be catastrophic, thereby resulting in the most severe transients and resulting in the greatest possible systems interactions.
- The 1985 walkdown information that provided the systems interaction information utilized extremely conservative jet impingement assumptions and "zone-of-influence" assumptions.
- The PRA risk calculations include the risk from accident sequences that were unaffected by the HELB systems interactions.

The residual risks resulting from the remaining potential systems interactions were an acceptably small percentage (less than 0.1%) of the estimated total plant risk.

Table 4-3

Distribution of High Energy Lines by System

System Name	System Designator	Quantity
Feedwater Heaters	FWH	192
Main Steam System	MSS	93
High Pressure Turbine System	THP	89
Main Feedwater System	FWS	68
Turbine System	TBN	49
Condensate System	CND	40
Containment Spray and Recirculation System	CRS	35
Reactor Coolant Pump Seal Water System	RCP	34
Volume Control and Charging System	VCC	23
Reactor Coolant System	RCS	22
Auxiliary Feedwater System	AFW	20
Pressurizer and Pressure Relief Tank	PZR	19
Safety Injection System	SIS	17
Residual Heat Removal System	RHR	15
Low Pressure Turbine System	TLP	14
Flash Evaporators*	FES	14
Feedwater Sampling System*	FSS	8
Letdown Demineralizer System	LDS	6
Radwaste Liquid Collection System*	RLC	4
Radwaste Liquid Processing System*	RWL	4
Condenser Vents and Drains*	CVD	2
Secondary Chemical Feed System*	SCF	2
TOTAL		770

Table 4-4

Distribution of High Energy Lines by Disposition Category

Method	Quantity
Usage Factor (UF)	239
Leak-Before-Break (LBB)	19
Augmented Inservice Inspection (ISI)	13
Considered for System Interactions In PRA	**499**
TOTAL	770

Table 4-5

Primary Side Piping Materials Description

SCE Piping Classification	Quantity of Lines	Line Size Range (inches)	Pressure Rating (psi)	Material
BH2	53	1-1/4 - 29	2500	Stainless steel
BH3	33	2 - 4	2500	Stainless steel
DG	1	1-1/2	900	Stainless steel
EG2	18	2 - 10	600	Stainless steel
EG3	7	2 - 10	600	Stainless steel
S2	1	2	600	Stainless steel

Table 4-6

Secondary Side Piping Materials Description

SCE Piping Classification	Quantity of Lines	Line Size Range (inches)	Pressure Rating (psi)	Material
BH4	3	3 - 4	2500	Carbon steel
CL	4	3 - 14	1500	Stainless steel
EG	241	1-1/2 - 54	600	Carbon steel
EGX	28	1-1/2 - 12	600	Carbon steel
GG	73	1-1/2 - 28	300	Carbon steel
GGX	9	3 - 12	300	Carbon steel
H	164	1-1/2 - 22	150	Carbon steel
HHX	40	4 - 24	150	Carbon steel
HP	1	4	150	Stainless steel
KN1	1	4	125	Cast iron
S1	1	2	300	Stainless steel

Table 4-7

Transients Resulting from Pipe Breaks
Reviewed for Possible Systems Interactions

Resulting Transient	Quantity of Lines
Loss of Coolant Accidents	51
Steam Line Breaks	118
Feedwater Line Breaks#	143
Losses of Main Feedwater	30
Other Transients (e.g., loss of load, loss of RCP)	59
None*	138

* Break does not result in Reactor Trip or Turbine Trip.

Existing walkdown data grouped loss of feedwater transients and feedwater line breaks together as "loss of feedwater". For purposes of this tabulation, "loss of feedwater" occurring in FWS, FWH, CND and AFW systems have been assumed to be feedwater line breaks.

NOTE: The total quantity of lines tabulated above may vary from the totals indicated on other tables, because of different break locations in the same line resulting in different transient events.

Table 4-8

Inside Containment Case Summary

			Targets Lost					
Case	*Transients*	*Number of Lines*	*Charging*		*Recirc.*		*SIS*	
			A	*B*	*A*	*B*	*A*	*B*
A	*SBLOCA**	*3*	*X*		*X*			
B	*SBLOCA*	*3*			*X*	*X*		
C	*SBLOCA***	*6*				*X*		
D	*SBLOCA***	*1*			*X*	*X*		

* Can be isolated by automatic closure of LCV-1112

** Can be isolated by automatic closure of LCV-1112 or CV-202/203/204

Table 4-9

Outside Containment Case Summary

			Targets Lost				
Case	Representative Transient*	Number of Lines	FW 1 Train	FW 2 Trains	AFW 1 Train	SI 1 Train	SI 2 Trains
E	Loss of Feedwater	26	X				
F	Loss of Feedwater	22		X			
G	Steam Line Break	17	X			X	
H	Feed Line Break	16		X		X	
I	Steam Line Break	14		X		X	
J	Feed Line Break	13		X	X		
K	Loss of Feedwater	9	X		X	X	
L	Steam Line Break	12		X			X
M	Feed Line Break	10		X			X
N	Feed Line Break	6		X	**		X
	Feed Line Break	6		X	X		X

* Original 1985 walkdown data indicates that several cases shown above are feed line breaks or steam line breaks. While the pipes in question are, in fact, feedwater or steam lines, the effects of these particular breaks are more appropriately considered to be losses of main feedwater.

** Pump G-10 only

Table 4-10

Quantification of Inside Containment Pipe Break Frequencies

Case	Line ID	System	Calculated Pipe Rupture Frequency (per year)
A	LDS-2067-2"-BH2 LDS-2068-2"-BH2 LDS-2071-2"-BH2	Letdown Letdown Letdown	2.21E-6 2.21E-6 3.69E-6 Total = 8.11E-6
B	PZR-5011-3"-BH2 VCC-2081-2"-BH2 LDS/RCS-5008-2"-BH2	RCS Charging RCS	4.56E-6 4.44E-6 7.58E-6 Total = 1.66E-5
C	RHR-3000-6"-EG2 RHR-3001-6"-EG2 RHR-3003-4"-EG2 RHR-3015-6"-EG2 RHR-3019-2"-EG2 RHR-3019-6"-EG2	RHR RHR RHR RHR RHR RHR	1.21E-5 6.07E-5 8.67E-6 6.07E-5 1.73E-6 1.62E-5 Total = 1.60E-4
D	LDS-2071-2"-EG2	Letdown	4.43E-6 Total = 4.43E-6

Table 4-11

Quantification of Outside Containment Pipe Break Frequencies

Case	Line ID	System	Calculated Pipe Rupture Frequency (per year)
E	FWS-318-14"-GG	Feedwater	9.76E-5
	The above line is a worst case surrogate for 26 lines. The total pipe break frequency for this case is 2.54E-3.		
F	FWS-374-3"-GG	Feedwater	1.80E-5
	The above line is a worst case surrogate for 22 lines. The total pipe break frequency for this case is 3.96E-4.		
G	FWH-106-6"-GG	Feedwater	8.54E-5
	FWH-109-8"-HH	Feedwater	8.54E-5
	FWH-127-14"-HHX	Feedwater	1.22E-5
	FWH-11085-4"-EG	Feedwater	4.51E-6
	FWH-11101-4"-EG	Feedwater	2.26E-6
	MSS-17-6"-EG	Main Steam	1.03E-5
	MSS-17-8"-EG	HP Turbine	6.89E-6
	MSS-18-6"-EG	Main Steam	8.60E-6
	MSS-20-6"-EG	Main Steam	1.71E-6
	MSS-64-4"-EG	Main Steam	1.48E-6
	MSS-1316-8"-EG	HP Turbine	2.24E-5
	THP-12-10"-GG	HP Turbine	1.71E-6
	THP-16-16"-HH	HP Turbine	1.71E-6
	THP-17-6"-EG	HP Turbine	0
	THP-23-16"-GG	HP Turbine	8.61E-6
	THP-9103-36"-EG	HP Turbine	1.03E-5
	THP-9119-28"-GG	HP Turbine	1.71E-6
			Total = 2.70E-4

Table 4-11 (Continued)

Quantification of Outside Containment Pipe Break Frequencies

Case	Line ID	System	Calculated Pipe Rupture Frequency (per year)
H	CND-317-14"-CG	Condensate	2.44E-5
	FWH-103-8"-EGX	Feedwater	4.88E-5
	FWH-105-6"-GG	Feedwater	8.54E-5
	FWH-113-14"-HH	Feedwater	6.10E-5
	FWH-116-8"-GG	Feedwater	8.54E-5
	FWH-118-8"-EG	Feedwater	3.66E-5
	FWH-127-10"-HHX	Feedwater	4.88E-5
	FWH-235-2"-G	Feedwater	0
	FWH-235-3"-GG	Feedwater	1.58E-5
	FWS-317-14"-EG	Feedwater	6.10E-5
	FWS-320-14"-EG	Feedwater	2.44E-5
	FWS-324-12"-EG	Feedwater	3.66E-5
	FWS-340-3"-EG	Feedwater	2.25E-5
	FWS-375-2"-GG	Feedwater	1.13E-5
	FWS-6004-14"-CL	Feedwater	1.22E-5
	FWS-6005-14"-CL	Feedwater	1.22E-5
			Total = 5.86E-4
I	THP-9120-28"-GG	HP Turbine	1.21E-5
	The above line is a worst case surrogate for 14 lines. The total pipe break frequency for this case is 1.69E-4.		
J	CND-305-10"-GG	Condensate	6.10E-5
	CND-305-12"-GG	Condensate	6.10E-5
	CND-313-12"-GG	Condensate	9.76E-5
	CND-336-8"-GG	Condensate	6.10E-5
	CND-337-12"-GG	Condensate	8.54E-5
	FWH-104-8"-EGX	Feedwater	3.66E-5
	FWH-128-10"-HHX	Feedwater	2.44E-5
	FWH-319-14"-EGX	Feedwater	1.22E-5
	FWS-321-14"-EG	Feedwater	2.44E-5
	FWS-329-8"-EG	Feedwater	1.22E-5
	FWS-392-8"-EG	Feedwater	1.22E-5
	MSS-65-4"-EG	Main Steam	7.30E-7
	MSS-65-6"-EG	Main Steam	1.71E-6
			Total = 5.03E-4

Table 4-11 (Continued)

Quantification of Outside Containment Pipe Break Frequencies

Case	Line ID	System	Calculated Pipe Rupture Frequency (per year)
K	CND-314-12"-GG	Condensate	8.54E-5
	CND-315-14"-GG	Condensate	4.88E-5
	FWH-110-8"-HH	Feedwater	9.76E-5
	FWH-114-14"-HH	Feedwater	6.10E-5
	FWH-116-10"-GG	Feedwater	4.88E-5
	FWH-128-10"-HHX	Feedwater	4.88E-5
	FWH-196-1.5"-EG	Feedwater	3.14E-5
	MSS-8-2"-EG	Main Steam	1.10E-5
	MSS-8-4"-EG	Main Steam	1.48E-6
			Total = 4.34E-4
L	THP-24-16"-GG	HP Turbine	2.07E-5
	The above line is a worst case surrogate for 17 lines. The total pipe break frequency for this case is 3.52E-4.		
M	FWS-320-12"-EG	Feedwater	1.34E-4
	The above line is a worst case surrogate for 10 lines. The total pipe break frequency for this case is 1.34E-3.		
N	FWS-319-12"-EG	Feedwater	1.34E-4
	FWS-321-12"-EG	Feedwater	7.32E-5
	FWS-322-12"-EG	Feedwater	6.10E-5
	MSS-69-3"-EG	Main Steam	2.96E-6
	THP-20-6"-EG	HP Turbine	6.89E-6
	THP-23-16"-HH	HP Turbine	8.61E-6
			Total = 2.88E-4
O	FWS-326-8"-EG	Feedwater	1.22E-5
	FWS-339-3"-EG	Feedwater	2.71E-5
	FWS-391-8"-EG	Feedwater	1.22E-5
	THP-21-10"-EG/GG	HP Turbine	2.06E-5
	THP-22-10"-EG/GG	HP Turbine	2.06E-5
	THP-24-16"-HH	HP Turbine	8.60E-6
			Total = 1.01E-4

Table 4-12

PRA Evaluation Results for Inside Containment Cases

Case	HELB-Induced Transient	Calculated Core Damage Frequency
A	Isolable Small LOCA	4.26E-9 per year
B	Small LOCA	8.43E-6 per year
C	Isolable Small LOCA	2.11E-8 per year
D	Isolable Small LOCA	1.60E-9 per year
	Total Core Damage Frequency Due to HELB Systems Interactions	8.46E-6 per year

Table 4-13

PRA Evaluation Results for Outside Containment Cases
(After Modifications to the Recirculation System)

Case	Representative HELB-Induced Transient	Calculated Core Damage Frequency
E	Loss of Feedwater	5.33E-9 per year
F	Loss of Feedwater	6.96E-9 per year
G	Steam Line Break	2.88E-8 per year
H	Feed Line Break	1.03E-8 per year
I	Steam Line Break	1.80E-8 per year
J	Feed Line Break	1.29E-6 per year
K	Loss of Feedwater	1.26E-7 per year
L	Steam Line Break	3.75E-8 per year
M	Feed Line Break	2.40E-8 per year
N	Feed Line Break	3.10E-8 per year
O	Feed Line Break	2.61E-7 per year
	Total Core Damage Frequency Due to HELB Systems Interactions	1.87E-6 per year

Table 4-14

Results of Recirculation System Sensitivity Study

	Core Damage Frequency-Current Plant Design	Core Damage Frequency With Recirculation System Modification	Estimated Percentage of Total Internal Events Risk*
Inside Containment HELB Systems Interactions	8.46E-6 per year	3.22E-8 per year	< 0.02%
Outside Containment HELB Systems Interactions	1.84E-6 per year	1.84E-6 per year	< 1.0%
Total HELB Systems Interactions Risk	1.03E-5 per year	1.87E-6 per year	< 1.0%

* The estimated risk of core damage due to other internal initiating events is 2E-4 per year. The percentages assumed the recirculation system modifications are installed.

Figure 4-1

Comparison of HELB Risk to Other Internally Initiated Core Damage

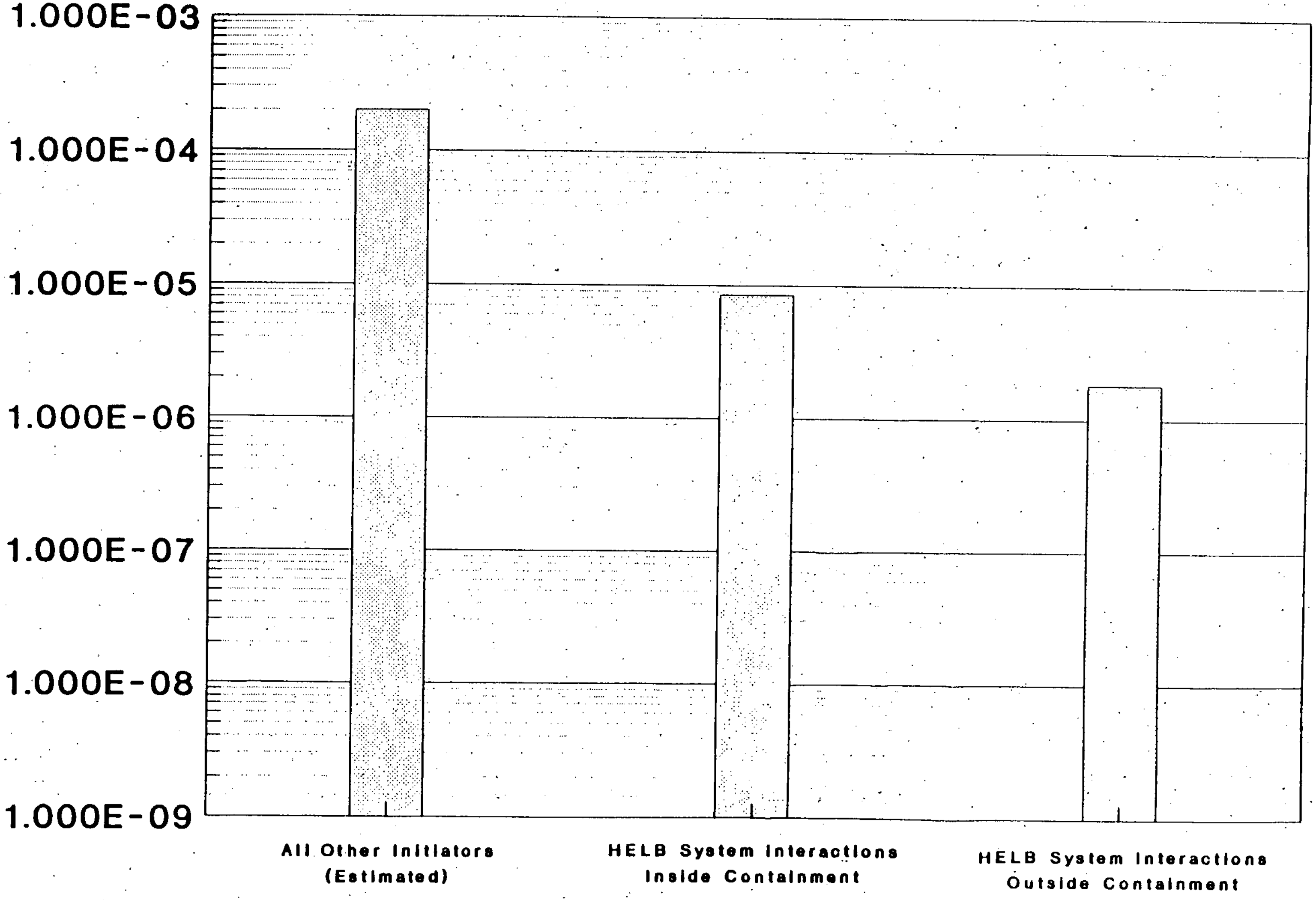
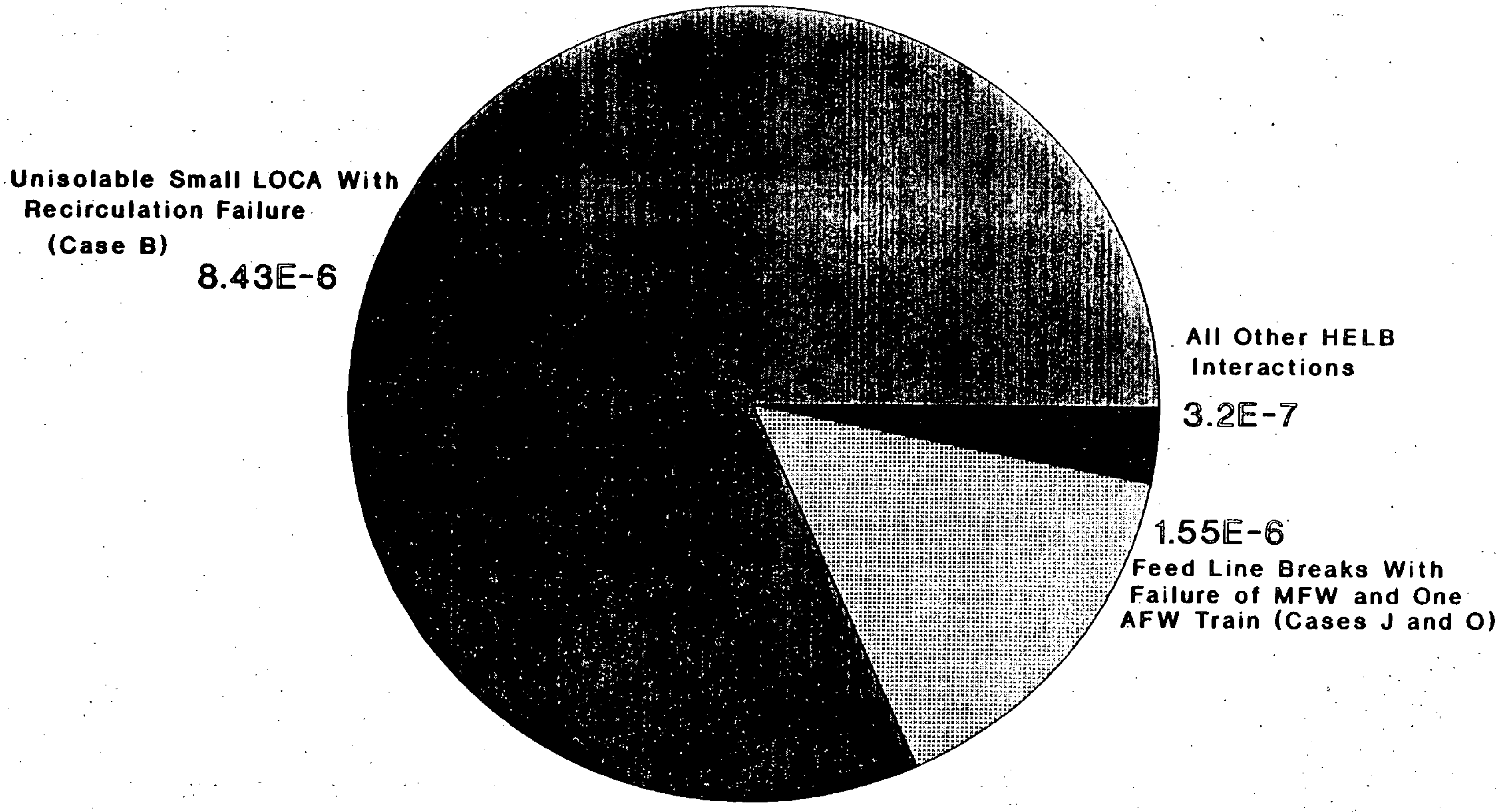


Figure 4-2

Breakdown of HELB Systems
Interaction Risk Contributions



Total HELB Systems Interaction Risk = 1.03E-5 per year

4.4 Structural Interactions

Five hundred and six (506) structural interactions were identified as a result of the 1985 walkdowns and post-walkdown design review. The structural targets were initially evaluated using a deterministic screening process. Lower bound capacities for various structural member types were developed and compared to the conservative pipe rupture loading case. More refined screening levels considered more specific load geometry and member/connection details. As a result of this screening process, 397 of the 506 structural target interactions were determined to be acceptable.

The remaining subset of 109 (506-397) potential HELB structural interactions was reduced to 21 using further refined deterministic evaluation, stress calculation, and walkdowns as follows:

- Fifty (50) were resolved by determining that pipe breaks which are located farther than 10 pipe diameters away from the targets have insufficient jet impingement force to cause structural damage.
- Fourteen (14) were resolved based on walkdown verification of pipe whip/jet impingement configuration which indicated that the targets are outside the applicable zones-of-influence.
- Three (3) were resolved by comparing the section properties of the whipping pipe and impacted structure.
- Seven (7) interactions were resolved by crediting the Augmented ISI Program.
- Fourteen (14) were resolved by stress calculations.

The resulting 21 (of 506) structural interactions which could not be eliminated by other deterministic methods were analyzed using inelastic analysis. The details and results of that analysis are described below. Evaluations were performed for the postulated HELB loadings (pipe whip or jet impingement) on structural members based on the inelastic criteria and methodology.

Evaluation results of the 21 structural members are summarized in Table 4-15. The evaluation results show that the acceptance criteria for the 21 structural members is satisfied for the applicable loading conditions and the HELBA loads, except for two interactions that cause one structural steel member (Column K2) to be above the allowable ductility ratio limits.

The ductility ratios exceed the acceptance criteria for the two HELBA interactions, such that it would be impractical to strengthen Column K2 to withstand the energy of the whipping pipes. Design modifications consisting of pipe whip restraints or stops will be implemented to prevent the pipes from whipping and thus preclude the associated large kinetic energy from developing. The modifications will consist of adding beams from the column to the two pipes. The beams will reduce the travel distances of the two postulated pipe breaks and the kinetic energy impacting the column.

4.5 Environmental Impacts

4.5.1 Results - Equipment Qualification (EQ)

The qualification test/analysis results for all of the equipment are provided in the Equipment Qualification Data Package (EQDP) for the subject equipment. The EQDP contains information that demonstrate equipment operability in required environments. Based on the results of the test/analyses described in the EQDP, all safety related equipment will remain operable in the environmental condition resulting from a high energy line break. A summary of all EQ components are provided in the EQ Master List (Document No. M85003).

4.5.2 Compartmental Pressurization

Compartment pressurization effects were evaluated for the Reactor Auxiliary Building, Fuel Storage Building and the Turbine Building. Only these three buildings could be affected by high energy line breaks other than the containment which has been evaluated for LOCA and main steam line breaks. The pressure profile was calculated as part of the EQ Program for high energy line breaks. The peak pressure results are 1.0 psi for the Reactor Auxiliary Building, and 3.7 psi for the Turbine Building and Fuel Storage Building. These pressures values were conservatively calculated for the purpose of environmentally qualifying equipment and may not accurately reflect the actual pressures that could be imposed on the structural elements of the building.

The main concern of pressure effects on structures is the reinforced masonry walls. The peak reflected pressure capacities of the reinforced masonry walls are 1 psi for the Reactor Auxiliary Building, 2.4 psi for the Fuel Storage Building (480 Volt Room) and 1.8 psi for the turbine building. In comparing the EQ pressure profiles versus the wall capacities, the Reactor Auxiliary Building is satisfactory, but the Fuel Storage Building and Turbine Building wall capacities are exceeded by 1.3 psi and 1.9 psi, respectively.

Additional analyses will be performed for the Fuel Storage Building and Turbine Building walls. The masonry walls will be analyzed for non-linear behavior using time dependent pressure profile. Also, compartment pressurization will be reviewed within the Turbine Building because the building is completely open to the atmosphere on the east side and partially open on the west side. The east side of the Turbine Building consist of chain-link fencing for security purposes, and the west side has a 12'-0" by 9'-10" open doorway and 5'-0" high louver vents along the top of the enclosure wall. Thus, pressure build-up is not judged to be possible inside the Turbine Building due to its openness, but an analysis will be performed to quantify this judgement.

4.5.3 Flooding Effects

Flooding effects associated with postulated rupture of piping were addressed in the SONGS-1 UFSAR section 3.6.2 for outside containment. The results indicated that SONGS-1 plant design was adequate to accommodate the worst case flooding developed in the event of a Main Feedwater line break or any other line carrying high energy fluid.

Table 4-15

Finite Element Analysis Results (Structural Interactions)

Line Number	Target	Jet Impingement Ductility Ratio	Pipe Whip Ductility Ratio	Comment
CND-310-12"-GG	Column L4	4.3	n/a	Member is O.K.
CND-311-12"-GG	WHP-B16,H12/J12	9.2	n/a	Member is O.K.
CND-312-12"-GG	Column K2	n/a	73.4	Modification Proposed
CND-312-12"-GG	EHP-B14,H2/J2	9.5	n/a	Member is O.K.
CND-313-12"-GG	WHP-B14,J13/H13	Elastic	n/a	Member is O.K.
CND-314-12"-GG	EHP-B1,E1/F1	6.3	n/a	Member is O.K.
CND-314-12"-GG	EHP-B8,H1/J1	1.2	n/a	Member is O.K.
CND-314-12"-GG	EHP-B8,G1/H1	1.2	n/a	Member is O.K.
CND-314-12"-GG	Column K2	n/a	221	Modification Proposed
CND-337-12"-GG	Column H12	Elastic	n/a	Member is O.K.
CND-337-12"-GG	WHP-B16,H12/J12	1.3	n/a	Member is O.K.
FWH-105-6"-GG	EHP-B5,E3/F2	Elastic	n/a	Member is O.K.
FWH-106-6"-GG	WHP-B5,E11/F12	Elastic	n/a	Member is O.K.
FWH-113-14"-HH	Column G2	n/a	12.6*	Member is O.K.
FWH-116-10"-GG	WHP-B23.1,E9/E11	1.10	n/a	Member is O.K.
TBN-1307-4"-HH	WHP-B2.6,K9/L9	n/a	Elastic	Member is O.K.
TBN-1308-4"-HH	WHP-B20,K5/L5	n/a	Elastic	Member is O.K.
TBN-1318-8"-HH	WHP-B2.6,K9/L9	n/a	Elastic	Member is O.K.
TBN-1323-8"-HH	WHP-B20,K5/L5	n/a	Elastic	Member is O.K.
THP-21-10"-GG	EHP-B5,E3/F2	1.48	n/a	Member is O.K.
THP-22-10"-GG	WHP-B5,E11/F12	1.27	n/a	Member is O.K.

WHP & EHP are girders or beams in the West Heater Platform and East Heater Platform, respectively.

* This pipe whip interaction impacts a non-essential brace which has an allowable ductility ratio of 20.

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Appendix A
HELB Resolution Summary (System Interactions)

	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
1	00069-03-EG	AFW	PRA	5178221	Steam Line Break	
2	00070-08-HH	AFW	2%	5178221		Exclusion criteria
3	00087-10-HH	AFW	PRA	5178221	None	
4	00088-04-HH	AFW	2%	5178221		Exclusion criteria
5	00381-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater/Steam LIne Break	
6	00381-03-EG-4CCB	AFW	PRA	5178220	Loss of Feedwater/Steam LIne Break	
7	00381A-03-EG-3ACB	AFW	ISI/PRA	5178220	Loss of Feedwater	
8	00381A-04-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
9	00381B-03-EG-3ACB	AFW	ISI/PRA	5178220	Loss of Feedwater	
10	00381C-03-EG-3ACB	AFW	ISI/PRA	5178220	Loss of Feedwater	
11	00381C-04-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
12	00397-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater/Steam LIne Break	
13	00397-03-EG-4CCB	AFW	PRA	5178220	Loss of Feedwater/Steam LIne Break	
14	00397A-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
15	00397A-04-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
16	00397B-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
17	00397C-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
18	00397C-04-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
19	13106-03-EG	AFW	PRA	5178221	None	
20	14101-03-EG-3ACB	AFW	PRA	5178220	Loss of Feedwater	
21	00305-10-GG	CND	PRA	5178201	Loss of Feedwater	
22	00305-12-GG	CND	PRA	5178201	Loss of Feedwater	
23	00306-10-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
24	00306-12-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
25	00307-10-GG	CND	PRA	5178201	Loss of Feedwater	
26	00307-12-GG	CND	PRA	5178201	Loss of Feedwater	
27	00308-10-GG	CND	PRA	5178201	Loss of Feedwater	
28	00308-12-GG	CND	PRA	5178201	Loss of Feedwater	
29	00309-12-GG	CND	PRA	5178201	Loss of Feedwater	
30	00310-12-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
31	00311-12-GG	CND	PRA	5178201	Loss of Feedwater	

Appendix A
HELB Resolution Summary (System Interactions)

	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
32	00312-12-GG	CND	PRA	5178201	Loss of Feedwater	
33	00313-12-GG	CND	PRA	5178201	Loss of Feedwater	
34	00314-12-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
35	00315-12-GG	CND	PRA	5178201	Loss of Feedwater	
36	00315-14-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
37	00316-12-GG	CND	PRA	5178201	Loss of Feedwater	
38	00316-14-GG	CND	PRA	5178201	Loss of Feedwater	
39	00317-14-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
40	00318-14-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
41	00330-1.5-GG	CND	PRA	5178201	None	
42	00331-1.5-GG	CND	PRA	5178201	Loss of Feedwater	
43	00334-02-GG	CND	PRA	5178201	Loss of Feedwater	
44	00336-08-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
45	00337-08-GG	CND	PRA	5178201	Loss of Feedwater	
46	00337-12-GG	CND	PRA	5178201	Loss of Feedwater	
47	00338-08-GG	CND	PRA	5178201	Loss of Feedwater/Steam LIne Break	
48	00338-12-GG	CND	PRA	5178201	Loss of Feedwater	
49	00338-14-GG	CND	PRA	5178201	Loss of Feedwater	
50	00345-03-GG	CND	PRA	5178201	None	
51	00345-03-HP	CND	2%	5178200		Exclusion criteria
52	00355-04-GG	CND	PRA	5178201	Loss of Feedwater	
53	00355-06-GG	CND	2%	5178201		Exclusion criteria
54	00356-04-GG	CND	PRA	5178201	Loss of Feedwater	
55	00356-06-GG	CND	2%	5178201		Exclusion criteria
56	00363-1.5-GG	CND	PRA	5178201	Loss of Feedwater	
57	00368-02-GG	CND	2%	5178202		Exclusion criteria
58	00374-03-GG	CND	PRA	5178201	Loss of Feedwater	
59	00396-04-HP	CND	2%	5178200		Exclusion criteria
60	10852-03-GG	CND	PRA	5178207	Loss of Feedwater	
61	00728-08-HP	CRS	2%	5178120		Exclusion criteria
62	00729-08-JN	CRS	2%	5178201		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
63	00734-06-GM	CRS	2%	5178120		Exclusion criteria
64	00734-06-HH	CRS	2%	5178120		Exclusion criteria
65	00734-06-HM2	CRS	2%	5178120		Exclusion criteria
66	00735-04-HM2	CRS	2%	5178120		Exclusion criteria
67	00737-08-HP	CRS	2%	5178120		Exclusion criteria
68	00737-08-JN	CRS	2%	5178120		Exclusion criteria
69	00765-04-HH	CRS	2%	5178120		Exclusion criteria
70	00765-04-HM2	CRS	2%	5178120		Exclusion criteria
71	00876-1.5-HP	CRS	2%	5178121		Exclusion criteria
72	00891-02-GM	CRS	2%	5178120		Exclusion criteria
73	00891-02-HP	CRS	2%	5178120		Exclusion criteria
74	03122-02-SI	CRS	Partial 2%/PRA	5178120		Exclusion criteria
75	06015-04-HK	CRS	2%	5178121		Exclusion criteria
76	06015-06-HK	CRS	2%	5178121		Exclusion criteria
77	06015-08-HK	CRS	2%	5178121		Exclusion criteria
78	06016-04-BH3	CRS	PRA	5178110		
79	06016-04-EK	CRS	2%	5178120		Exclusion criteria
80	06018-04-HH9	CRS	2%	5178121		Exclusion criteria
81	06018-04-HM2	CRS	2%	5178121		Exclusion criteria
82	06018-06-HH9	CRS	2%	5178121		Exclusion criteria
83	06018-06-HM2	CRS	2%	5178121		Exclusion criteria
84	06019-04-HM2	CRS	2%	5178121		Exclusion criteria
85	06019-06-HH9	CRS	2%	5178121		Exclusion criteria
86	06019-06-HM2	CRS	2%	5178121		Exclusion criteria
87	07175-02-GM	CRS	2%	5178120		Exclusion criteria
88	08020-06-HM2	CRS	2%	5178120		Exclusion criteria
89	08021-02-HP	CRS	2%	5178120		Exclusion criteria
90	08021-02-JN	CRS	2%	5178120		Exclusion criteria
91	08021-1.5-HP	CRS	2%	5178120		Exclusion criteria
92	08730-1.5-HM2	CRS	2%	5178120		Exclusion criteria
93	10371-06-GM	CRS	2%	5178120		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
94	10375-04-GM	CRS	2%	5178120		Exclusion criteria
95	10375-06-GM	CRS	2%	5178120		Exclusion criteria
96	00241-06-HH	CVD	2%	5178245		Exclusion criteria
97	00242-06-HH	CVD	2%	5178245		Exclusion criteria
98	00181-06-HH	FES	2%	5178275		Exclusion criteria
99	00181-10-HH	FES	2%	5178275		Exclusion criteria
100	00182-06-HH	FES	2%	5178276		Exclusion criteria
101	00182-10-HH	FES	2%	5178276		Exclusion criteria
102	00214-02-HH	FES	2%	5178276		Exclusion criteria
103	00215-02-HH	FES	2%	5178275		Exclusion criteria
104	00251-06-HH9	FES	2%	5178275		Exclusion criteria
105	00252-03-HH9	FES	2%	5178276		Exclusion criteria
106	00252-06-HH9	FES	2%	5178276		Exclusion criteria
107	00254-03-HH9	FES	2%	5178276		Exclusion criteria
108	00255-03-HH9	FES	2%	5178275		Exclusion criteria
109	10168-03-HH	FES	2%	5178275		Exclusion criteria
110	10168-2.5-HH	FES	2%	5178275		Exclusion criteria
111	12983-03-HH	FES	2%	5178275		Exclusion criteria
112	01201-02-EGI	FSS	2%	5178261		Exclusion criteria
113	01202-02-EGI	FSS	2%	5178260		Exclusion criteria
114	01203-02-EGI	FSS	2%	5178260		Exclusion criteria
115	01207-02-EGI	FSS	2%	5178261		Exclusion criteria
116	01208-02-EGI	FSS	2%	5178261		Exclusion criteria
117	01209-02-EGI	FSS	2%	5178261		Exclusion criteria
118	01213-02-EGI	FSS	2%	5178261		Exclusion criteria
119	01214-02-EGI	FSS	2%	5178261		Exclusion criteria
120	00100-04-EG	FWH	PRA	5178210	None	
121	00100A-04-EG	FWH	PRA	5178210	None	
122	00102-04-EG	FWH	PRA	5178212	None	
123	00102A-04-EG	FWH	PRA	5178212	None	
124	00103-06-EGX	FWH	PRA	5178210	None	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
125	00103-08-EGX	FWH	PRA	5178210	Loss of Feedwater	
126	00103A-04-EG	FWH	PRA	5178210	None	
127	00103A-06-EGX	FWH	PRA	5178210	Loss of Feedwater	
128	00104-04-EG	FWH	PRA	5178212	None	
129	00104-06-EG	FWH	PRA	5178212	None	
130	00104-06-EGX	FWH	PRA	5178212	None	
131	00104-08-EGX	FWH	PRA	5178212	Loss of Feedwater/Steam Line Break	
132	00104A-04-EG	FWH	PRA	5178212	None	
133	00104A-06-EG	FWH	PRA	5178212	None	
134	00104A-06-EGX	FWH	PRA	5178212	None	
135	00105-06-GG	FWH	PRA	5178211	Loss of Feedwater	
136	00105-10-GG	FWH	PRA	5178211	Loss of Feedwater	
137	00106-06-GG	FWH	PRA	5178213	Loss of Feedwater	
138	00106-10-GG	FWH	PRA	5178213	None	
139	00107-04-GGX	FWH	PRA	5178211	None	
140	00107-08-GGX	FWH	PRA	5178211	None	
141	00107-12-GGX	FWH	PRA	5178211	None	
142	00108-04-GGX	FWH	PRA	5178213	None	
143	00108-08-GGX	FWH	PRA	5178213	None	
144	00108-12-GGX	FWH	PRA	5178213	None	
145	00109-08-HH	FWH	PRA	5178211	Loss of Feedwater	
146	00109-14-HH	FWH	PRA	5178211	Loss of Feedwater	
147	00110-08-HH	FWH	PRA	5178213	Loss of Feedwater	
148	00110-14-HH	FWH	PRA	5178213	Loss of Feedwater	
149	00111-06-HHX	FWH	PRA	5178211	Loss of Feedwater	
150	00111-10-HHX	FWH	PRA	5178211	Loss of Feedwater	
151	00111-14-HHX	FWH	PRA	5178211	Loss of Feedwater	
152	00112-06-HHX	FWH	PRA	5178213	Loss of Feedwater	
153	00112-10-HHX	FWH	PRA	5178213	Loss of Feedwater	
154	00112-14-HHX	FWH	PRA	5178213	Loss of Feedwater	
155	00113-10-HH	FWH	PRA	5178211	Loss of Feedwater	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
156	00113-14-HH	FWH	PRA	5178211	Loss of Feedwater	
157	00113-18-HH	FWH	PRA	5178211	Loss of Feedwater	
158	00114-10-HH	FWH	PRA	5178213	Loss of Feedwater	
159	00114-14-HH	FWH	PRA	5178213	Loss of Feedwater/Steam Line Break	
160	00114-18-HH	FWH	PRA	5178213	Loss of Feedwater	
161	00115-08-GG	FWH	PRA	5178211	Loss of Feedwater	
162	00115-10-GG	FWH	PRA	5178211	Loss of Feedwater	
163	00116-08-GG	FWH	PRA	5178213	Loss of Feedwater	
164	00116-10-GG	FWH	PRA	5178213	Loss of Feedwater	
165	00117-08-EG	FWH	PRA	5178210	Loss of Feedwater	
166	00118-08-EG	FWH	PRA	5178212	Loss of Feedwater	
167	00119-08-EG	FWH	PRA	5178210	None	
168	00120-08-EG	FWH	PRA	5178212	Loss of Feedwater	
169	00121-06-HH	FWH	PRA	5178210	Loss of Feedwater	
170	00121-08-HH	FWH	PRA	5178210	None	
171	00122-06-HH	FWH	PRA	5178212	Loss of Feedwater	
172	00122-08-HH	FWH	PRA	5178212	None	
173	00123-08-HH	FWH	PRA	5178210	None	
174	00124-08-HH	FWH	PRA	5178212	None	
175	00127-06-HHX	FWH	PRA	5178210	None	
176	00127-10-HHX	FWH	PRA	5178210	Loss of Feedwater	
177	00127-14-HHX	FWH	PRA	5178211	Loss of Feedwater	
178	00128-06-HHX	FWH	PRA	5178212	Loss of Feedwater	
179	00128-10-HHX	FWH	PRA	5178212	Loss of Feedwater	
180	00128-14-HHX	FWH	PRA	5178213	None	
181	00129-14-HH	FWH	PRA	5178211	None	
182	00130-14-HH	FWH	PRA	5178213	Loss of Feedwater	
183	00131-12-HHX	FWH	2%	5178211		Exclusion criteria
184	00131-16-HHX	FWH	2%	5178211		Exclusion criteria
185	00131-24-HHX	FWH	2%	5178211		Exclusion criteria
186	00132-12-HHX	FWH	2%	5178213		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
187	00132-16-HHX	FWH	2%	5178213		Exclusion criteria
188	00132-24-HHX	FWH	2%	5178213		Exclusion criteria
189	00155-03-EG	FWH	Partial 2%/PRA	5178210		Exclusion criteria
190	00155-04-EG	FWH	PRA	5178210	None	
191	00155-06-EG	FWH	2%	5178210		Exclusion criteria
192	00155-06-HHX	FWH	2%	5178210		Exclusion criteria
193	00155-08-HHX	FWH	2%	5178210		Exclusion criteria
194	00156-03-EG	FWH	Partial 2%/PRA	5178212		Exclusion criteria
195	00156-04-EG	FWH	PRA	5178212		
196	00156-06-EG	FWH	2%	5178212		Exclusion criteria
197	00156-06-HHX	FWH	2%	5178212		Exclusion criteria
198	00156-08-HHX	FWH	2%	5178212		Exclusion criteria
199	00157-08-HHX	FWH	Partial 2%/PRA	5178211		Exclusion criteria
200	00158-08-HHX	FWH	Partial 2%/PRA	5178213		Exclusion criteria
201	00181-10-HH	FWH	2%	5178211		Exclusion criteria
202	00182-10-HH	FWH	2%	5178213		Exclusion criteria
203	00182-12-HH	FWH	2%	5178213		Exclusion criteria
204	00183-03-HH	FWH	PRA	5178211	None	
205	00183-04-HH	FWH	2%	5178211		Exclusion criteria
206	00183-06-HH	FWH	2%	5178211		Exclusion criteria
207	00184-04-HH	FWH	PRA	5178213	None	
208	00184-06-HH	FWH	2%	5178213		Exclusion criteria
209	00185-03-HH	FWH	PRA	5178211	None	
210	00185-04-HH	FWH	2%	5178211		Exclusion criteria
211	00185-06-HH	FWH	2%	5178211		Exclusion criteria
212	00186-03-HH	FWH	PRA	5178213	None	
213	00186-04-HH	FWH	2%	5178213		Exclusion criteria
214	00186-06-HH	FWH	2%	5178213		Exclusion criteria
215	00187-04-HH	FWH	PRA	5178211	None	
216	00187-06-HH	FWH	2%	5178211		Exclusion criteria
217	00188-04-HH	FWH	PRA	5178213	None	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
218	00188-06-HH	FWH	2%	5178213		Exclusion criteria
219	00189-02-HH	FWH	PRA	5178211	None	
220	00190-02-EG	FWH	PRA	5178212	None	
221	00191-02-EG	FWH	PRA	5178210	Loss of Feedwater	
222	00192-02-EG	FWH	PRA	5178212	Loss of Feedwater	
223	00193-02-EG	FWH	PRA	5178210	Loss of Feedwater	
224	00194-1.5-EG	FWH	PRA	5178212	None	
225	00194-1.5-HH	FWH	2%	5178212		Exclusion criteria
226	00195-1.5-EG	FWH	PRA	5178210	None	
227	00195-1.5-HH	FWH	2%	5178210		Exclusion criteria
228	00196-1.5-EG	FWH	PRA	5178212	Loss of Feedwater/Steam Line Break	
229	00197-1.5-HH	FWH	2%	5178213		Exclusion criteria
230	00198-1.5-EG	FWH	PRA	5178212	None	
231	00199-1.5-EG	FWH	PRA	5178210	None	
232	00200-1.5-EG	FWH	PRA	5178213	None	
233	00200-1.5-HH	FWH	2%	5178213		Exclusion criteria
234	00201-1.5-EG	FWH	PRA	5178211	None	
235	00201-1.5-HH	FWH	2%	5178211		Exclusion criteria
236	00202-1.5-GG	FWH	PRA	5178213	Loss of Feedwater/Steam Line Break	
237	00203-1.5-EG	FWH	PRA	5178211	Loss of Feedwater	
238	00203-1.5-GG	FWH	PRA	5178211	Loss of Feedwater	
239	00204-06-HHX	FWH	2%	5178212		Exclusion criteria
240	00204-10-HHX	FWH	2%	5178212		Exclusion criteria
241	00205-08-HH	FWH	PRA	5178210	None	
242	00206-06-HH	FWH	PRA	5178212	None	
243	00206-08-HH	FWH	PRA	5178212	None	
244	00208-02-HH	FWH	PRA	5178213	Loss of Feedwater	
245	00209-06-HHX	FWH	2%	5178210		Exclusion criteria
246	00209-10-HHX	FWH	2%	5178245		Exclusion criteria
247	00212-02-HH	FWH	2%	5178213		Exclusion criteria
248	00213-02-HH	FWH	2%	5178211		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
249	00235-02-GG	FWH	PRA	5178211	Loss of Feedwater	
250	00235-03-GG	FWH	PRA	5178211	Loss of Feedwater	
251	00236-02-GG	FWH	PRA	5178213	Loss of Feedwater	
252	00236-03-GG	FWH	PRA	5178213	Loss of Feedwater	
253	11000-12-HH	FWH	PRA	5178213	Loss of Feedwater	
254	11000-12-HHX	FWH	2%	5178213		Exclusion criteria
255	11001-12-HH	FWH	PRA	5178211	Loss of Feedwater	
256	11001-12-HHX	FWH	2%	5178211		Exclusion criteria
257	11018-06-HH	FWH	PRA	5178213	Loss of Feedwater	
258	11018-06-HHX	FWH	PRA	5178213	None	
259	11019-06-HH	FWH	PRA	5178211	Loss of Feedwater	
260	11019-06-HHX	FWH	PRA	5178211	None	
261	11023-03-GG	FWH	PRA	5178211	None	
262	11023-03-GGX	FWH	PRA	5178211	None	
263	11023-08-GGX	FWH	PRA	5178211	None	
264	11024-03-GG	FWH	PRA	5178213	None	
265	11024-03-GGX	FWH	PRA	5178213	None	
266	11049-06-HH	FWH	PRA	5178210	Loss of Feedwater	
267	11049-06-HHX	FWH	2%	5178210		Exclusion criteria
268	11052-06-HH	FWH	PRA	5178212	Loss of Feedwater	
269	11052-06-HHX	FWH	2%	5178212		Exclusion criteria
270	11085-04-EG	FWH	PRA	5178210	Loss of Feedwater	
271	11087-04-EG	FWH	PRA	5178210	None	
272	11088-04-EG	FWH	PRA	5178212	None	
273	11089-04-HH	FWH	2%	5178210		Exclusion criteria
274	11090-04-EG	FWH	PRA	5178212	None	
275	11091-04-EG	FWH	PRA	5178210	None	
276	11091-04-EGX	FWH	PRA	5178210	None	
277	11091-06-EGX	FWH	PRA	5178210	None	
278	11092-04-EG	FWH	PRA	5178212	None	
279	11092-04-EGX	FWH	PRA	5178212	None	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
280	11093-03-EG	FWH	PRA	5178210	None	
281	11093-04-EG	FWH	PRA	5178210	None	
282	11094-04-EG	FWH	PRA	5178212	None	
283	11095-04-EG	FWH	PRA	5178210	None	
284	11095-04-HHX	FWH	PRA	5178210	None	
285	11096-04-EG	FWH	PRA	5178212	None	
286	11096-04-HHX	FWH	2%	5178212		Exclusion criteria
287	11097-04-EG	FWH	PRA	5178210	None	
288	11097-04-EGX	FWH	PRA	5178210	None	
289	11098-04-EG	FWH	PRA	5178212	None	
290	11098-04-EGX	FWH	PRA	5178212	None	
291	11099-03-EG	FWH	PRA	5178210	None	
292	11099-04-EG	FWH	PRA	5178210	None	
293	11100-04-EG	FWH	PRA	5178212	None	
294	11101-04-EG	FWH	PRA	5178210	None	
295	11101-04-HHX	FWH	2%	5178210		Exclusion criteria
296	11102-04-EG	FWH	PRA	5178212	None	
297	11102-04-HHX	FWH	2%	5178212		Exclusion criteria
298	11199-1.5-EG	FWH	PRA	5178210	None	
299	12643-04-EG	FWH	PRA	5178210	None	
300	12643-06-EG	FWH	PRA	5178210	None	
301	12643-06-EGX	FWH	PRA	5178210	None	
302	12644-1.5-EG	FWH	PRA	5178212	None	
303	12644-1.5-HH	FWH	2%	5178212		Exclusion criteria
304	14303-03-EG	FWH	Partial 2%/PRA	5178210		Exclusion criteria
305	14303-04-EG	FWH	PRA	5178210	None	
306	14303-06-EG	FWH	2%	5178210		Exclusion criteria
307	14303-06-HHX	FWH	2%	5178210		Exclusion criteria
308	14304-03-EG	FWH	Partial 2%/PRA	5178212		Exclusion criteria
309	14304-04-EG	FWH	PRA	5178212	None	
310	14304-06-EG	FWH	2%	5178212		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
311	14304-06-HHX	FWH	2%	5178212		Exclusion criteria
312	00180-16-HH	FWS	2%	5178206		Exclusion criteria
313	00317-14-GG	FWS	PRA	5178205		
314	00317-16-GG	FWS	PRA	5178205		
315	00318-14-GG	FWS	PRA	5178205	Loss of Feedwater	
316	00319-12-EG	FWS	ISI	5178205	Loss of Feedwater	
317	00319-14-EG	FWS	ISI	5178205	Loss of Feedwater	
318	00320-12-EG	FWS	ISI/PRA	5178205	Loss of Feedwater/Small Break LOCA	
319	00320-14-EG	FWS	ISI/PRA	5178205	Loss of Feedwater/Small Break LOCA	
320	00321-12-EG	FWS	ISI/PRA	5178205	Loss of Feedwater	
321	00321-14-EG	FWS	ISI/PRA	5178205	Loss of Feedwater	
322	00322-12-EG	FWS	ISI/PRA	5178205	Loss of Feedwater/Steam Line Break	
323	00322-14-EG	FWS	ISI/PRA	5178205	Loss of Feedwater/Small Break LOCA	
324	00323-12-EG	FWS	ISI/PRA	5178205	Loss of Feedwater/Steam Line Break	
325	00324-12-EG	FWS	ISI/PRA	5178205	Loss of Feedwater	
326	00325-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
327	00325-10-EG	FWS	PRA	5178205	Loss of Feedwater	
328	00325-18-EG	FWS	ISI	5178205		
329	00326-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
330	00326-10-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
331	00329-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
332	00329-10-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
333	00339-03-EG	FWS	PRA	5178205	Loss of Feedwater/Steam Line Break	
334	00340-03-EG	FWS	PRA	5178205	Loss of Feedwater	
335	00341-02-EG	FWS	PRA	5178206	Loss of Feedwater	
336	00341-1.5-EG	FWS	PRA	5178206	Loss of Feedwater	
337	00342-02-EG	FWS	PRA	5178206	Loss of Feedwater	
338	00342-1.5-EG	FWS	PRA	5178206	Loss of Feedwater	
339	00343-02-EG	FWS	PRA	5178206	Loss of Feedwater	
340	00343-1.5-EG	FWS	PRA	5178206	Loss of Feedwater	
341	00347-02-EGX	FWS	PRA	5178206	None	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
342	00347-03-EGX	FWS	PRA	5178206	Steam Line Break	
343	00348-02-HH	FWS	PRA	5178206	None	
344	00349-02-HH	FWS	PRA	5178157	None	
345	00350-04-HH	FWS	PRA	5178206	None	
346	00350-04-KNI	FWS	2%	5178330		Exclusion criteria
347	00351-02-EG	FWS	PRA	5178205	None	
348	00351-04-EGX	FWS	2%	5178205		Exclusion criteria
349	00352-02-EG	FWS	PRA	5178205	None	
350	00352-04-EGX	FWS	2%	5178205		Exclusion criteria
351	00374-02-GG	FWS	PRA	5178207	Loss of Feedwater	
352	00374-03-GG	FWS	PRA	5178207	Loss of Feedwater	
353	00375-02-GG	FWS	PRA	5178207	Loss of Feedwater/Steam Line Break	
354	00389-06-EGX	FWS	2%	5178200		Exclusion criteria
355	00390-06-EGX	FWS	2%	5178205		Exclusion criteria
356	00391-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
357	00391-10-EG	FWS	LBB/ISI	5178206		See Note (1)
358	00392-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
359	00392-10-EG	FWS	LBB/ISI	5178206		See Note (1)
360	00393-08-EG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
361	00393-10-EG	FWS	LBB/ISI	5178206		See Note (1)
362	00462-03-HH	FWS	2%	5178206		Exclusion criteria
363	06004-14-CL	FWS	PRA	5178205	Loss of Feedwater	
364	06005-14-CL	FWS	PRA	5178205	Loss of Feedwater	
365	06020-03-BH4	FWS	2%	5178205		Exclusion criteria
366	06020-03-CL	FWS	PRA	5178205	Loss of Feedwater	
367	06020-04-BH4	FWS	2%	5178205		Exclusion criteria
368	06021-03-BH4	FWS	2%	5178205		Exclusion criteria
369	06021-03-CL	FWS	PRA	5178205	Loss of Feedwater	
370	10852-03-GG	FWS	PRA	5178207	Loss of Feedwater	
371	14103-02-GG	FWS	PRA	5178206	Loss of Feedwater	
372	14104-04-GG	FWS	ISI	5178206		

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
373	14108-02-GG	FWS	PRA	5178206	Loss of Feedwater	
374	14109-04-GG	FWS	ISI	5178206		
375	14111-02-GG	FWS	PRA	5178206	Loss of Feedwater/Steam Line Break	
376	14114-04-GG	FWS	ISI	5178206		
377	14115-02-GG	FWS	PRA	5178206	None	
378	14115-03-GG	FWS	PRA	5178206	None	
379	14115-04-GG	FWS	2%	5178206		Exclusion criteria
380	02067-02-BH2	LDS	PRA	5178130	Small Break LOCA	
381	02068-02-BH2	LDS	PRA	5178130	Small Break LOCA	
382	02071-02-BH2	LDS	PRA	5178130	Small Break LOCA	
383	02071-02-EG2	LDS	PRA	5178130	Small Break LOCA	
384	03006-02-EG2	LDS	PRA	5178130	Small Break LOCA	
385	05008-02-BH2	LDS	PRA	5178130	Small Break LOCA	
386	00001-16-EG	MSS	PRA	5178226	Steam Line Break	
387	00001-24-EG	MSS	ISI	5178226		
388	00002-16-EG	MSS	PRA	5178226	Steam Line Break	
389	00002-24-EG	MSS	ISI	5178226		
390	00003-20-EG	MSS	LBB	5178225		
391	00004-20-EG	MSS	LBB	5178225		
392	00005-20-EG	MSS	LBB	5178225		
393	00006-24-EG	MSS	LBB	5178225		
394	00007-24-EG	MSS	LBB	5178225		
395	00008-02-EG	MSS	PRA	5178226	Steam Line Break	
396	00008-04-EG	MSS	PRA	5178226	Steam Line Break	
397	00009-03-EG	MSS	PRA	5178226	Loss of Feedwater/Steam Line Break	
398	00010-1.5-EG	MSS	PRA	5178226	None	
399	00013-12-EGX	MSS	2%	5178226		Exclusion criteria
400	00014-20-EG	MSS	ISI	5178226		
401	00015-04-EG	MSS	PRA	5178226	Steam Line Break	
402	00015-06-EG	MSS	PRA	5178226	Steam Line Break	
403	00015-06-EGX	MSS	2%	5178226		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
404	00015-08-EG	MSS	PRA	5178226	Steam Line Break	
405	00015-10-EG	MSS	PRA	5178226	Steam Line Break	
406	00017-06-EG	MSS	PRA	5178226	Steam Line Break	
407	00017-08-EG	MSS	PRA	5178226	Steam Line Break	
408	00018-06-EG	MSS	PRA	5178226	Steam Line Break	
409	00018-10-EG	MSS	ISI	5178226		
410	00019-06-EG	MSS	PRA	5178226	Loss of Feedwater/Steam Line Break	
411	00020-06-EG	MSS	PRA	5178231	Steam Line Break	
412	00020-08-EG	MSS	PRA	5178226	Steam Line Break	
413	00050-24-EG	MSS	PRA	5178225	Steam Line Break	
414	00051-24-EG	MSS	ISI	5178225		
415	00052-10-HH	MSS	2%	5178225		Exclusion criteria
416	00052-14-HH	MSS	2%	5178225		Exclusion criteria
417	00053-10-HH	MSS	2%	5178225		Exclusion criteria
418	00053-14-HH	MSS	2%	5178225		Exclusion criteria
419	00054-10-HH	MSS	2%	5178225		Exclusion criteria
420	00054-14-HH	MSS	2%	5178225		Exclusion criteria
421	00055-10-HH	MSS	2%	5178225		Exclusion criteria
422	00055-14-HH	MSS	2%	5178225		Exclusion criteria
423	00056-10-HH	MSS	2%	5178225		Exclusion criteria
424	00056-14-HH	MSS	2%	5178225		Exclusion criteria
425	00057-10-HH	MSS	2%	5178225		Exclusion criteria
426	00057-14-HH	MSS	2%	5178225		Exclusion criteria
427	00058-10-HH	MSS	2%	5178225		Exclusion criteria
428	00058-14-HH	MSS	2%	5178225		Exclusion criteria
429	00059-10-HH	MSS	2%	5178225		Exclusion criteria
430	00059-14-HH	MSS	2%	5178225		Exclusion criteria
431	00060-10-HH	MSS	2%	5178225		Exclusion criteria
432	00060-14-HH	MSS	2%	5178225		Exclusion criteria
433	00061-10-HH	MSS	2%	5178225		Exclusion criteria
434	00061-14-HH	MSS	2%	5178225		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
435	00062-04-EG	MSS	PRA	5178225	Steam Line Break	
436	00062-06-EG	MSS	PRA	5178225	Steam Line Break	
437	00062-10-HH	MSS	2%	5178225		Exclusion criteria
438	00063-04-EG	MSS	PRA	5178225	Steam Line Break	
439	00063-06-EG	MSS	PRA	5178225	Steam Line Break	
440	00063-10-HH	MSS	2%	5178225		Exclusion criteria
441	00064-04-EG	MSS	PRA	5178225	Steam Line Break	
442	00064-06-EG	MSS	PRA	5178225	Steam Line Break	
443	00064-10-HH	MSS	2%	5178225		Exclusion criteria
444	00065-04-EG	MSS	PRA	5178225	Steam Line Break	
445	00065-06-EG	MSS	PRA	5178225	Steam Line Break	
446	00065-10-HH	MSS	2%	5178225		Exclusion criteria
447	00069-03-EG	MSS	PRA	5178221	Steam Line Break	
448	00341-02-EG	MSS	PRA	5178206	Loss of Feedwater	
449	00341-1.5-EG	MSS	PRA	5178206	Loss of Feedwater	
450	00342-02-EG	MSS	PRA	5178206	Loss of Feedwater	
451	00342-1.5-EG	MSS	PRA	5178206	Loss of Feedwater	
452	00343-02-EG	MSS	PRA	5178206	Loss of Feedwater	
453	00343-1.5-EG	MSS	PRA	5178206	Loss of Feedwater	
454	01300-04-EG	MSS	PRA	5178226	Steam Line Break	
455	01301-04-EG	MSS	PRA	5178226	Steam Line Break	
456	01312-08-HH	MSS	PRA	5178226	Steam Line Break	
457	01313-12-HH	MSS	2%	5178213		Exclusion criteria
458	01314-02-EG	MSS	2%	5178226		Exclusion criteria
459	01315-02-EG	MSS	2%	5178226		Exclusion criteria
460	01316-03-HH	MSS	PRA	5178226	Loss of Feedwater/Steam Line Break	
461	01316-06-HH	MSS	PRA	5178226	Steam Line Break	
462	01316-08-HH	MSS	PRA	5178226	Steam Line Break	
463	01317-03-HH	MSS	PRA	5178226	Steam Line Break	
464	01319-10-HH	MSS	2%	5178226		Exclusion criteria
465	01319-12-HH	MSS	2%	5178226		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
466	08594-1.5-EG	MSS	PRA	5178226	None	
467	08599-04-EGX	MSS	2%	5178226		Exclusion criteria
468	08599-06-EGX	MSS	2%	5178226		Exclusion criteria
469	08599-08-EGX	MSS	2%	5178226		Exclusion criteria
470	08603-1.5-EG	MSS	PRA	5178226	None	
471	10521-02-EG	MSS	PRA	5178226	Steam Line Break	
472	10521-02-HH	MSS	PRA	5178226	Steam Line Break	
473	12591-02-HH	MSS	PRA	5178226	Steam Line Break	
474	13388-16-EG	MSS	PRA	5178226	Steam Line Break	
475	13390-16-EG	MSS	PRA	5178226	Steam Line Break	
476	13399-06-HH	MSS	PRA	5178226	Steam Line Break	
477	13400-06-HH	MSS	PRA	5178226	Steam Line Break	
478	13403-06-HH	MSS	PRA	5178226	Steam Line Break	
479	05011-03-BH2	PZR	PRA	5178105	Small Break LOCA	
480	05011-04-BH2	PZR	PRA	5178105	Small Break LOCA	
481	05025-03-BH2	PZR	PRA	5178105	Small Break LOCA	
482	05027-03-BH2	PZR	PRA	5178105	Small Break LOCA	
483	05028-06-EG3	PZR	2%	5178105		Exclusion criteria
484	05030-03-BH2	PZR	PRA	5178105	Small Break LOCA	
485	05031-06-EG3	PZR	2%	5178105		Exclusion criteria
486	05034-02-BH2	PZR	PRA	5178105	Small Break LOCA	
487	05034-02-EG2	PZR	2%	5178105		Exclusion criteria
488	05034-02-EG3	PZR	2%	5178105		Exclusion criteria
489	05034-03-BH2	PZR	PRA	5178105	Small Break LOCA	
490	05034-04-EG3	PZR	2%	5178105		Exclusion criteria
491	05035-02-BH2	PZR	PRA	5178105	Small Break LOCA	
492	05035-02-EG2	PZR	2%	5178105		Exclusion criteria
493	05035-02-EG3	PZR	2%	5178105		Exclusion criteria
494	05035-04-EG3	PZR	2%	5178105		Exclusion criteria
495	05035-10-EG2	PZR	2%	5178105		Exclusion criteria
496	05035-10-EG3	PZR	2%	5178105		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
497	08315-03-EG2	PZR	2%	5178105		Exclusion criteria
498	02005-02-BH2	RCP	PRA	5178110	Small Break LOCA	
499	02005-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
500	02005-02.5-BH3	RCP	PRA	5178110	Loss of RCP Transient	
501	02005-04-BH3	RCP	PRA	5178110	Loss of RCP Transient	
502	02006-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
503	02008-02-BH2	RCP	PRA	5178110	Small Break LOCA	
504	02008-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
505	02009-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
506	02011-02-BH2	RCP	PRA	5178110	Small Break LOCA	
507	02011-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
508	02012-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
509	02014-02-BH2	RCP	PRA	5178111	Small Break LOCA	
510	02018-02-BH2	RCP	PRA	5178111	Small Break LOCA	
511	02020-02-BH2	RCP	PRA	5178111	Small Break LOCA	
512	02090-02-BH2	RCP	PRA	5178115	Small Break LOCA	
513	02090-02-BH3	RCP	PRA	5178115	Loss of RCP Transient	
514	02091-02-BH2	RCP	PRA	5178115	Small Break LOCA	
515	02091-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
516	02092-02-BH2	RCP	PRA	5178115	Small Break LOCA	
517	02092-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
518	02105-02-BH3	RCP	PRA	5178110	None	
519	02105-03-BH3	RCP	PRA	5178110	Loss of RCP Transient	
520	02105-04-BH3	RCP	PRA	5178110	Loss of RCP Transient	
521	02106-04-BH3	RCP	PRA	5178110	Loss of RCP Transient	
522	02108-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
523	02108-03-BH3	RCP	PRA	5178110	Loss of RCP Transient	
524	02109-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
525	02109-03-BH3	RCP	PRA	5178110	Loss of RCP Transient	
526	02109-04-BH3	RCP	PRA	5178110	Loss of RCP Transient	
527	02110-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
528	02110-03-BH3	RCP	PRA	5178110	Loss of RCP Transient	
529	02121-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
530	02122-02-BH3	RCP	PRA	5178110	Loss of RCP Transient	
531	02123-02-BH3	RCP	PRA	5178110	Loss of RCP Transient/Small Break LOCA	
532	05000-1.5-DG	RCS	2%	5178100		Exclusion criteria
533	05001-27.5-BH2	RCS	LBB	5178100		
534	05002-08-BH2	RCS	LBB	5178100		
535	05003-02-BH2	RCS	PRA	5178100	Small Break LOCA	
536	05003-02-HP	RCS	2%	5178100		Exclusion criteria
537	05005-29-BH2	RCS	LBB	5178100		
538	05006-27.5-BH2	RCS	LBB	5178100		
539	05007-27.5-BH2	RCS	LBB	5178100		
540	05008-02-BH2	RCS	PRA	5178200	Small Break LOCA	
541	05009-29-BH2	RCS	LBB	5178200		
542	05010-27.5-BH2	RCS	LBB	5178200		
543	05011-03-BH2	RCS	PRA	5178110	Small Break LOCA	
544	05012-27.5-BH2	RCS	LBB	5178110		
545	05013-10-BH2	RCS	LBB	5178110		
546	05015-29-BH2	RCS	LBB	5178110		
547	05016-02-BH2	RCS	PRA	5178100	Small Break LOCA	
548	05016-02-HP	RCS	2%	5178100		Exclusion criteria
549	05017-27.5-BH2	RCS	LBB	5178100		
550	05019-02-HK	RCS	2%	5178100		Exclusion criteria
551	05025-03-BH2	RCS	PRA	5178100	Small Break LOCA	
552	05037-02-BH2	RCS	PRA	5178100	Small Break LOCA	
553	05037-02-HP	RCS	2%	5178100		Exclusion criteria
554	03000-06-EG2	RHR	PRA	5178130	LOCA	
555	03001-06-BH2	RHR	PRA	5178100	LOCA	
556	03001-06-EG2	RHR	PRA	5178130	Small Break LOCA	
557	03003-04-EG2	RHR	PRA	5178130	Small Break LOCA	
558	03004-04-HK	RHR	2%	5178130		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
559	03004-2.5-EG2	RHR	PRA	5178130	Small Break LOCA	
560	03015-06-EG2	RHR	PRA	5178130	Small Break LOCA	
561	03016-06-EG2	RHR	PRA	5178130	Small Break LOCA	
562	03019-02-EG2	RHR	PRA	5178130	Small Break LOCA	
563	03019-06-EG2	RHR	PRA	5178130	Small Break LOCA	
564	05002-06-EG2	RHR	PRA	5178130	Small Break LOCA	
565	05002-08-EG2	RHR	PRA	5178130	Small Break LOCA	
566	05038-06-EG2	RHR	PRA	5178130	Small Break LOCA	
567	05038-08-EG2	RHR	PRA	5178130	Small Break LOCA	
568	05056-02-S2	RHR	PRA	5178130	Small Break LOCA	
569	00349-02-HH	RLC	2%	5178157		Exclusion criteria
570	07037-02-HP2	RLC	2%	5178158		Exclusion criteria
571	07076-02-HP2	RLC	2%	5178158		Exclusion criteria
572	07170-03-HP2	RLC	2%	5178156		Exclusion criteria
573	07027-02-HH6	RWL	2%	5178165		Exclusion criteria
574	07028-02-HH6	RWL	2%	5178166		Exclusion criteria
575	07039-03-HH6	RWL	2%	5178166		Exclusion criteria
576	07177-02-HP2	RWL	2%	5178156		Exclusion criteria
577	01104-1.5-HH5	SCF	2%	5178270		Exclusion criteria
578	01100-1.5-HH5	SCF	2%	5178210		Exclusion criteria
579	06004-03-CL	SIS	PRA	5178115	Loss of Feedwater	
580	06004-14-CL	SIS	PRA	5178115	Loss of Feedwater	
581	06005-03-CL	SIS	PRA	5178115	Loss of Feedwater	
582	06005-14-CL	SIS	PRA	5178115	Loss of Feedwater	
583	06006-06-BH2	SIS	PRA	5178100	LOCA	
584	06006-06-CL	SIS	2%	5178115		Exclusion criteria
585	06007-06-BH2	SIS	PRA	5178100	LOCA	
586	06007-06-CL	SIS	2%	5178115		Exclusion criteria
587	06008-06-BH2	SIS	PRA	5178100	LOCA	
588	06008-06-CL	SIS	2%	5178115		Exclusion criteria
589	06009-02-CL	SIS	2%	5178115		Exclusion criteria

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
590	06010-02-CL	SIS	2%	5178115		Exclusion criteria
591	06011-02-CL	SIS	2%	5178115		Exclusion criteria
592	06011-02-HK	SIS	2%	5178115		Exclusion criteria
593	06012-02-CL	SIS	2%	5178115		Exclusion criteria
594	06012-02-HK	SIS	2%	5178115		Exclusion criteria
595	06028-02-CL	SIS	2%	5178115		Exclusion criteria
596	01302-1.5-EGX	TBN	PRA	5178240	Loss of Feedwater	
597	01303-1.5-EGX	TBN	PRA	5178240	Loss of Feedwater	
598	01304-1.5-EGX	TBN	PRA	5178240	Loss of Feedwater	
599	01305-1.5-EGX	TBN	PRA	5178240	Loss of Feedwater	
600	01307-04-HH	TBN	PRA	5178240	None	
601	01308-04-HH	TBN	PRA	5178240	Loss of RCP Transient	
602	01311-1.5-EGX	TBN	PRA	5178240	Loss of Feedwater	
603	01316-06-HH	TBN	PRA	5178226	Loss of RCP Transient	
604	01318-04-HH	TBN	PRA	5178240	None	
605	01318-08-HH	TBN	PRA	5178251	None	
606	01323-04-HH	TBN	PRA	5178240	None	
607	01323-08-HH	TBN	PRA	5178251	Loss of Load Transient	
608	11416-1.25-EG	TBN	PRA	5178240	Loss of Load Transient	
609	11417-1.25-EG	TBN	PRA	5178240	Loss of Load Transient	
610	11421-1.5-EG	TBN	PRA	5178240	Loss of Load Transient	
611	13382-16-EG	TBN	PRA	5178240	Loss of Load Transient	
612	13383-16-EG	TBN	PRA	5178240	Loss of Load Transient	
613	13386-16-EG	TBN	PRA	5178240	Loss of Load Transient	
614	13387-16-EG	TBN	PRA	5178240	Loss of Load Transient	
615	13392-1.5-EG	TBN	PRA	5178240	Loss of Load Transient	
616	13393-1.5-EG	TBN	PRA	5178240	Loss of Load Transient	
617	13394-03-EG	TBN	PRA	5178240	Loss of Load Transient	
618	13394-1.25-EG	TBN	PRA	5178240	Loss of Load Transient	
619	13394-1.5-EG	TBN	PRA	5178240	Loss of Load Transient	
620	13395-04-EG	TBN	PRA	5178240	Loss of Load Transient	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
621	13396-04-EG	TBN	PRA	5178240	Loss of Load Transient	
622	13397-1.25-EG	TBN	PRA	5178240	Loss of Load Transient	
623	13397-1.5-EG	TBN	PRA	5178240	Loss of Load Transient	
624	13397-03-EG	TBN	PRA	5178240	Loss of Load Transient	
625	13398-06-HH	TBN	PRA	5178240	Loss of Load Transient	
626	13399-06-HH	TBN	PRA	5178240	Steam Line Break	
627	13400-06-HH	TBN	PRA	5178240	Steam Line Break	
628	13401-06-HH	TBN	PRA	5178240	Loss of Load Transient	
629	13402-06-HH	TBN	PRA	5178240	Loss of Load Transient	
630	13403-06-HH	TBN	PRA	5178240	Steam Line Break	
631	13404-06-HH	TBN	PRA	5178240	Loss of Load Transient	
632	13427-02-HH	TBN	PRA	5178240	Loss of Load Transient	
633	13428-04-HH	TBN	PRA	5178240	Loss of Load Transient	
634	13429-2.5-HH	TBN	PRA	5178240	None	
635	13431-04-HH	TBN	PRA	5178240	Loss of Load Transient	
636	13434-02-HH	TBN	PRA	5178240	Loss of Load Transient	
637	13435-2.5-HH	TBN	PRA	5178240	None	
638	13445-1.25-EG	TBN	PRA	5178240	None	
639	13446-1.25-EG	TBN	PRA	5178240	None	
640	13447-1.25-EG	TBN	PRA	5178240	None	
641	13448-04-HH	TBN	PRA	5178240	Loss of Load Transient	
642	13448-06-HH	TBN	PRA	5178240	Loss of Load Transient	
643	13449-04-HH	TBN	PRA	5178240	Loss of Load Transient	
644	13449-06-HH	TBN	PRA	5178240	Loss of Load Transient	
645	00012-10-GG	THP	PRA	5178240	Steam Line Break	
646	00016-16-HH	THP	PRA	5178240	Steam Line Break	
647	00017-06-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
648	00018-06-EG	THP	PRA	5178231	Steam Line Break	
649	00019-06-EG	THP	PRA	5178231	Steam Line Break	
650	00020-06-EG	THP	PRA	5178231	Steam Line Break	
651	00021-10-GG	THP	PRA	5178230	Steam Line Break	

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	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
652	00022-10-GG	THP	PRA	5178213	Steam Line Break/Loss of Feedwater	
653	00023-16-GG	THP	PRA	5178211	Steam Line Break	
654	00023-16-HH	THP	PRA	5178211	Steam Line Break/Small Break LOCA	
655	00024-16-GG	THP	PRA	5178213	Steam Line Break/Loss of Feedwater	
656	00024-16-HH	THP	PRA	5178213	Steam Line Break/Loss of Feedwater /Small Break LOCA	
657	00078-04-EG	THP	PRA	5178231	Steam Line Break	
658	00079-04-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
659	00945-18-EG	THP	PRA	5178231	Steam Line Break	
660	08824-36-EG	THP	PRA	5178231	Loss of Feedwater	
661	08825-18-EG	THP	PRA	5178232	None	
662	08825-22-HH	THP	2%	5178232		Exclusion criteria
663	08826-18-EG	THP	PRA	5178232	None	
664	08826-22-HH	THP	2%	5178232		Exclusion criteria
665	08827-18-EG	THP	PRA	5178232	None	
666	08827-22-HH	THP	2%	5178232		Exclusion criteria
667	08828-18-EG	THP	PRA	5178232	None	
668	08828-22-HH	THP	2%	5178232		Exclusion criteria
669	08829-18-EG	THP	PRA	5178232	None	
670	08829-22-HH	THP	2%	5178232		Exclusion criteria
671	08830-02-HH	THP	2%	5178232		Exclusion criteria
672	08836-18-EG	THP	PRA	5178232	None	
673	08836-22-HH	THP	2%	5178232		Exclusion criteria
674	08837-18-EG	THP	PRA	5178232	None	
675	08837-22-HH	THP	2%	5178232		Exclusion criteria
676	08838-18-EG	THP	PRA	5178232	None	
677	08838-22-HH	THP	2%	5178232		Exclusion criteria
678	08839-18-EG	THP	PRA	5178232	None	
679	08839-22-HH	THP	2%	5178232		Exclusion criteria
680	08840-18-EG	THP	PRA	5178232	None	
681	08840-22-HH	THP	2%	5178232		Exclusion criteria

Appendix A
HELB Resolution Summary (System Interactions)

	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
682	08841-02-HH	THP	2%	5178232		Exclusion criteria
683	08847-36-EG	THP	PRA	5178231	None	
684	08849-24-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
685	09092-24-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
686	09093-24-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
687	09094-24-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
688	09095-24-EG	THP	PRA	5178231	Steam Line Break	
689	09096-24-EG	THP	PRA	5178231	Steam Line Break	
690	09097-24-EG	THP	PRA	5178231	Steam Line Break	
691	09098-24-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
692	09099-24-EG	THP	PRA	5178231	Steam Line Break	
693	09100-24-EG	THP	PRA	5178231	Steam Line Break	
694	09101-24-EG	THP	PRA	5178231	Steam Line Break	
695	09102-30-EG	THP	PRA	5178231	Steam Line Break	
696	09102-36-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
697	09102-42-EG	THP	PRA	5178231	Steam Line Break	
698	09102-54-EG	THP	PRA	5178235	None	
699	09103-36-EG	THP	PRA	5178231	Steam Line Break/Loss of RCP Transient	
700	09103-42-EG	THP	PRA	5178231	Steam Line Break	
701	09104-30-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
702	09104-36-EG	THP	PRA	5178231	Steam Line Break/Loss of Feedwater	
703	09104-42-EG	THP	PRA	5178231	Steam Line Break	
704	09104-54-EG	THP	PRA	5178235	None	
705	09105-36-EG	THP	PRA	5178231	Steam Line Break	
706	09106-24-EG	THP	PRA	5178231	Steam Line Break	
707	09107-18-EG	THP	PRA	5178231	Steam Line Break	
708	09108-18-EG	THP	PRA	5178231	Steam Line Break	
709	09109-18-EG	THP	PRA	5178231	Steam Line Break	
710	09110-18-EG	THP	PRA	5178231	Steam Line Break	
711	09111-02-EG	THP	PRA	5178231	None	
712	09112-02-EG	THP	PRA	5178231	None	

Appendix A
HELB Resolution Summary (System Interactions)

	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
713	09113-18-EG	THP	PRA	5178231	Steam Line Break	
714	09114-18-EG	THP	PRA	5178231	Steam Line Break	
715	09116-18-EG	THP	PRA	5178231	Steam Line Break	
716	09117-02-EG	THP	PRA	5178231	Steam Line Break	
717	09118-02-EG	THP	PRA	5178231	None	
718	09119-28-GG	THP	PRA	5178230	Steam Line Break	
719	09120-28-GG	THP	PRA	5178231	Steam Line Break	
720	09123-03-GG	THP	PRA	5178231	None	
721	09123-2.5-GG	THP	PRA	5178231	None	
722	09123-28-GG	THP	PRA	5178231	Steam Line Break	
723	09124-28-GG	THP	PRA	5178230	Steam Line Break	
724	09140-1.5-HH	THP	2%	5178232		Exclusion criteria
725	09141-1.5-HH	THP	2%	5178232		Exclusion criteria
726	12195-1.5-HH	THP	2%	5178232		Exclusion criteria
727	12196-1.5-HH	THP	2%	5178232		Exclusion criteria
728	12197-1.5-HH	THP	2%	5178232		Exclusion criteria
729	12203-1.5-HH	THP	2%	5178232		Exclusion criteria
730	12204-1.5-HH	THP	2%	5178232		Exclusion criteria
731	12205-1.5-HH	THP	2%	5178232		Exclusion criteria
732	12206-1.5-HH	THP	2%	5178232		Exclusion criteria
733	12207-1.5-HH	THP	2%	5178232		Exclusion criteria
734	00025-18-HH	TLP	PRA	5178235	Loss of Feedwater	
735	00026-18-HH	TLP	PRA	5178235	Loss of Feedwater	
736	00027-20-HH	TLP	2%	5178235		Exclusion criteria
737	00028-20-HH	TLP	2%	5178235		Exclusion criteria
738	00029-20-HH	TLP	2%	5178235		Exclusion criteria
739	00030-20-HH	TLP	2%	5178235		Exclusion criteria
740	00039-16-HH	TLP	2%	5178235		Exclusion criteria
741	00040-16-HH	TLP	2%	5178235		Exclusion criteria
742	00043-16-HH	TLP	2%	5178235		Exclusion criteria
743	00044-16-HH	TLP	2%	5178235		Exclusion criteria

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HELB Resolution Summary (System Interactions)

	LINE NO	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	REMARKS
744	00213-02-HH	TLP	2%	5178235		Exclusion criteria
745	08500-16-HH	TLP	2%	5178235		Exclusion criteria
746	08508-16-HH	TLP	2%	5178235		Exclusion criteria
747	08509-16-HH	TLP	2%	5178235		Exclusion criteria
748	02002-02-BH2	VCC	PRA	5178135	None	Exclusion criteria
749	02002-02-BH3	VCC	PRA	5178135	Loss of RCP Transient	
750	02002-03-BH2	VCC	PRA	5178135	None	
751	02002-03-BH3	VCC	PRA	5178135	None	
752	02003-02-BH2	VCC	PRA	5178135	None	
753	02003-02-BH3	VCC	PRA	5178135	None	
754	02003-03-BH2	VCC	PRA	5178135	None	
755	02004-03-BH2	VCC	PRA	5178135	None	
756	02005-02-BH2	VCC	PRA	5178135	None	
757	02005-02-BH3	VCC	PRA	5178110	None	
758	02005-04-BH3	VCC	PRA	5178110	None	
759	02005-2.5-BH3	VCC	PRA	5178110	Loss of RCP Transient	
760	02010-02-HN1	VCC	2%	5178135		Exclusion criteria
761	02031-02-BH3	VCC	PRA	5178135	None	
762	02033-02-BH3	VCC	PRA	5178135	None	
763	02033-02-HK	VCC	PRA	5178135	None	
764	02080-02-BH2	VCC	PRA	5178105	Small Break LOCA	
765	02080-04-BH2	VCC	PRA	5178135	Small Break LOCA	
766	02081-02-BH2	VCC	PRA	5178100	Small Break LOCA	
767	02093-1.5-HK	VCC	PRA	5178135	None	
768	02094-1.5-HK	VCC	PRA	5178135	None	
769	08936-1.25-BH2	VCC	2%	5178135		Exclusion Criteria
770	08941-1.25-BH2	VCC	2%	5178135		Exclusion Criteria

NOTE : (1) Inside Containment --- LBB
Outside Containment --- ISI

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
1	Column F12	AFW-69-03-EG	J.I.	O.C.	Yes	
2	Column G13	AFW-69-03-EG	J.I.	O.C.	Yes	
3	Column F13	AFW-69-03-EG	J.I.	O.C.	Yes	
4	Column G12	AFW-381-03-EG-3ACB	J.I.	O.C.	Yes	
5	Column G12	AFW-381A-04-EG	J.I.	O.C.	Yes	
6	Column G13	AFW-381A-04-EG	J.I.	O.C.	Yes	
7	Column G12	AFW-381C-04-EG	J.I.	O.C.	Yes	
8	Column G13	AFW-381C-04-EG	J.I.	O.C.	Yes	
9	Column H9	CND-305-10-GG	J.I.	O.C.	Yes	
10	Column H12	CND-305-10-GG	J.I.	O.C.	Yes	
11	Column K9	CND-305-12-GG	J.I.	O.C.	Yes	
12	Column H9	CND-305-12-GG	J.I.	O.C.	Yes	
13	Column H12	CND-305-12-GG	J.I.	O.C.	Yes	
14	Column K12	CND-305-12-GG	J.I.	O.C.	Yes	
15	Column G2	CND-306-10-GG	J.I.	O.C.	Yes	
16	Column H2	CND-306-10-GG	J.I.	O.C.	Yes	
17	Column J1	CND-306-12-GG	J.I.	O.C.	Yes	
18	Column J2	CND-306-12-GG	J.I.	O.C.	Yes	
19	Column G2	CND-306-12-GG	J.I.	O.C.	Yes	
20	Column H2	CND-306-12-GG	J.I.	O.C.	Yes	
21	Column K1	CND-306-12-GG	J.I.	O.C.	Yes	
22	Column K5	CND-306-12-GG	J.I.	O.C.	Yes	
23	EHP-B24, H2/H5	CND-306-12-GG	J.I.	O.C.	Yes	
24	Column K5	CND-310-12-GG	J.I.	O.C.	Yes	
25	Column L4	CND-310-12-GG	J.I.	O.C.	Yes	
26	Column L5	CND-310-12-GG	J.I.	O.C.	Yes	
27	Column G12	CND-311-12-GG	J.I.	O.C.	Yes	
28	Column H13	CND-311-12-GG	J.I.	O.C.	Yes	
29	Column H12	CND-311-12-GG	J.I.	O.C.	Yes	
30	Column K12	CND-311-12-GG	J.I.	O.C.	Yes	
31	Column J12	CND-311-12-GG	J.I.	O.C.	Yes	

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HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
32	Column K9	CND-311-12-GG	J.I.	O.C.	Yes	
33	Column L10	CND-311-12-GG	J.I.	O.C.	Yes	
34	Column L9	CND-311-12-GG	J.I.	O.C.	Yes	
35	WHP-B14, H13/J13	CND-311-12-GG	J.I.	O.C.	Yes	
36	WHP-B16, H12/J12	CND-311-12-GG	J.I.	O.C.	Yes	
37	WHP-B26, K9/L9	CND-311-12-GG	J.I.	O.C.	Yes	
38	WHP-B17, L9/L10	CND-311-12-GG	J.I.	O.C.	Yes	
39	Column H1	CND-312-12-GG	J.I.	O.C.	Yes	
40	Column J1	CND-312-12-GG	J.I.	O.C.	Yes	
41	Column J2	CND-312-12-GG	J.I.	O.C.	Yes	
42	Column K2	CND-312-12-GG	J.I.	O.C.	Yes	
43	Column K5	CND-312-12-GG	J.I.	O.C.	Yes	
44	Column L4	CND-312-12-GG	J.I.	O.C.	Yes	
45	Column L5	CND-312-12-GG	J.I.	O.C.	Yes	
46	EHP-B14, H2/J2	CND-312-12-GG	J.I.	O.C.	Yes	
47	Column K2	CND-312-12-GG	Pipe Whip	O.C.	No	Modification Proposed
48	WHP-B14, J13/H13	CND-313-12-GG	J.I.	O.C.	Yes	
49	WHP-B2.10, J13/K13	CND-313-12-GG	J.I.	O.C.	Yes	
50	WHP-B26, K9/K12	CND-313-12-GG	J.I.	O.C.	Yes	
51	Column K2	CND-314-12-GG	J.I.	O.C.	Yes	
52	Column H1	CND-314-12-GG	J.I.	O.C.	Yes	
53	EHP-B1, E1/F1	CND-314-12-GG	J.I.	O.C.	Yes	
54	EHP-B8, H1/J1	CND-314-12-GG	J.I.	O.C.	Yes	
55	EHP-B8, G1/H1	CND-314-12-GG	J.I.	O.C.	Yes	
56	EHP-B13, G2/H2	CND-314-12-GG	J.I.	O.C.	Yes	
57	EHP-B23, E1/E3	CND-314-12-GG	J.I.	O.C.	Yes	
58	EHP-B24, H1/H2	CND-314-12-GG	J.I.	O.C.	Yes	
59	EHP-B26, J1/J2	CND-314-12-GG	J.I.	O.C.	Yes	
60	Column K2	CND-314-12-GG	Pipe Whip	O.C.	No	Modification Proposed
61	Column E11	CND-317-14-GG	J.I.	O.C.	Yes	
62	Column E13	CND-317-14-GG	J.I.	O.C.	Yes	

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HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
63	Column F12	CND-317-14-GG	J.I.	O.C.	Yes	
64	Column F13	CND-317-14-GG	J.I.	O.C.	Yes	
65	Column A7	CND-331-1.5-GG	J.I.	O.C.	Yes	
66	Column H5	CND-331-1.5-GG	J.I.	O.C.	Yes	
67	Column A7	CND-331-1.5-GG	Pipe Whip	O.C.	Yes	
68	Column H5	CND-331-1.5-GG	Pipe Whip	O.C.	Yes	
69	Column G2	CND-336-08-GG	J.I.	O.C.	Yes	
70	Column H2	CND-336-08-GG	J.I.	O.C.	Yes	
71	Column H5	CND-336-08-GG	J.I.	O.C.	Yes	
72	Column H9	CND-336-08-GG	J.I.	O.C.	Yes	
73	Column J2	CND-336-08-GG	J.I.	O.C.	Yes	
74	Column H12	CND-336-08-GG	J.I.	O.C.	Yes	
75	Column F12	CND-337-08-GG	J.I.	O.C.	Yes	
76	Column F13	CND-337-08-GG	J.I.	O.C.	Yes	
77	Column G12	CND-337-08-GG	J.I.	O.C.	Yes	
78	Column H12	CND-337-08-GG	J.I.	O.C.	Yes	
79	Column H13	CND-337-08-GG	J.I.	O.C.	Yes	
80	WHP-B16, G12/H12	CND-337-08-GG	J.I.	O.C.	Yes	
81	WHP-B25.1, F12/F13	CND-337-08-GG	J.I.	O.C.	Yes	
82	WHP-B25.2, H12/H13	CND-337-08-GG	J.I.	O.C.	Yes	
83	Column H9	CND-337-12-GG	J.I.	O.C.	Yes	
84	Column H12	CND-337-12-GG	J.I.	O.C.	Yes	
85	Column H13	CND-337-12-GG	J.I.	O.C.	Yes	
86	Column G12	CND-337-12-GG	J.I.	O.C.	Yes	
87	Column K12	CND-337-12-GG	J.I.	O.C.	Yes	
88	Column J12	CND-337-12-GG	J.I.	O.C.	Yes	
89	WHP-B16, H12/J12	CND-337-12-GG	J.I.	O.C.	Yes	
90	WHP-B25.2, H12/H13/H9	CND-337-12-GG	J.I.	O.C.	Yes	
91	Column F2	CND-338-14-GG	J.I.	O.C.	Yes	
92	Column G2	CND-338-14-GG	J.I.	O.C.	Yes	
93	Column H2	CND-374-03-GG	J.I.	O.C.	Yes	

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HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
94	Column F5	FWH-100A-04-EG	J.I.	O.C.	Yes	
95	Column F2	FWH-103-08-EGX	J.I.	O.C.	Yes	
96	Column F5	FWH-103-08-EGX	J.I.	O.C.	Yes	
97	Column G2	FWH-103-08-EGX	J.I.	O.C.	Yes	
98	EHP-B26, G2/G5	FWH-103-08-EGX	J.I.	O.C.	Yes	
99	Column F5	FWH-103A-04-EG	J.I.	O.C.	Yes	
100	Column F5	FWH-103A-06-EGX	J.I.	O.C.	Yes	
101	Column F9	FWH-104-08-EGX	J.I.	O.C.	Yes	
102	Column F12	FWH-104-08-EGX	J.I.	O.C.	Yes	
103	Column G12	FWH-104-08-EGX	J.I.	O.C.	Yes	
104	WHP-B25.1, F9/F12	FWH-104-08-EGX	J.I.	O.C.	Yes	
105	Column F9	FWH-104A-04-EG	J.I.	O.C.	Yes	
106	Column F9	FWH-104A-06-EGX	J.I.	O.C.	Yes	
107	Column F2	FWH-105-06-GG	J.I.	O.C.	Yes	
108	EHP-B25, F1/F2	FWH-105-06-GG	J.I.	O.C.	Yes	
109	EHP-B5, E3/F2	FWH-105-06-GG	J.I.	O.C.	Yes	
110	Column F12	FWH-106-06-GG	J.I.	O.C.	Yes	
111	WHP-B25, F12/F13	FWH-106-06-GG	J.I.	O.C.	Yes	
112	WHP-B5, E11/F12	FWH-106-06-GG	J.I.	O.C.	Yes	
113	EHP-B5, E3/F2	FWH-108-08-EGX	J.I.	O.C.	Yes	
114	EHP-B24, F5/F2	FWH-108-08-EGX	J.I.	O.C.	Yes	
115	Column F1	FWH-109-08-HH	J.I.	O.C.	Yes	
116	Column F2	FWH-109-08-HH	J.I.	O.C.	Yes	
117	WHP-B25, F1/F2	FWH-109-08-HH	J.I.	O.C.	Yes	
118	Column E11	FWH-110-08-HH	J.I.	O.C.	Yes	
119	Column F12	FWH-110-08-HH	J.I.	O.C.	Yes	
120	EHP-B5, E11/F12	FWH-110-08-HH	J.I.	O.C.	Yes	
121	Column E3	FWH-113-10-HH	J.I.	O.C.	Yes	
122	Column F2	FWH-113-10-HH	J.I.	O.C.	Yes	
123	Column E3	FWH-113-14-HH	J.I.	O.C.	Yes	
124	Column F2	FWH-113-14-HH	J.I.	O.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
125	Column F5	FWH-113-14-HH	J.I.	O.C.	Yes	
126	Column G2	FWH-113-14-HH	J.I.	O.C.	Yes	
127	Column F5	FWH-113-14-HH	Pipe Whip	O.C.	Yes	
128	Column G2	FWH-113-14-HH	Pipe Whip	O.C.	Yes	
129	Column E11	FWH-114-10-HH	J.I.	O.C.	Yes	
130	Column F12	FWH-114-10-HH	J.I.	O.C.	Yes	
131	Column F9	FWH-114-14-HH	J.I.	O.C.	Yes	
132	Column F12	FWH-114-14-HH	J.I.	O.C.	Yes	
133	Column F13	FWH-114-14-HH	J.I.	O.C.	Yes	
134	Column G9	FWH-114-14-HH	J.I.	O.C.	Yes	
135	Column G12	FWH-114-14-HH	J.I.	O.C.	Yes	
136	Column G13	FWH-114-14-HH	J.I.	O.C.	Yes	
137	Column E3	FWH-115-08-GG	J.I.	O.C.	Yes	
138	Column E5	FWH-115-08-GG	J.I.	O.C.	Yes	
139	Column F2	FWH-115-08-GG	J.I.	O.C.	Yes	
140	EHP-B5, E3/F2	FWH-115-08-GG	J.I.	O.C.	Yes	
141	Column E3	FWH-115-10-GG	J.I.	O.C.	Yes	
142	EHP-B5, E3/F2	FWH-115-10-GG	J.I.	O.C.	Yes	
143	Column C9	FWH-116-08-GG	J.I.	O.C.	Yes	
144	Column C11	FWH-116-08-GG	J.I.	O.C.	Yes	
145	Column E9	FWH-116-08-GG	J.I.	O.C.	Yes	
146	Column E11	FWH-116-08-GG	J.I.	O.C.	Yes	
147	WHP-B23.1, E9/E11	FWH-116-08-GG	J.I.	O.C.	Yes	
148	Column E11	FWH-116-10-GG	J.I.	O.C.	Yes	
149	WHP-B23.1, E11/E13	FWH-116-10-GG	J.I.	O.C.	Yes	
150	Column E3	FWH-117-08-EG	J.I.	O.C.	Yes	
151	Column F2	FWH-117-08-EG	J.I.	O.C.	Yes	
152	Column C11	FWH-118-08-EG	J.I.	O.C.	Yes	
153	Column E9	FWH-118-08-EG	J.I.	O.C.	Yes	
154	Column F2	FWH-121-06-HH	J.I.	O.C.	Yes	
155	Column F12	FWH-122-06-HH	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
156	Column E11	FWH-122-08-HH	J.I.	O.C.	Yes	
157	Column F12	FWH-122-08-HH	J.I.	O.C.	Yes	
158	Column F2	FWH-127-06-HHX	J.I.	O.C.	Yes	
159	Column F1	FWH-127-10-HHX	J.I.	O.C.	Yes	
160	Column F2	FWH-127-10-HHX	J.I.	O.C.	Yes	
161	Column F5	FWH-127-10-HHX	J.I.	O.C.	Yes	
162	Column G2	FWH-127-10-HHX	J.I.	O.C.	Yes	
163	Column F5	FWH-127-14-HHX	J.I.	O.C.	Yes	
164	Column F12	FWH-128-06-HHX	J.I.	O.C.	Yes	
165	Column F9	FWH-128-10-HHX	J.I.	O.C.	Yes	
166	Column F12	FWH-128-10-HHX	J.I.	O.C.	Yes	
167	Column E11	FWH-128-10-HHX	J.I.	O.C.	Yes	
168	Column F2	FWH-189-02-HH	J.I.	O.C.	Yes	
169	Column G2	FWH-189-02-HH	J.I.	O.C.	Yes	
170	Column E3	FWH-193-02-EG	J.I.	O.C.	Yes	
171	Column F12	FWH-196-1.5-EG	J.I.	O.C.	Yes	
172	Column G2	FWH-203-1.5-EG	J.I.	O.C.	Yes	
173	Girder, F2/G2	FWH-203-1.5-EG	J.I.	O.C.	Yes	
174	Column G2	FWH-203-1.5-EG	Pipe Whip	O.C.	Yes	
175	Column F12	FWH-208-02-HH	J.I.	O.C.	Yes	
176	Column F2	FWH-235-03-GG	J.I.	O.C.	Yes	
177	Column F1	FWH-11019-06-HH	J.I.	O.C.	Yes	
178	Column F2	FWH-11019-06-HH	J.I.	O.C.	Yes	
179	Column E9	FWH-11049-06-HH	J.I.	O.C.	Yes	
180	Column F2	FWH-11049-06-HH	J.I.	O.C.	Yes	
181	Column E11	FWH-11052-06-HH	J.I.	O.C.	Yes	
182	Column E3	FWH-11085-04-EG	J.I.	O.C.	Yes	
183	Column F2	FWH-11085-04-EG	J.I.	O.C.	Yes	
184	Column F2	FWH-11087-04-EG	J.I.	O.C.	Yes	
185	Column F5	FWH-11091-04-EG	J.I.	O.C.	Yes	
186	Column E5	FWH-11091-04-EGX	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
187	Column F5	FWH-11091-06-EGX	J.I.	O.C.	Yes	
188	Column F5	FWH-11093-04-EG	J.I.	O.C.	Yes	
189	Column F5	FWH-11095-04-EG	J.I.	O.C.	Yes	
190	Column F5	FWH-11097-04-EGX	J.I.	O.C.	Yes	
191	Column F5	FWH-11097-04-EG	J.I.	O.C.	Yes	
192	Column F9	FWH-11098-04-EG	J.I.	O.C.	Yes	
193	Column F9	FWH-11098-04-EGX	J.I.	O.C.	Yes	
194	Column F5	FWH-11099-04-EG	J.I.	O.C.	Yes	
195	Column F9	FWH-11100-04-EG	J.I.	O.C.	Yes	
196	Column F5	FWH-11101-04-EG	J.I.	O.C.	Yes	
197	Column F9	FWH-11102-04-EG	J.I.	O.C.	Yes	
198	Column E5	FWH-12643-04-EG	J.I.	O.C.	Yes	
199	Column E5	FWH-12643-06-EGX	J.I.	O.C.	Yes	
200	EHP-B5, E3/F2	FWS-318-14-GG	J.I.	O.C.	Yes	
201	Column E11	FWS-319-12-EG	J.I.	O.C.	Yes	
202	Column F12	FWS-319-12-EG	J.I.	O.C.	Yes	
203	Column F13	FWS-319-12-EG	J.I.	O.C.	Yes	
204	Column E1	FWS-320-12-EG	J.I.	O.C.	Yes	
205	Column E3	FWS-320-12-EG	J.I.	O.C.	Yes	
206	Column F1	FWS-320-12-EG	J.I.	O.C.	Yes	
207	Column F2	FWS-320-12-EG	J.I.	O.C.	Yes	
208	Column G1	FWS-320-12-EG	J.I.	O.C.	Yes	
209	EHP-B23, E1/E3	FWS-320-12-EG	J.I.	O.C.	Yes	
210	Column E11	FWS-321-12-EG	J.I.	O.C.	Yes	
211	Column F12	FWS-321-12-EG	J.I.	O.C.	Yes	
212	WHP-B5, E11/F12	FWS-321-12-EG	J.I.	O.C.	Yes	
213	WHP-B24.1, E11/E9	FWS-321-12-EG	J.I.	O.C.	Yes	
214	WHP-B5, E11/F12	FWS-321-12-EG	Pipe Whip	O.C.	Yes	
215	Column E3	FWS-322-12-EG	J.I.	O.C.	Yes	
216	Column E5	FWS-322-12-EG	J.I.	O.C.	Yes	
217	Column D6	FWS-322-12-EG	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
218	EHP-B5, E3/F2	FWS-322-12-EG	J.I.	O.C.	Yes	
219	EHP-B22, E3/E5	FWS-322-12-EG	J.I.	O.C.	Yes	
220	EHP-B22, E3/E5	FWS-322-12-EG	Pipe Whip	O.C.	Yes	
221	Column E11	FWS-323-12-EG	J.I.	O.C.	Yes	
222	Column F12	FWS-323-12-EG	J.I.	O.C.	Yes	
223	WHP-B5, E11/F12	FWS-323-12-EG	J.I.	O.C.	Yes	
224	WHP-B5, E11/F12	FWS-323-12-EG	Pipe Whip	O.C.	Yes	
225	Column E3	FWS-324-12-EG	J.I.	O.C.	Yes	
226	Column F1	FWS-324-12-EG	J.I.	O.C.	Yes	
227	Column F2	FWS-324-12-EG	J.I.	O.C.	Yes	
228	Column G2	FWS-324-12-EG	J.I.	O.C.	Yes	
229	EHP-B5, E3/F2	FWS-324-12-EG	J.I.	O.C.	Yes	
230	EHP-B5, E3/F2	FWS-324-12-EG	Pipe Whip	O.C.	Yes	
231	NE-B4.4, B7/B8	FWS-325-10-EG	J.I.	O.C.	Yes	
232	NE-B2, South of B7	FWS-325-10-EG	J.I.	O.C.	Yes	
233	Column D6	FWS-325-18-EG	J.I.	O.C.	Yes	
234	NE-B2, A7/B7	FWS-326-08-EG	J.I.	O.C.	Yes	
235	Column B6	FWS-326-10-EG	J.I.	O.C.	Yes	
236	NE-B2, South of B7	FWS-326-10-EG	J.I.	O.C.	Yes	
237	NE-B2, A7/B7	FWS-329-08-EG	J.I.	O.C.	Yes	
238	Column B6	FWS-329-10-EG	J.I.	O.C.	Yes	
239	NE-B2, South of B7	FWS-329-10-EG	J.I.	O.C.	Yes	
240	Column E11	FWS-339-03-EG	J.I.	O.C.	Yes	
241	Column F9	FWS-339-03-EG	J.I.	O.C.	Yes	
242	Column F12	FWS-339-03-EG	J.I.	O.C.	Yes	
243	WHP-B5, E11/F12	FWS-339-03-EG	J.I.	O.C.	Yes	
244	Column E1	FWS-340-03-EG	J.I.	O.C.	Yes	
245	Column E3	FWS-340-03-EG	J.I.	O.C.	Yes	
246	Column F1	FWS-340-03-EG	J.I.	O.C.	Yes	
247	Column F2	FWS-340-03-EG	J.I.	O.C.	Yes	
248	EHP-B25, F1/F2	FWS-340-03-EG	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
249	Column G2	FWS-374-02-GG	J.I.	O.C.	Yes	
250	Column A7	FWS-392-10-EG	J.I.	O.C.	Yes	
251	Column A7	FWS-393-10-EG	J.I.	O.C.	Yes	
252	Column C11	FWS-6020-03-CL	J.I.	O.C.	Yes	
253	Column E13	FWS-6020-03-CL	J.I.	O.C.	Yes	
254	Column F12	FWS-6020-03-CL	J.I.	O.C.	Yes	
255	Column C11	FWS-6020-03-BH4	J.I.	O.C.	Yes	
256	Column E13	FWS-6020-03-BH4	J.I.	O.C.	Yes	
257	Column E1	FWS-6021-03-CL	J.I.	O.C.	Yes	
258	Column E3	FWS-6021-03-CL	J.I.	O.C.	Yes	
259	Column F2	FWS-6021-03-CL	J.I.	O.C.	Yes	
260	Column A7	FWS-14103-02-EG	J.I.	O.C.	Yes	
261	NE-B4.4, B6/B7	FWS-14103-02-EG	J.I.	O.C.	Yes	
262	NE-B4.8, B7/B8	FWS-14103-02-EG	J.I.	O.C.	Yes	
263	Column A7	FWS-14108-02-EG	J.I.	O.C.	Yes	
264	NE-B4.4, B6/B7	FWS-14108-02-EG	J.I.	O.C.	Yes	
265	NE-B4.8, B7/B8	FWS-14108-02-EG	J.I.	O.C.	Yes	
266	Column D7	FWS-14109-04-EG	J.I.	O.C.	Yes	
267	Column A7	FWS-14111-02-EG	J.I.	O.C.	Yes	
268	NE-B4.4, B6/B7	FWS-14111-02-EG	J.I.	O.C.	Yes	
269	NE-B4.8, B7/B8	FWS-14111-02-EG	J.I.	O.C.	Yes	
270	Column D6	MSS-1-24-EG	J.I.	O.C.	Yes	
271	Column B7	MSS-2-24-EG	J.I.	O.C.	Yes	
272	Column B8	MSS-2-24-EG	J.I.	O.C.	Yes	
273	Column E9	MSS-8-02-EG	J.I.	O.C.	Yes	
274	Column E11	MSS-8-02-EG	J.I.	O.C.	Yes	
275	WHP-B1.1, E9/C9	MSS-8-02-EG	J.I.	O.C.	Yes	
276	Column B7	MSS-9-03-EG	J.I.	O.C.	Yes	
277	NE-B4.8, B6/B7	MSS-9-03-EG	J.I.	O.C.	Yes	
278	NE-B4.4, B7/B8	MSS-9-03-EG	J.I.	O.C.	Yes	
279	Column E9	MSS-10-1.5-EG	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
280	WHP-B25.1, F9/F12	MSS-15-06-EG	J.I.	O.C.	Yes	
281	WHP-B10.1, F9/G9	MSS-15-06-EG	J.I.	O.C.	Yes	
282	WHP-B25, F9/F12	MSS-15-08-EG	J.I.	O.C.	Yes	
283	Column E5	MSS-17-08-EG	J.I.	O.C.	Yes	
284	EHP-B22, E3/E5	MSS-17-08-EG	J.I.	O.C.	Yes	
285	EHP-B5, E3/F2	MSS-17-08-EG	J.I.	O.C.	Yes	
286	EHP-B7, E5/F5	MSS-17-08-EG	J.I.	O.C.	Yes	
287	NE-B4.8, B6/B7	MSS-17-08-EG	J.I.	O.C.	Yes	
288	EHP-B24, F2/F5	MSS-17-08-EG	J.I.	O.C.	Yes	
289	Column E5	MSS-17-08-EG	Pipe Whip	O.C.	Yes	
290	Column B7	MSS-18-10-EG	J.I.	O.C.	Yes	
291	Column E9	MSS-18-10-EG	J.I.	O.C.	Yes	
292	Column F2	MSS-19-06-EG	J.I.	O.C.	Yes	
293	EHP-B5, E3/F2	MSS-19-06-EG	J.I.	O.C.	Yes	
294	WHP-B25.1, F9/F12	MSS-20-06-EG	J.I.	O.C.	Yes	
295	WHP-B25.1, F9/F12	MSS-20-10-EG	J.I.	O.C.	Yes	
296	Column B8	MSS-69-03-EG	J.I.	O.C.	Yes	
297	Column D8	MSS-69-03-EG	J.I.	O.C.	Yes	
298	Column E11	MSS-69-03-EG	J.I.	O.C.	Yes	
299	Column F12	MSS-69-03-EG	J.I.	O.C.	Yes	
300	NE-B4.4, B7/B8	MSS-69-03-EG	J.I.	O.C.	Yes	
301	Column G5	MSS-1312-08-HH	J.I.	O.C.	Yes	
302	EHP-B7, F5/E5	MSS-1312-08-HH	J.I.	O.C.	Yes	
303	Column J5	MSS-1316-06-HH	J.I.	O.C.	Yes	
304	Column B6	MSS-1316-08-HH	J.I.	O.C.	Yes	
305	Column B7	MSS-1316-08-HH	J.I.	O.C.	Yes	
306	Column E5	MSS-1316-08-HH	J.I.	O.C.	Yes	
307	Column G5	MSS-1316-08-HH	J.I.	O.C.	Yes	
308	Column H5	MSS-1316-08-HH	J.I.	O.C.	Yes	
309	Column J5	MSS-1316-08-HH	J.I.	O.C.	Yes	
310	Column B6	MSS-1317-03-HH	J.I.	O.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
311	Column B7	MSS-1317-03-HH	J.I.	O.C.	Yes	
312	Column E9	MSS-1317-03-HH	J.I.	O.C.	Yes	
313	Column G5	MSS-13399-06-HH	J.I.	O.C.	Yes	
314	Column H5	MSS-13400-06-HH	J.I.	O.C.	Yes	
315	Column J5	MSS-13403-06-HH	J.I.	O.C.	Yes	
316	W42 Beam @ EL 49' SG Support	PZR-5011-04-BH2	J.I.	I.C.	Yes	
317	C10 @ EL 54' West of PZR	PZR-5011-04-BH2	J.I.	I.C.	Yes	
318	North Wall	PZR-5011-04-BH2	J.I.	I.C.	Yes	
319	Roof	PZR-5011-04-BH2	J.I.	I.C.	Yes	
320	W10 @ EL54' West of Steam Gen. "B"	PZR-5011-04-BH2	J.I.	I.C.	Yes	
321	W10 @ EL54' West of Steam Gen. "B"	PZR-5034-02-BH2	J.I.	I.C.	Yes	
322	W42 @ EL49'-5" W of Steam Gen. B	PZR-5034-02-BH2	J.I.	I.C.	Yes	
323	C10 @ EL 54'	PZR-5034-02-BH2	J.I.	I.C.	Yes	
324	W10 @ EL54' West of Steam Gen. "B"	PZR-5035-02-BH2	J.I.	I.C.	Yes	
325	W42 @ EL49'-5" W of Steam Gen. B	PZR-5035-02-BH2	J.I.	I.C.	Yes	
326	C10 @ EL 54'	PZR-5035-02-BH2	J.I.	I.C.	Yes	
327	W10 @ EL14' North Side of RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
328	W18 @ EL22' North Side of RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
329	W10 @ EL14' East Side of RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
330	W18 @ EL22' East	RCP-2005-02-BH3	J.I.	I.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
	Side of RCP G-2A					
331	W10 @ EL22' North Side of RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
332	W10 @ EL 31' West of RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
333	3X3 Angle @ EL 31' West RCP G-2A	RCP-2005-02-BH3	J.I.	I.C.	Yes	
334	W10 @ EL14' North Side of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
335	W18 @ EL22' North Side of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
336	W10 @ EL14' East Side of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
337	W18 @ EL22' East Side of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
338	W10 @ EL22' North Side of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
339	W10 @ EL 31' West of RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
340	3X3 Angle @ EL 31' West RCP G-2A	RCP-2005-02-BH3	Pipe Whip	I.C.	Yes	
341	Wall	RCP-2005-04-BH3	J.I.	I.C.	Yes	
342	N-S Beam @ EL 25'	RCP-2005-04-BH3	J.I.	I.C.	Yes	
343	Beam @ EL 26' North of Break	RCP-2005-04-BH3	J.I.	I.C.	Yes	
344	N-S beam 4' above the 8" VCC Line	RCP-2005-04-BH3	J.I.	I.C.	Yes	
345	Supports @ EL 24' and EL 33'	RCP-2006-02-BH3	J.I.	I.C.	Yes	
346	N-S and E-W Beam	RCP-2006-02-BH3	J.I.	I.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
	@ EL 26'					
347	Platform @ EL 22'	RCP-2008-02-BH3	J.I.	I.C.	Yes	
348	RCS Tank	RCP-2008-02-BH3	J.I.	I.C.	Yes	
349	Column 6	RCP-2008-02-BH3	J.I.	I.C.	Yes	
350	E-W Beam @ El 26'	RCP-2009-02-BH3	J.I.	I.C.	Yes	
351	N-S Beam @ EL 26'	RCP-2009-02-BH3	J.I.	I.C.	Yes	
352	Support @ EL 33'&24'	RCP-2009-02-BH3	J.I.	I.C.	Yes	
353	W18 @ EL 22' North of RCP-G-2C	RCP-2011-02-BH2	J.I.	I.C.	Yes	
354	W10 @ EL 14' North of RCP-G-2C	RCP-2011-02-BH2	J.I.	I.C.	Yes	
355	L3X3 @ EL 22 West of RCP-G-2C	RCP-2011-02-BH3	J.I.	I.C.	Yes	
356	W10 @ EL 14' East of RCP-G-2C	RCP-2011-02-BH3	J.I.	I.C.	Yes	
357	W10 @ EL 00' South of RCP-G-2C	RCP-2011-02-BH3	J.I.	I.C.	Yes	
358	W18 @ EL 22' North of RCP-G-2C	RCP-2011-02-BH3	J.I.	I.C.	Yes	
359	W10 @ EL 14' North of RCP-G-2C	RCP-2011-02-BH3	J.I.	I.C.	Yes	
360	Column # 9	RCP-2011-02-BH3	J.I.	I.C.	Yes	
361	Supports @ EL 24' and 33'	RCP-2012-02-BH3	J.I.	I.C.	Yes	
362	E-W & N-S Beams @ EL 26'	RCP-2012-02-BH3	J.I.	I.C.	Yes	
363	W10 @ EL 14' East of RCP-G-2A	RCP-2014-02-BH2	J.I.	I.C.	Yes	
364	W10 @ EL 14' North of RCP-G-2A	RCP-2014-02-BH2	J.I.	I.C.	Yes	
365	Beam @ EL 22'	RCP-2018-02-BH2	J.I.	I.C.	Yes	

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	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
	North of Column 8					
366	Beam @ EL 22' West of Column 18	RCP-2018-02-BH2	J.I.	I.C.	Yes	
367	Beam @ EL 22' SW of Column 18	RCP-2018-02-BH2	J.I.	I.C.	Yes	
368	Column # 18	RCP-2018-02-BH2	J.I.	I.C.	Yes	
369	W18 @ EL 22' North of RCP-G-2C	RCP-2020-02-BH2	J.I.	I.C.	Yes	
370	W10 @ EL 14' North of RCP-G-2C	RCP-2020-02-BH2	J.I.	I.C.	Yes	
371	W10 Beam @ EL 14'	RCP-2090-02-BH2,-BH3	J.I.	I.C.	Yes	Non Essential Steel
372	Beams W18 @ EL 22' NS of RCP-G-2A	RCP-2090-02-BH2,-BH3	J.I.	I.C.	Yes	
373	Platform @ EL 14'	RCP-2091-02-BH2	Pipe Whip	I.C.	Yes	
374	Steel South of RCP-G-2B	RCP-2091-02-BH3	J.I.	I.C.	Yes	
375	Grating Platform	RCP-2091-02-BH3	J.I.	I.C.	Yes	
376	W 10	RCP-2092-02-BH2	J.I.	I.C.	Yes	Non Essential Steel
377	W 10	RCP-2092-02-BH2	Pipe Whip	I.C.	Yes	Non Essential Steel
378	W 10	RCP-2092-02-BH3	Pipe Whip	I.C.	Yes	
379	2" Support for Platform @ EL 26'	RCP-2105-03-BH3	J.I.	I.C.	Yes	
380	E-W Beam 5' above El 26'	RCP-2105-03-BH3	J.I.	I.C.	Yes	
381	E-W Beam @ EL 26' 7' South of Break	RCP-2105-03-BH3	J.I.	I.C.	Yes	
382	W4 Platform Brace @ EL 22'	RCP-2105-04-BH3	J.I.	I.C.	Yes	
383	N-S & E-W Beam @ EL 25'	RCP-2105-04-BH3	J.I.	I.C.	Yes	
384	Beam @ EL 27'	RCP-2106-04-BH3	J.I.	I.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
385	WAll	RCP-2109-02-BH3	J.I.	I.C.	Yes	Non Essential Steel
386	Beam @ EL 25’	RCP-2109-02-BH3	J.I.	I.C.	Yes	
387	Column 8’ South & 6" East of Break	RCP-2109-02-BH3	J.I.	I.C.	Yes	
388	Column 8’ South & 2’ East of Break	RCP-2109-02-BH3	J.I.	I.C.	Yes	
389	NS & EW Beam @ EL 27’	RCP-2109-03-BH3	J.I.	I.C.	Yes	
390	NS Beam	RCP-2109-04-BH3	J.I.	I.C.	Yes	
391	Column 2’ South & 1’ East of Break	RCP-2109-04-BH3	J.I.	I.C.	Yes	
392	NS Beam	RCP-2110-03-BH3	J.I.	I.C.	Yes	
393	EW Beam	RCP-2110-03-BH3	J.I.	I.C.	Yes	
394	Col 3’ S. of Break	RCP-2110-03-BH3	J.I.	I.C.	Yes	
395	W10 @ EL 22’ North of RCP-G-2A	RCP-2121-02-BH3	J.I.	I.C.	Yes	
396	Beam @ EL 22’ N. of Column # 18	RCP-2122-02-BH3	J.I.	I.C.	Yes	
397	Steel for Platform @ EL 22’	RCP-2123-02-BH3	J.I.	I.C.	Yes	
398	Steel @ EL 14’	RCP-2123-02-BH3	J.I.	I.C.	Yes	
399	Platform @ El 22’	RCP-2123-02-BH3	J.I.	I.C.	Yes	
400	W10 Attached to Column #9	RCS-5003-02-BH2	J.I.	I.C.	Yes	
401	Column # 9	RCS-5003-02-BH2	J.I.	I.C.	Yes	
402	Floor	RCS-5008-02-BH2	J.I.	I.C.	Yes	
403	W18 above 2" Line	RCS-5008-02-BH2	J.I.	I.C.	Yes	
404	W18 above 2" Line	RCS-5008-02-BH2	Pipe Whip	I.C.	Yes	
405	Steel @ Platform EL 14’ (W10s)	RCS-5011-03-BH2	J.I.	I.C.	Yes	
406	Steel @ Platform	RCS-5011-03-BH2	J.I.	I.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
	EL 22' (W10s)					
407	Steel for S.G. "B" Supports	RCS-5011-03-BH2	J.I.	I.C.	Yes	
408	Steel @ Platform El 31' (W10s)	RCS-5011-03-BH2	J.I.	I.C.	Yes	
409	Steel @ Platform El 54' (W10s)	RCS-5011-03-BH2	J.I.	I.C.	Yes	
410	Steel @ Platform EL 14' (W10s)	RCS-5011-03-BH2	Pipe Whip	I.C.	Yes	
411	Steel @ Platform EL 22' (W10s)	RCS-5011-03-BH2	Pipe Whip	I.C.	Yes	
412	Steel for S.G. "B" Supports	RCS-5011-03-BH2	Pipe Whip	I.C.	Yes	
413	Steel @ Platform El 31' (W10s)	RCS-5011-03-BH2	Pipe Whip	I.C.	Yes	
414	Steel @ Platform El 54' (W10s)	RCS-5011-03-BH2	Pipe Whip	I.C.	Yes	
415	Beam @ EL 50'	RCS-5025-03-BH2	J.I.	I.C.	Yes	
416	W18 @ EL 22' above	RHR-3001-06-BH2	J.I.	I.C.	Yes	
417	C10 arround RCP	RHR-3001-06-BH2	J.I.	I.C.	Yes	
418	Steel @ EL 14'	RHR-3001-06-BH2	J.I.	I.C.	Yes	
419	W10 @ EL 22' above	SIS-6006-06-BH2	J.I.	I.C.	Yes	
420	W10 @ EL 14' at RCP-G-2B	SIS-6006-06-BH2	J.I.	I.C.	Yes	
421	Column # 18	SIS-6006-06-BH2	J.I.	I.C.	Yes	
422	W10 @ EL 22' above	SIS-6007-06-BH2	J.I.	I.C.	Yes	
423	W10 @ EL 14' at RCP-G-2B	SIS-6007-06-BH2	J.I.	I.C.	Yes	
424	W18 @ EL 22' above	SIS-6007-06-BH2	J.I.	I.C.	Yes	
425	C10 Beam @ EL 14'	SIS-6008-06-BH2	J.I.	I.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
	around RCP-G-2A					
426	Steel @ EL 22' around RCP-G-2A	SIS-6008-06-BH2	J.I.	I.C.	Yes	
427	Column K9	TBN-1307-04-HH	J.I.	O.C.	Yes	
428	Column L9	TBN-1307-04-HH	J.I.	O.C.	Yes	
429	WHP-B2.6, K9/L9	TBN-1307-04-HH	Pipe Whip	O.C.	Yes	
430	Column K5	TBN-1308-04-HH	J.I.	O.C.	Yes	
431	EHP-B20, K5/L5	TBN-1308-04-HH	Pipe Whip	O.C.	Yes	
432	Column J5	TBN-1316-06-HH	J.I.	O.C.	Yes	
433	Column K9	TBN-1318-08-HH	J.I.	O.C.	Yes	
434	WHP-B2.6, K9/L9	TBN-1318-08-HH	Pipe Whip	O.C.	Yes	
435	Column K2	TBN-1323-08-HH	J.I.	O.C.	Yes	
436	EHP-B20, K5/L5	TBN-1323-08-HH	Pipe Whip	O.C.	Yes	
437	Column G5	TBN-13399-06-HH	J.I.	O.C.	Yes	
438	Column H5	TBN-13400-06-HH	J.I.	O.C.	Yes	
439	Column J5	TBN-13403-06-HH	J.I.	O.C.	Yes	
440	Column F2	THP-17-06-EG	J.I.	O.C.	Yes	
441	EHP-B5, E3/F2	THP-17-06-EG	J.I.	O.C.	Yes	
442	EHP-B22	THP-17-06-EG	J.I.	O.C.	Yes	
443	WHP-B5, E11/F12	THP-18-06-EG	J.I.	O.C.	Yes	
444	WHP-B24.1	THP-18-06-EG	J.I.	O.C.	Yes	
445	Column F2	THP-19-06-EG	J.I.	O.C.	Yes	
446	Column F5	THP-19-06-EG	J.I.	O.C.	Yes	
447	EHP-B5, F2/E3	THP-19-06-EG	J.I.	O.C.	Yes	
448	EHP-B24, F2/F5	THP-19-06-EG	J.I.	O.C.	Yes	
449	Column F12	THP-20-06-EG	J.I.	O.C.	Yes	
450	Column F2	THP-21-10-GG	J.I.	O.C.	Yes	
451	EHP-B5, E3/F2	THP-21-10-GG	J.I.	O.C.	Yes	
452	Column E11	THP-22-10-GG	J.I.	O.C.	Yes	
453	WHP-B5, E11/F12	THP-22-10-GG	J.I.	O.C.	Yes	
454	WHP-B24.1	THP-22-10-GG	J.I.	O.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
455	Column E11	THP-24-16-HH	J.I.	O.C.	Yes	
456	Column F2	THP-78-04-EG	J.I.	O.C.	Yes	
457	Column F5	THP-78-04-EG	J.I.	O.C.	Yes	
458	EHP-B5, F2/F3	THP-78-04-EG	J.I.	O.C.	Yes	
459	EHP-B24, F2/F5	THP-78-04-EG	J.I.	O.C.	Yes	
460	Beam @ EL 40'	THP-79-04-EG	J.I.	O.C.	Yes	
461	Column F12	THP-79-04-EG	J.I.	O.C.	Yes	
462	Column E5	THP-8849-24-EG	J.I.	O.C.	Yes	
463	Column F5	THP-9093-24-EG	J.I.	O.C.	Yes	
464	Column F2	THP-9094-24-EG	J.I.	O.C.	Yes	
465	Column F5	THP-9094-24-EG	J.I.	O.C.	Yes	
466	EHP-B24, F2/F5	THP-9094-24-EG	J.I.	O.C.	Yes	
467	Column F5	THP-9095-24-EG	J.I.	O.C.	Yes	
468	Column E9	THP-9097-24-EG	J.I.	O.C.	Yes	
469	Column E9	THP-9098-24-EG	J.I.	O.C.	Yes	
470	Column F9	THP-9099-24-EG	J.I.	O.C.	Yes	
471	Column F12	THP-9099-24-EG	J.I.	O.C.	Yes	
472	Column F9	THP-9100-24-EG	J.I.	O.C.	Yes	
473	Column F9	THP-9101-24-EG	J.I.	O.C.	Yes	
474	Column E5	THP-9102-36-EG	J.I.	O.C.	Yes	
475	Column F5	THP-9103-36-EG	J.I.	O.C.	Yes	
476	Column F9	THP-9105-36-EG	J.I.	O.C.	Yes	
477	WHP-B25	THP-9105-36-EG	J.I.	O.C.	Yes	
478	Column E5	THP-9106-24-EG	J.I.	O.C.	Yes	
479	Column E1	TLP-25-18-HH	J.I.	O.C.	Yes	
480	Column E3	TLP-25-18-HH	J.I.	O.C.	Yes	
481	Column F1	TLP-25-18-HH	J.I.	O.C.	Yes	
482	Column F2	TLP-25-18-HH	J.I.	O.C.	Yes	
483	Column F5	TLP-25-18-HH	J.I.	O.C.	Yes	
484	Column G1	TLP-25-18-HH	J.I.	O.C.	Yes	
485	Column G2	TLP-25-18-HH	J.I.	O.C.	Yes	

Appendix B
HELB Resolution Summary (Structural Interactions)

	TARGET	LINE NO	TYPE	LOCATION	QUALIFIED	REMARKS
486	Column G5	TLP-25-18-HH	J.I.	O.C.	Yes	
487	Column H1	TLP-25-18-HH	J.I.	O.C.	Yes	
488	Column H12	TLP-25-18-HH	J.I.	O.C.	Yes	
489	EHP-B1	TLP-25-18-HH	J.I.	O.C.	Yes	
490	EHP-B8	TLP-25-18-HH	J.I.	O.C.	Yes	
491	EHP-B2.5	TLP-25-18-HH	J.I.	O.C.	Yes	
492	Column E11	TLP-26-18-HH	J.I.	O.C.	Yes	
493	Column E13	TLP-26-18-HH	J.I.	O.C.	Yes	
494	Column F12	TLP-26-18-HH	J.I.	O.C.	Yes	
495	Column F13	TLP-26-18-HH	J.I.	O.C.	Yes	
496	Column G9	TLP-26-18-HH	J.I.	O.C.	Yes	
497	Column G12	TLP-26-18-HH	J.I.	O.C.	Yes	
498	Column G13	TLP-26-18-HH	J.I.	O.C.	Yes	
499	Column H12	TLP-26-18-HH	J.I.	O.C.	Yes	
500	Grating Platform @ EL 14'	VCC-2081-02-BH2	J.I.	I.C.	Yes	
501	W18 above Line	VCC-2081-02-BH2	J.I.	I.C.	Yes	
502	Steel Framing for Platform @ El. 14'	VCC-2081-02-BH2	J.I.	I.C.	Yes	
503	Grating Platform @ EL 14'	VCC-2081-02-BH2	Pipe Whip	I.C.	Yes	
504	W18 above Line	VCC-2081-02-BH2	Pipe Whip	I.C.	Yes	
505	Steel Framing for Platform @ El. 14'	VCC-2081-02-BH2	Pipe Whip	I.C.	Yes	Non Essential Steel
506	TS 2X2	VCC-2094-1.5-HK	Pipe Whip	I.C.	Yes	

APPENDIX C

Event Tree Models Developed For The PRA Analysis

The particular high energy line breaks evaluated using PRA were assumed to result in one of the following four plant transients:

- Loss of main feedwater
- Small LOCA
- Steam line break (downstream of the turbine stop valves)
- Feedwater line break (upstream of the feedwater regulating valves)

A number of the outside containment lines would result in a transient less severe than a loss of feedwater event. However for conservatism, it is assumed that these breaks result in a loss of feedwater transient. Several lines inside containment associated with the charging and letdown systems communicate with the reactor coolant system, but would be isolated from the RCS by multiple isolation devices (i.e. check valves, fail-closed control valves, etc.) should a line break occur. These lines were not considered due to the low likelihood of these particular lines rupturing, coupled with the low probability of failure of two or more isolation devices.

Each of the sections below describe the four classes of plant transients considered in this evaluation and how event tree models were constructed.

Loss of Main Feedwater Event Tree

Event Description and Plant Response

Upon a loss of main feedwater, the reactor will trip automatically upon a steam/feedwater flow mismatch signal or may be tripped manually. Initially, upon reactor trip, steam will immediately be relieved from the steam generators via the steam dump valves to the main condenser or the main steam safety valves. The safeties will maintain steam generator pressure at approximately 1000 psia.

The loss of main feedwater and subsequent reactor trip results in, at most, a small RCS pressure rise that is insufficient to lift the pressurizer power-operated relief valves or safety valves.

Steam generator makeup will be provided by the Auxiliary Feedwater System. An auxiliary feedwater actuation signal (AFWAS) on Train "B" will be generated on low steam generator water level, and the motor-driven AFW pump and Train "A"

motor-driven pump will start in response to an AFWAS Train "A" signal and low flow signal from Train "B" pump.
Plant operators could attempt to restart one of the main feedwater pumps. Operation of a main feedwater pump requires that at least one condensate pump be available to provide adequate condensate flow.

Steam generator makeup flow needs to be established prior to the time that the existing water inventory is boiled off (estimated to be approximately 30 minutes after reactor trip). Should steam generator makeup not be available from either of the above sources, plant operators could provide adequate decay heat removal through the use of the Charging System and the pressurizer PORVs to establish RCS "feed and bleed" cooling.

Maintenance of Critical Functions

The reactivity control function is achieved following a loss of main feedwater by an automatic reactor trip actuated from a steam/feedwater flow mismatch signal. Failure of the reactor to trip and cease power operation constitutes an unanalyzed ATWS event.

The reactor core heat removal function is achieved via heat transfer from the reactor core to the RCS. Normal forced circulation of the RCS coolant, via the RCPs, provides for heat transport from the reactor core to the steam generators. In the unlikely event that forced circulation of the coolant is not possible, the heat can be adequately removed via natural circulation.

RCS heat removal is achieved by heat transfer to the steam generators and release of steam to the condenser, or to the atmosphere via the safety relief valves. Makeup water is provided to the steam generators via the AFW System or by restoration of a feedwater pump.

Makeup to the RCS is not required in a loss of main feedwater event. Sufficient RCS inventory is available for natural circulation flow to continue for at least 10 hours following the loss of main feedwater.

If the operators utilize RCS "feed and bleed" to cool the RCS, then RCS makeup (using the charging system) is required to maintain reactor vessel water level above the reactor core.

Summary of Success Criteria

The loss of main feedwater results in a loss of makeup to the steam generators. Success or recovery from the initiating event requires that feedwater flow be established to at least one steam generator within 30 minutes, or else RCS "feed and bleed" must be established to provide RCS cooling.

The specific success requirements for the loss of main feedwater event are as follows:

1. The reactor trips successfully on a steam flow/feed flow mismatch signal or manual actuation.

2. Makeup is provided to at least one steam generator by an AFW pump or a recovered MFW pump within 30 minutes.

3. Steam is relieved from the steam generators to the main condenser via the steam dump valves, or to the atmosphere via the steam generator safety valves. Any one of the five atmospheric safety relief valves can remove all the decay heat.

4. "Feed and bleed" cooling is initiated within 50 minutes if steam generator makeup flow is not re-established.

Small Break LOCA Event Tree

Event Description and Plant Response

The initiating event for this tree is a small LOCA based upon a break diameter between 3/4 inch and 3 inches. This range of breaks will result in a moderately rapid decrease in pressurizer pressure causing a reactor trip/turbine trip (at 1872 psig) and safety injection actuation (at 1735 psig). The signals most probably will be generated automatically, due to the rapid depressurization rate, but they may be initiated manually if the operators respond quickly.

SONGS-1 does not have main steam isolation valves. However, the main condenser will most likely remain available for heat removal. If the condenser is not available, steam generator pressure will rise up to the steam generator safety valve set point pressure.

Secondary makeup must be provided prior to the time that the steam generators have nearly depleted their inventory (approximately 30 minutes). One auxiliary feedwater pump is required to supply makeup inventory to the steam generators during the cooldown following the reactor trip. Note that since the main feedwater pumps are aligned in the SI mode, they cannot be used as an alternate source of steam generator makeup should the Auxiliary Feedwater System fail. However, SI flow diversion to the steam generators back through failed open isolation valves(s) in the Feedwater System is modeled for failure of the SI System to provide sufficient inventory for RCS recirculation.

For breaks of this size, either the Charging System or the Safety Injection system has sufficient flow capacity to prevent significant core uncovery. Safety Injection actuation enables the Charging System to be aligned to provide cold leg injection flow and allows the Safety Injection system to be automatically started and aligned. The length of time required for the injection phase is dependent upon the size of the break. However, it is assumed that in all cases the injection phase will not be required beyond 24 hours, at which time the plant will commence cold leg recirculation.

Recirculation is initiated through EOI SO1-1.0-23, "Transfer to Cold Leg Injection and Recirculation," and automatic SI and MFW pump trip at the 21% level of the RWST tank. This confirms the need to commence

recirculation by starting both recirculation pumps and opening the pump discharge MOVs. The recirculation pumps provide flow to the recirculation heat exchanger and on to the suction of each charging pump, which discharge directly into the cold legs. Since the Recirculation System also supplies water to the Containment Spray System, it is necessary to shut spray header isolation valves CV-517 and CV-518 (or, if needed, the spray ring isolation valves) so that excess water is not diverted from the Recirculation System.

The Recirculation System is assumed to be required for 30 days to allow for sufficient decay heat removal.

Maintenance of Critical Safety Functions

The reactivity control function is achieved following a small break LOCA by an automatic trip on low pressurizer pressure (at 1872 psig). Failure of the reactor to trip and cease power operation constitutes an unanalyzed ATWS event.

The reactor core heat removal function is achieved via heat transfer from the RCS to the feedwater in the steam generators. Significant heat is removed from the RCS via the LOCA blowdown; however, this heat removal process is not sufficient for all small break LOCA sizes to ensure adequate RCS heat removal. Natural circulation of the RCS provides for heat transport from the core to the steam generators.

Summary of Success Criteria

The small break LOCA event results in a loss of RCS inventory initially threatening core uncovery and later a loss of natural circulation cooling. Success or recovery from the event requires that RCS makeup be established soon after the LOCA occurs (approximately one minute) and that steam generator makeup via the AFW System be established within 30 minutes to prevent steam generator dryout.

The specific success requirements for the small break LOCA event are as follows:

1. The reactor trips successfully on an automatic signal (low pressurizer pressure) or by manual operator action.

2. Makeup (injection) to the RCS is provided within approximately a minute of LOCA initiation by either the Charging System (aligned for cold leg

injection) or the Safety Injection System via one of the intact RCS injection legs (i.e., a leg not containing the break).

3. The main condenser is available for steam generator heat removal or the steam generator safety valves function.

4. The Recirculation System functions to provide long-term core cooling.

Steam Line Break Event Tree

Event Description and Plant Response

The steam line breaks of concern in this evaluation consist of either:

- Breaks in large diameter piping downstream of the turbine stop valves (e.g., turbine exhaust piping, moisture separator reheater (MSR) piping that would be isolated from the main steam lines due to closure of the turbine stop valves.

- Smaller diameter lines that are upstream of the turbine stop valve (e.g., main steam supply to the MSRs). These lines are not isolated from the main steam system should they rupture. However, their piping diameters are such that only a fraction of the main steam flow would be diverted through these breaks.

Design basis steam-line breaks (Reference 48, Chapter 15 of the UFSAR) result in significantly more severe transients than those that would occur should the lines considered in this HELB evaluation rupture.

The line break would result in a reactor trip automatically upon a steam flow/feedwater flow mismatch signal. The operators would manually trip the reactor if the break resulted in an insufficient rise in steam flow rate to result in an automatic trip signal. Steam from the steam generators would continue to be released directly to the atmosphere through the break (if the break occurred in a line upstream of the turbine stop valves) or through the steam generator safety valves.

Main feedwater would most likely still be available following the break, but it is conservatively assumed that it is unavailable due to the possible generation of a Safety Injection Signal (which would result in realignment of the feedwater pumps to the Safety Injection System).

Auxiliary feedwater would need to provide steam generator makeup flow. An AFWAS would be generated for both AFW trains (AFW train "A" would,however only deliver flow if a loss of flow is detected on AFW train "B"). For the purposes of this analysis it is conservatively assumed that the steam driven AFW pump in train A is unable to function due to low steam line pressure following the break. Should the AFW System fail to provide steam generator makeup, then the plant operators would initiate "feed and bleed" RCS cooling using the charging system and the pressurizer PORVs.

Maintenance of Critical Functions

The reactivity control function is achieved by an automatic or manual reactor trip. Excessive RCS cooldown would not be expected in this event. Therefore emergency boration of the RCS is not required. Failure of the reactor to trip and cease power operation constitutes an unanalyzed ATWS event.

The reactor core heat removal function is achieved via heat transfer from the reactor core to the RCS. Normal forced circulation of the RCS coolant, via the RCPs, provides for heat transport from the reactor core to the steam generators. In the unlikely event that forced circulation of the coolant is not possible, the heat can be adequately removed via natural circulation.

RCS heat removal is achieved by the steam generators and released through the boiling of feedwater to the atmosphere through either the line break or the steam generator safety valves. Makeup water is provided by the motor driven AFW pumps.

Makeup to the RCS would not be required for this steam line break event. Sufficient RCS inventory is available for natural circulation flow to continue for at least 10 hours following the break.

If the operators utilize RCS "feed and bleed" to cool the RCS, then RCS makeup (using the charging system) is required to maintain reactor vessel water level above the reactor core.

Summary of Success Criteria

The steam line break results in a loss of makeup to the steam generators. Success or recovery from the initiating event requires that auxiliary feedwater flow be established to at least one steam generator within 30 minutes, or else RCS "feed and bleed" must be established to provided RCS cooling.

1. The reactor trips successfully on a steam flow/feed flow mismatch signal or manual actuation.

2. Makeup is provided to at least one steam generator by one motor-driven AFW pump within 30 minutes.

3. Steam is relieved from the steam generators through either the break or the steam generator safety valves.

4. "Feed and bleed" cooling is initiated within 50 minutes if steam generator makeup flow cannot be re-established.

Feedwater Line Break Event Tree

Event Description and Plant Response

The feedwater line breaks evaluated in this study involve ruptures of piping that is located upstream of the feedwater regulating valves. As noted in Chapter 15 of reference 48, these break locations are significantly less severe than the design basis feedwater line breaks.

The occurrence of such a pipe break would result in an automatic reactor trip upon a feedwater flow/steam flow mismatch signal or, possibly, a low steam generator level signal. Steam from the steam generators would be released to the main condenser (through the steam dump valves) or to the atmosphere (through the steam generator safety valves).

Main feedwater is assumed to be lost following pipe rupture. (This assumption is conservative for those pipe breaks that would only affect one feedwater train). Because the steam generator inventories remain intact following the break (due to the presence of multiple isolation devices between the break and the steam generator), this transient behaves like a loss of feedwater event. AFW flow would be available to perform steam generator makeup and would not be diverted through the break since AFW flow enters the MFW piping downstream of the MFW check valves. AFW would be actuated upon receipt of a low steam generator level signal.

Should AFW fail to provide steam generator makeup, then the plant operators would initiate "feed and bleed" RCS cooling using the charging system and the pressurizer PORVs.

Maintenance of Critical Functions

The reactivity control function is achieved by an automatic or manual reactor trip. Failure of the reactor to trip and cease power operation constitutes an unanalyzed ATWS event.

The reactor core heat removal function is achieved via heat transfer from the reactor core to the RCS. Normal forced circulation of the RCS coolant, via the RCPs, provides for heat transport from the reactor core to the steam generators. In the unlikely event that forced circulation of the coolant is not possible, the heat can be adequately removed via natural circulation.

RCS heat removal is achieved by the steam generators and released through the boiling of feedwater to the atmosphere through either the steam dump valves or the steam generator safety valves. Makeup water is provided by the AFW pumps.

Makeup to the RCS would not be required for this line break event. Sufficient RCS inventory is available for natural circulation flow to continue for at least 10 hours following the break.

If the operators utilize RCS "feed and bleed" to cool the RCS, then RCS makeup (using the charging system) is required to maintain reactor vessel level above the reactor core.

Summary of Success Criteria

The line break results in a loss of makeup to the steam generators. Success or recovery from the initiating event requires that auxiliary feedwater flow be established to at least one steam generator within 30 minutes, or else RCS "feed and bleed" must be established to provide RCS cooling.

The specific requirements for the feedwater line break event are as follows:

1. The reactor trips successfully on a steam flow/feed flow mismatch signal, low steam generator level signal, or manual actuation.

2. Makeup is provided to at least one steam generator by at least one AFW pump within 30 minutes.

3. Steam is relieved from the steam generators through either the steam dump valves or the steam generator safety valves.

4. "Feed and bleed" cooling is initiated within 50 minutes if steam generator makeup flow cannot be re-established.

PRA Data Sources

In order to quantify the PRA models, it is necessary to utilize probabilistic data concerning the occurrence of initiating events, component failures and human actions. The data base used for this PRA contains over 1000 "basic events." The sections below present a summary description of the data used to develop this data base.

Initiating Event Data

The initiating events of concern in this evaluation are the result of random pipe ruptures. The rupture itself is considered to be the initiating event. The simultaneous random occurrence of a rupture and another internal initiating event (e.g., LOCA, loss of offsite power, etc.) is considered to be too remote to warrant consideration.

Pipe rupture frequencies for each "representative line" were calculated using the methodology of EPRI NP-6992-L, "A Study of Pipe Failures in U.S. Commercial Nuclear Power Plants" (Reference 47). This study utilizes pipe rupture experience data obtained from Licensee Event Reports (LERs), Nuclear Power Experience (NPE), and NPRDS. The methodology accounts for various quantifiable factors such as NSSS vendor, system type, pipe size, and piping discontinuities.

Component Failure Data

Component failure rates and probabilities were obtained from several industry data sources. The majority of the data was obtained from the IREP Procedures Guide (Reference 49) and EGG-SSRE-8875 (Reference 50). Other sources were used (Reference 51) to supplement the data obtained from the primary sources. Plant-specific data was included only for the diesel generators. Insufficient data exists for other plant components to derive meaningful plant-specific failure estimates.

Component Maintenance Unavailability Data

Plant-specific maintenance unavailability data was used for the diesel generators and auxiliary feedwater pumps. Maintenance unavailability estimates for other pumps was based upon the estimates used in the Calvert Cliffs IREP study (Reference 52) A previous review of this data indicated that it would be a reasonable estimate of maintenance practices at SONGS-1.

Common Cause Failure Data

Common cause failures of active components were generally treated using a conservative "beta factor" of 0.1 for failures of a second like components and 0.5 for failures of a third like component. Check valve common cause factors were obtained from NUREG/CR-2770 (Reference 53). Common cause failure rates for other components (such as diesel generators, pumps, and MOVs) were taken from NUREG-1150 (Reference 54).

Human Actions

Human actions modeled in the fault trees included errors of omission associated with the operation of plant systems and selected equipment recovery actions. No credit was given for recovery actions taken outside the control room since it was not certain that areas of the plant containing key equipment would be accessible post-accident (due either to the steam environment or post-accident radiation levels). Operator actions were conservatively estimated using the techniques presented in NUREG/CR-1278 (Reference 55) and other published sources.