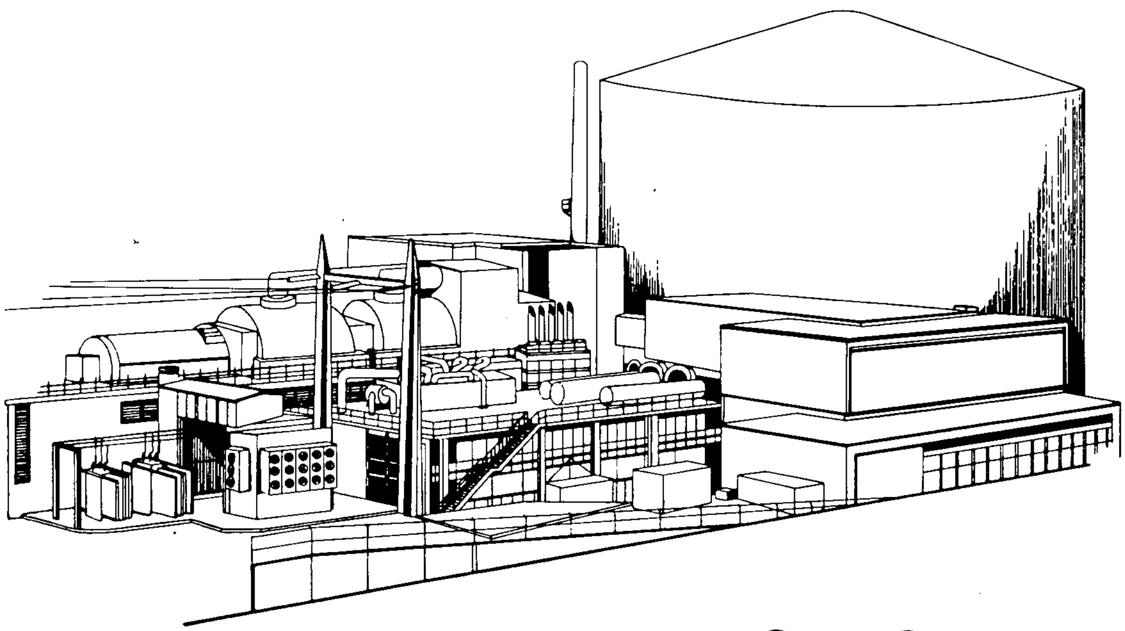
High Energy Line Break Analysis

Inside and Outside Containment



San Onofre Nuclear Generating Station Unit 1

Southern California Edison

SDGE San Diego Gas & Electric

Resolution of Systematic Evaluation Program Topics III-5.A and III-5.B for San Onofre Nuclear Generating Station Unit 1

Southern California
Edison Company

January, 1989

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

This report summarizes the results of the analyses and evaluations performed to resolve SEP Topics III-5.A and III-5.B for Southern California Edison Company's (SCE) San Onofre Nuclear Generating Station Unit 1 (SONGS-1). This report is the culmination of a comprehensive evaluation to resolve SEP Topics concerning High Energy Line Break Analysis (HELBA).

Background

The issue of high energy line breaks was first addressed by SCE in a study submitted to the Atomic Energy Commission in December, 1973 (Reference 1). This report along with its two addenda submitted in November, 1974 and April, 1975 analyzed those pipe segments outside containment with service temperatures exceeding 200°F and/or service pressures above 275 psig. Those lines exceeding both temperature and pressure limits were analyzed for full pipe break effects, while those exceeding only one were analyzed only for jet impingement effects. This study was performed prior to the issuance by the NRC of formal High Energy Line Break Analysis criteria. The analysis of high energy systems was later expanded in Standard Review Plan (SRP) 3.6.1 (Reference 6) to include an evaluation of full break effects for any pipe segments which met either the temperature or pressure values cited. Several modifications resulted from this study and an augmented inservice inspection program was established for certain main steam, feedwater, and extraction steam piping. This program is specified in the SONGS 1 Technical Specification 4.10. A Safety Evaluation Report (SER) was issued by the NRC affirming the results of this study (Reference 5).

Edison later submitted a supplemental study on the effects of a pipe break outside containment to the NRC in March, 1983 and an amended version in October, 1983 (Reference 2). This 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 SONGS 1 design met current regulatory criteria. In that report it was identified that an evaluation of electrical interactions was being deferred until modifications required by 10 CFR 50 Appendix R were implemented. The result of this study was the identification of approximately one hundred interactions requiring further analysis.

High energy line breaks inside the SONGS-1 containment were evaluated in a report submitted to the 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 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.

Draft NUREG-0829 (Reference 4) was published by the NRC to document unresolved issues related to the SEP at SONGS-1. It included a summary of the results of the two analyses and recommended further analysis. A scoping study was performed following the issuance of NUREG-0829 to develop a plan to resolve all 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, had made the previous studies obsolete. It was also decided that the 1973 report would be revalidated and combined in this updated comprehensive report.

This report documents the criteria, methodology, and results of the current comprehensive effort. The evaluations performed and results stated supersede all previous submittals.

Criteria for performing the necessary analyses were established and technical instructions were written to ensure consistent interpretation and application of criteria. The total list of high energy lines was reverified and documented. Lines were excluded from further analysis based on criteria in the standard review plan. Damage zones defined in the methodology phase were used during plant walkdowns to define affected targets. Interaction evaluations, leak-before-break analyses, and target qualification evaluations were performed and documented. The augmented ISI program established in 1975 for certain main steam, main feedwater and first point extraction steam piping was reviewed against recent Long-Term-Service (LTS) seismic evaluation pipe stress results and confirmed to be still applicable.

Results

In all, 770 piping lines were initially identified as meeting the definition of high energy. The distribution of number of lines versus resolution approach used is shown in the table below. Based on the target walkdowns, systems interaction evaluations, and bounding case screenings, 171 component interactions involving 59 of the 770, or 7%, of lines were identified which did not meet the acceptance criteria.

Six hundred (600) structural target interactions were identified and evaluated. Structural targets were evaluated using a screening process where lower bound capacities for various structural member types were developed and compared to the conservative case pipe rupture loading. More refined screening levels considered more specific load geometry and member and connection details. As a result of this screening process 505 structural target interactions were qualified. The 95 of 600, or 16%, interactions which did not meet the acceptance criteria involve 39 lines and 57 different targets.

The LBB approach was used to resolve nineteen (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 43). One of the 19 lines, or 5%, did not meet the acceptance criteria.

Thirteen piping segments were resolved by application of ISI as covered by Technical Specification 4.10, Augmented ISI program. Three of the thirteen lines were resolved by application of the ISI program outside containment while the inside containment portions of these lines were resolved by the LBB approach indicated above.

Table 2

<u>High Energy Line Break Analysis Results Summary</u>

Analysis Method	Evaluated	Not Meeting Criteria
Systems Interactions Evaluations	>2,500	171 Interactions (59 Lines)
Structural Targets	600	95 Interactions (39 Lines)
Leak Before Break	19 (Lines)	1 Location on 1 Line
Existing Augmented ISI	13 (Lines)	0

1.0 INTRODUCTION

This report describes the scope, criteria, methodology, assumptions, and results for the evaluation of high energy line breaks 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" and supersedes all previous submittals concerning these topics. 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 to assure that the plant can be shutdown in the event of such breaks.

1.1 Background

The issue of High Energy Line Break Analysis (HELBA) for SONGS-1 was first addressed by SCE in a study submitted to the Atomic Energy Commission on December 26, 1973 (Reference 1). That report, along with Addendum 1 dated November 1974, and Addendum 2, dated May 1975, analyzed those lines 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 one</u> were analyzed only for jet impingement. This study was performed prior to issuance of formal high energy line break analysis criteria by the NRC. The analysis of high energy systems was later expanded in Standard Review Plan (SRP) 3.6.1 (Reference 6) to include an evaluation of full pipe break effects for any pipe segments which met <u>either</u> the temperature <u>or</u> pressure values cited. The 1973 Report and Addendum described the analyses performed and identified proposed plant modifications as well as an estimated implementation schedule. Several modifications resulted and an augmented inservice inspection program was established for certain main steam, main feedwater, and extraction steam piping. The Commission notified SCE in a letter dated July 15, 1975 (Reference 5) that an amendment had been issued which incorporated the proposed ISI program in the SONGS-1 Technical Specifications. A Safety Evaluation Report (SER) was issued with these Technical Specifications affirming the results of the study.

A supplemental study on the effects of a piping break outside containment was submitted to the NRC in March, 1983 (Reference 2) and an amended version in August, 1983 (Reference 2). This supplemental study analyzed those lines with either service temperature exceeding 200°F or service pressures above 275 psig. The analysis was performed as part of the ongoing SEP and was intended to determine the extent to which SONGS-1 design did not meet current regulatory criteria. In that report, safety-related electrical interactions were identified but evaluation was deferred until modifications required by 10CFR50, Appendix R were implemented. The result of the study was the identification of over one hundred interactions requiring further analysis.

A report analyzing the effects of high energy line breaks inside the SONGS-1 containment was submitted to the NRC in October, 1983 (Reference 3). This report was intended as an initial assessment of SONGS-1 for compliance to the NRC HELBA criteria. It eliminated from further consideration those postulated break locations that would not adversely affect plant shutdown, and identified those locations where further analysis may be required. Safety-related structural member interactions were identified and evaluated for structural integrity. Essential mechanical equipment, piping, valves, and instrument and control devices were identified and either found acceptable based on certain pipe whip and jet impingement screening criteria defined in the report or were shown to require further analysis. Electrical interactions were not considered due to projected modifications required by 10CFR50, Appendix R. For large high energy lines inside the containment, preliminary evaluation or analysis indicated that modifications to alleviate the postulated pipe break effects would be very extensive. This included the main steam lines, the main feedwater lines, the reactor coolant pressure boundary portion of the residual heat removal system lines, the reactor coolant loops, the pressurizer surge line, and the reactor coolant pressure boundary portion of the safety injection system lines. The leak-before-break (LBB) approach was therefore proposed for future evaluation of these high energy lines.

1.0 INTRODUCTION

NUREG-0829 (Reference 4) was issued by the NRC in December 1986. The NUREG was an integrated assessment of SCE efforts to address SEP topics applicable to SONGS-1. Outstanding and unresolved issues related to SEP Topics III-5.A and III-5.B are noted in the report.

As a result of the findings of the draft issue of the NUREG (dated April 1985) NUREG, a scoping study was performed in June 1985 to develop a plan to resolve all outstanding issues related to high energy line break effects at SONGS-1. It was determined that significant modifications to the plant required by Appendix R, NUREG-0737, and Return to Service/Long Term Service (RTS/LTS) seismic reevaluation, had made the previous studies obsolete. Based on the results of the scoping study, this complete reevaluation was performed.

The results of the current comprehensive effort are presented in this report. A list of high energy lines was developed for SONGS-1 in accordance with current SRP criteria. The initial list of high energy piping was screened for various exclusion criteria identified in SRPs 3.6.1 (Reference 6) and 3.6.2 (Reference 7). The LBB approach was required and applied to several high energy lines inside containment where physical modifications were impractical. Piping segments covered by the augmented ISI program described in Technical Specification 4.10 were reviewed for continued applicability. Break locations covered by this technical specification were compared to break locations postulated using SEP break criteria and LTS seismic piping analysis results. If all postulated break locations were covered by the augmented ISI program, the line was considered resolved by augmented ISI. These specific break locations were reviewed against the existing augmented ISI points during the target qualification effort. A given interaction was resolved if the break location was already covered by augmented ISI. For the remaining breaks, plant walkdowns were performed using defined damage zones to identify structures, piping, and components impacted by pipe whip or impinged upon by jets due to postulated pipe ruptures. Safe shutdown logics were developed and systems interaction evaluations were performed to determine the effect of a break in the line on the ability of the plant to shutdown. Those lines, whose interaction evaluation against the safe shutdown logics did not indicate the presence of a safe shutdown path, were evaluated against a screening criteria developed to assess whether the break and its consequences can be bounded by the scenerios analyzed in detail in Reference 49. For those lines which could not be resolved by either the interaction evaluation or the screening criteria, the specific pipe rupture targets which were determined to be required for safe shutdown were then evaluated for their ability to withstand the postulated pipe rupture loads.

Consistent with the SEP philosophy, this report defines the criteria used in addressing Topics III-5.A and III-5.B and provides technical justification where departures from current criteria are implemented. In addition, factors considered important in reaching those decisions include safety significance, radiation exposure to workers, and implementation impact and schedule.

The report is structured as follows:

Section 2.0 describes the criteria used in defining high energy lines, postulating break locations, evaluating the impact of identified interactions, qualifying certain impacted components and structures, and performing leak-before-break evaluations.

Section 3.0 describes the methodology used in applying the criteria defined in Section 2.0.

Section 4.0 summarizes the results of this effort. High energy lines are identified and categorized by resolution approach. Impacted components or structures which did not pass the conservative acceptance criteria are also listed.

Appendix A is a matrix which identifies SONGS-1 high energy lines, the resolution method used, the transient caused by the line break, and the method of shutdown.

Appendix B is a set of color-coded piping and instrument diagrams. All high energy lines are highlighted and colors indicate method of resolution.

Appendix C provides a summary of the numerical results from the LBB evaluation.

Appendix D provides a description of the Computer Codes used for this evaluation.

2.0 CRITERIA

This high energy line analysis is based primarily on the criteria outlined in NRC Standard Review Plans (SRP) 3.6.1 and 3.6.2 (References 6 and 7) and the Safety Evaluation for the topic lead plant (Reference 8). Specific deviations from these documents are noted in this report.

2.1 High Energy Line Definition

High energy piping at SONGS-1 has been identified consistent with the definition provided in Reference 7, "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, 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 ASB 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 ASB 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 MEB 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., steam 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

Pipe break locations and types were postulated in accordance with the guidance contained in the NRC staff's lead topic 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, where the primary plus secondary stresses as calculated in accordance with LTS stress criterion (Reference 9), exceeds 0.8 (1.2 S_h+S_A). The seismic stresses (due to Modified Housner 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 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 interactions requiring target qualification and for which LTS seismic analyses were performed. Break locations were selected by reviewing the LTS results or by using the break location option of SUPERPIPE.

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.

Simplified Mechanistic Approach (SMA)

For high-energy lines not analyzed as part of the LTS effort, 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 are postulated at the break locations. Circumferential breaks are postulated at all break locations in piping runs with nominal pipe diameter greater than 1-inch. Longitudinal breaks are postulated at all break locations in piping runs with nominal pipe sizes greater or equal to 4 inches. In accordance with Reference 8 guidance, the break opening is 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 Safe Shutdown Systems

The safe shutdown functions and hence systems needed to implement these safe shutdown functions were selected in accordance with paragraph III.4 of SRP 3.6.1 (Reference 6) and 10CFR50.49 (Reference 11).

2.4.1 Safe Shutdown Functions

The following safe shutdown functions were identified as being required following a HELB event:

- Reactor Coolant Inventory Control
- Reactor Coolant Pressure Control
- Reactor Coolant Temperature Control
- Reactor Reactivity Control
- Containment Integrity/Leakage Control (for lines which result in discharges of reactor coolant inside containment)
- Necessary Support and Instrumentation Systems.

2.4.2 Safe Shutdown Methods

The methods used for achieving the safe shutdown functions identified in Section 2.4.1 can be categorized as follows:

- Accident Mitigation Systems
- Plant Shutdown Systems
- Alternate Plant Shutdown Systems
- Dedicated Shutdown Systems

Accident mitigation systems are those systems solely used for the purposes of accident mitigation. They are safety-related systems and are powered from diesel generator-backed AC power buses.

Those safety-related systems which are not needed to mitigate the consequences of an accident but which are used to cool the plant from a hot standy condition to a cold shutdown condition are considered in the second category. Also included in this category would be those necessary support systems.

For those line breaks where a reactor trip/turbine trip does not result from the break or its effects, paragraph B.3.b(1) of BTP ASB 3-1 of SRP 3.6.1 does not require that offsite power be considered lost.

The dedicated safe shutdown method utilized normal safe shutdown equipment in conjunction with a unique long term heat removal method (single phase heat exchange using the steam generators), a remote location for shutdown control, an independent onsite power source and independent instrumentation and controls. It was utilized to achieve safe shutdown when all normal and alternate methods of safe shutdown are made inoperable due to HELB.

The operability of the DSS considered pipe whip and jet impingement loads but did not evaluate these components for environmental considerations associated with the break.

Four analyses were performed and documented in reference 49 to determine the amount of time and minimum equipment required to recover following various combinations of loss or partial loss of both primary and secondary heat sinks, spurious operation of the PORV's, and uncontrolled cooldown. The result of these analyses was the demonstration that provided the secondary heat sink was restored within 15 minutes and a primary heat sink was established within 25 minutes that the reactor core remained covered. Based on these accident scenerios, a screening criteria, flow chart, was developed to be used to evaluate those lines where conventional shutdown criteria had not been successful.

2.4.3 Safe Shutdown Systems

The following safe shutdown systems or portions thereof were considered required in order to provide the functional requirements listed in Section 2.4.1:

- Containment Ventilation System (CVS) (containment isolation, radiation and hydrogen monitoring, and hydrogen recombiner portions only)
- Reactor Coolant System (RCS)
- Auxiliary Feedwater System (AFW)
- Main Steam System (MSS) (integrity up to and including the turbine stop valves, and atmospheric steam dump system)
- Residual Heat Removal System (RHR) (only for lines outside containment)
- Volume Control and Charging (VCC)
- Nuclear Instrumentation (source range for accident monitoring, power range for reactor trip initiation)
- Gaseous Nitrogen System (GNI)
- Reactor Protection System (RPS)
- Containment Spray and Recirculation System (CRS)
- Safety Injection System (SIS)
- H_2 Recombiner System (listed as part of the CVS)

The following auxiliary systems are also required to function:

- Component Cooling Water System (CCW)
- Saltwater Cooling System (SWC)
- Diesel Generator System (DG)
- Reactor Cavity Cooling Fans (RCC)*
  - * The reactor cavity cooling fans are used in conjunction with the source range nuclear instruments to monitor core reactivity for breaks outside containment.

For some breaks credit was taken for the ability to operate secondary side isolation components. These components were evaluated for pipe whip and jet impingement effects, but not for environmental considerations associated with the break.

The following shutdown systems or portions thereof were considered required in order to provide alternate methods of achieving the functional equivalent of a system identified above:

- Main Feedwater System (FWS) and Condensate System (CND) as an alternate to the Auxiliary Feedwater System (AFW)
- Boron concentration sampling through the post accident sampling system (PSS) and reactor sampling system (RSS) (as an alternate for source range NI)
- Auxiliary Saltwater Cooling (SWC) (G-13C as an alternate for G-13A and G-13B)

When the integrity of the reactor coolant system was not challenged by the HELB event, credit was taken for the availability of the dedicated safe shutdown system. This system provides remote shutdown capability, as well as instrumentation and controls independent of any onsite power system. The system provides the capability to independently shutdown the plant with minimal plant piping and without any normal onsite or offsite power systems. The dedicated shutdown system includes:

- Dedicated Diesel Generator System (DSD) (Dedicated Power Supply)
- Dedicated Auxiliary Feedwater System (AFW) (West Auxiliary Feedwater Pump)
- Boron concentration sampling through the post accident sampling and reactor sampling systems

This system was used principally to provide a third source of auxiliary feedwater, a source of power for charging pump G-8A, or a source of power to the group D pressurizer heaters. Also, its concept of single phase steam generator heat removal was used in some cases for long term heat removal.

2.5 Target Qualification

2.5.1 Components

The acceptance criteria for qualifying components for the effects of jet impingement were based in part on the acceptance criteria established for LTS evaluations of components (Reference 9). Gravity, thermal, and other normal operating loads, if considered in LTS evaluations, were considered to act concurrently with pipe rupture interaction loads. Otherwise, only gravity loads were considered concurrently. Seismic loads were not considered to act concurrently with HELBA loads and were not evaluated.

Alternately, if analysis of the interaction geometry and ruptured pipe fluid conditions could demonstrate an impingement pressure less than the interaction identification cut-off pressure (5 psi), the component was considered qualified.

Components were assumed to lose function if impacted by a whipping pipe and qualification for whip impact loads was not performed (except for structures as noted in the following section).

The following acceptance criteria are applied to the various types of component targets identified: cable trays and conduits; piping, supports, and penetrations; and electrical components including pump and valve motors.

Cable trays and conduits were qualified for jet impingement if the support loads were qualified in accordance with the LTS allowables and if the cables were not directly impinged upon by the jet issuing from the ruptured pipe. Indirect spray was not considered direct impingement. If the cables were directly impinged upon, qualification required demonstration through analysis of the interaction geometry that the impingement pressure met the cut-off pressure for the zone of influence for interaction identification (i.e., below 5 psi, as noted in Section 3.3.1).

Piping, supports, and penetrations identified as targets requiring qualification in accordance with the methodology of Section 3.0 were qualified in accordance with the LTS criteria.

Qualification of electrical components other than cables in trays and conduits was by demonstration through analysis of the interaction geometry that the impingement pressure was below 5 psi.

2.5.2 Essential Structures

Jet impingement and pipe whip interactions with essential structural members were identified by walkdown and evaluated. Essential structural members are those that 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. Detailed criteria for the structural steel are provided in the following sections. 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. Also, the ability of the turbine deck to maintain its structural integrity after the failure of a single support beam was shown generically and 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.

2.5.3 Jet Impingement on Structural Steel

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,

$$\frac{fa}{Fa} + \frac{fbx}{Fbx} + \frac{fby}{Fby} \leq 1.6$$

where

fa, fbx, fby = axial, major axis bending, and minor axis bending allowable stresses, respectively, in the member due to the total resultant applied loads

Fa, Fbx, Fby = 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.)

<u>Columns</u>

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.

$$\frac{P}{Py} + \frac{1}{1.18}\,\frac{Mx}{Mpx} + \frac{1}{1.67}\,\frac{My}{Mpy} \leq 1.0 \quad 1.0$$

where

P = Applied axial load [kips]

Py = $Fy \times A$ = Yield stress x section area [kips]

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

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

Mpx = $Zx \times Fy$ = Plastic moment capacity, major axis [kip-inches]

Mpy = $Zy \times Fy$ = 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.

2.5.4 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 permitted to exhibit limited inelastic behavior. Qualification criteria were based on ductility ratios. Inelastic girders were acceptable provided the ductility ratio is 3 or less.

2.0 CRITERIA

The ductility, μ, was computed as follows:

If $\frac{Mx}{Mpx} < 1$

$$\mu = [(\frac{P}{Py} + \frac{Mx}{Mpx'} + \frac{My}{Mpy})^2 + 1] /2$$

If $\frac{Mx}{Mpx} \geq 1$,

$$\mu = [(\frac{P}{Py} + \frac{Mx - M_{DL}}{Mpx'} + \frac{My}{Mpy})^2 + 1] /2$$

where

- P = Applied axial load
- Py = Fy x A = Yield stress x section area
- Mx = Applied total moment in vertical plane
- M_{DL} = Applied vertical plane moment due to dead load (Conservatively included in the equations to provide an upper bound estimate of required ductility).
- Mpx' = $Mpx - M_{DL}$ = Reduced plastic moment capacity
- Mpx = Zx x Fy = Plastic moment capacity in vertical plane
- My = Applied total moment in horizontal plane
- Mpy = Fy x Zy = Plastic moment capacity in horizontal plane

When inelastic criteria were used, the following was evaluated to ensure that member plastic moment capacity is achieved.

Local Buckling

$b/t \leq 17$ and $d/t \leq 70$

Lateral Buckling

For minor axis bending only, there was no limit on the unbraced length for symmetrical girders bent about the minor axis when local buckling requirements were satisfied.

For major axis and biaxial bending unbraced length requirements of AISC Specification Part 2 (Section 2.4) were satisfied. In lieu of this, unbraced length requirements corresponding to the demand rotations capacity per Appendix A, of Reference 13 were satisfied.

Shear

The plastic moment capacity of the girder was reduced where the effects of shear were considered to be significant. No reduction of the plastic moment capacity, Mp, was required for the effects of shear force provided its magnitude, V, at the maximum load was satisfied.

$V \leq Fy \times w \times d_w/1.732$

where

V = Shear force [kips]

Fy = Yield stress [ksi]

d_w = web depth [in.]

w = web thickness [in.]

Torsion

a) The local member stresses near the connections were less than the elastic criteria limits.

b) The torsional shear stresses in the connections were less than the elastic criteria limits.

Connections

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

2.5.5 Pipe Whip Loads on Columns

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

In lieu of the elastic criteria, inelastic criteria were used. Inelastic columns were acceptable provided:

$\mu \leq 5$ $\quad kl/r < 30$, (with local buckling requirements as for girders applied)

$\mu \leq 1$ $\quad kl/r \geq 30$

If ductilities were evaluated, the same approach as for girders was used.

Connections

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

2.5.6 Criteria for Pipewhip Load Definition

The pipe whip load is 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 load (R) is imposed on the beam, together with the static loading and member critical forces and moments (P, Mx, My) were determined. Using the interaction equation, the ductility ratios were determined. If this ductility is less than the allowable (i.e., 3 or less), the member were qualified.

2.6 Leak-Before-Break Evaluations

2.6.1 <u>General Criteria</u>

The criteria used for the LBB evaluation are those 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, are 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 in this section.

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

The following guidance and criteria were used in the LBB evaluation:

2.6.2 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 must be demonstrated. Both circumferential and longitudinal cracks must be 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 is to be considered. Cracks longer than 2t may be evaluated if necessary to demonstrate detectability.

2.6.3 Integrity Requirements

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

Prevention of general plastic instability is to be 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 will 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 are not considered in the LBB evaluation.

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

The jet impingement due to flow through the crack under seismic conditions is to be evaluated to show whether the jet will impair safe shutdown systems using the component damage criteria.

2.6.4 Subcritical Crack Development

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

2.6.5. Inservice Inspection

For lines with an explicit leak-before-break evaluation which demonstrates the ability of the line to tolerate large, detectable, through-wall flaws, existing ISI commitments have been considered acceptable.

3.0 METHODOLOGY

3.1 High Energy Line Identification

The purpose of this task 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.

3.1.1 Assumptions

The fundamental assumption for this task 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 all lines whose operating conditions met the criteria of a high energy line, Criteria 2.1, were identified.

Next, a review of the P&IDs was performed to identify any piping connected to a high energy pipe segment based on the information in the Master Line List, and not isolated by a normally closed valve. These pipe segments, if they were identifiable as having unique line identification, were added to the HELBA Line List data base. 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 not considered. The list of systems containing high energy lines and the list of high energy lines are contained in Table 3-1 (page 3-16) and Appendix A respectively. The list of systems excluded from the HELBA study are tabulated in Table 3-2 (page 3-17).

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 and its basis. Exclusion was based on various criteria from Section 2.2.

Using the HELB Line List from Task 3.1, exclusion review forms were prepared. Each line listed in the Task 3.1 List 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.

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 In-Service-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 consisting 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.

3.4 System Interaction Evaluation

For each high energy line segment which was the object of a pipe rupture interaction walkdown, a system interaction evaluation was performed in order to determine whether the loss of the line segment in conjunction with the loss of other plant systems and components with which it interacted could affect the ability to safely shutdown the plant. Prior to beginning the system interaction evaluations, three subtasks had to be performed. These were: (1) development of a list of safe shutdown equipment; (2) development of safe shutdown success logic diagrams; and (3) development of a safe shutdown circuit list. These subtasks will be discussed first followed by a discussion of how the interaction evaluations were performed.

The system interaction evaluations were performed based on the following assumptions:

3.4.1 System Interaction Analysis Assumptions

(1) The transient caused by the initiating event is determined by considering a single break occurring at any location along the pipe segment under consideration. Other design basis events (DBEs) including seismic events, other accidents, and transients are not assumed to occur concurrently unless induced by the HELB.

(2) Equipment impacted by fluid jet impingement or pipe whip from the high energy line will become inoperable or fail in whichever state of operation that creates the least desirable impact on the plant.

(3) A single, independent, worst case active component failure is assumed in one of the systems required to mitigate the consequences of the postulated piping failure and to achieve safe shutdown in addition to failures mechanistically caused by the high energy line break. The component selected as the single active failure was chosen based on a review of the safe shutdown functions and systems affected by the line break. Specifically, each of the safety functions identified in paragraph 2.4.1 of the criteria section of the report were reviewed and the component whose failure had the worst effect on safe shutdown capability was selected as the single active failure.

(4) Malfunction/loss of an electrical or electromechanical fluid system component constitutes a single active failure.

(5) Malfunction/loss of an active component of a fluid system is considered to be a loss of the component function (as a result of mechanical, hydraulic, pneumatic, or electrical malfunction), but not the loss of component structural integrity or pressure boundary.

(6) For the purpose of safe shutdown equipment identification, the plant is operating at full power at the time of high energy line break (HELB). This mode is assumed to be the most

limiting mode since the largest number of systems were identified as being required for safe shutdown. A review was made of all other operating modes to determine if any equipment was needed for shutdown which was not needed from full power operation.

(7) Safe shutdown for the plant is defined as cold shutdown with a long-term decay heat removal process in operation.

(8) All components and structures are assumed capable of remaining operational in the presence of a fluid jet with a pressure of 5 psig or lower. Therefore target identification for system interaction analysis and target qualification purposes will not go beyond a radius where the pressure wave of the fluid jet equals 5 psig.

(9) Safe shutdown capability in the event of a High Energy Line break is evaluated relative to the presence or loss of offsite power. A loss of offsite power is assumed to occur in the event that the line break results in an automatic reactor trip-turbine generator trip. For the operation of safe shutdown equipment, power availability is evaluated from the emergency diesel generators, and/or the dedicated shutdown diesel generator. The offsite power is assumed to be available in cases where the postulated high energy line break does not result in an automatic reactor trip-turbine generator trip.

3.4.2 Safe Shutdown Component Identification

Two previously developed lists of plant equipment were used as the basis for developing the HELBA safe shutdown equipment list. These were the 10CFR50 Appendix R safe shutdown equipment list and the Environmental Equipment Qualification list, references 16 and 17, respectively. After the basic HELBA component list was generated, a review against the SONGS-1 Emergency Operating Instructions (EOIs) was performed and any necessary equipment identified and added. For equipment that was credited for safe shutdown but was not part of the Environmental

Equipment Qualification list, an evaluation was performed to justify its use (e.g., equipment outside containment would always be acceptable for breaks inside the containment).

The list of SONGS-1 systems and whether they are used for safe shutdown is contained in Table 3-3. The list of safe shutdown equipment is contained in Reference 33.

3.4.3 Safe Shutdown Logic Development

Safe shutdown diagrams were needed in order to determine whether the combined loss of the initiating pipe segment and its pipe whip and pipe jet impingement interaction targets impacted the ability to mitigate the accident and to achieve and maintain safe shutdown. These were developed using the HELB safe shutdown component list, the appropriate P&IDs, and the safe shutdown logics developed as part of the 10CFR50, Appendix R effort. For HELB accident interaction analysis, accident mitigation/safe shutdown logics at the component level were needed. In order to develop the safe shutdown logics, the following six objectives were considered as needing to be satisfied:

A. Achieve and maintain shutdown reactivity control for both hot and cold shutdown conditions.

B. Maintain control of the reactor coolant inventory.

C. Achieve and maintain control of primary plant pressure and temperature. This includes providing immediate and long term core heat removal following an event to prevent damage to the fuel.

D. Provide containment integrity for releases of reactor coolant by (1) controlling the hydrogen concentration inside containment within acceptable limits; (2) controlling the primary containment pressure and temperature within acceptable limits; and (3) establish containment isolation in order to prevent the spread of radioactive materials.

E. Provide direct readings of the process variables necessary to perform and control above functions.

F. Provide cooling, lubrication, etc. as necessary to permit the operation of the primary equipment used for safe shutdown functions, e.g., charging pump cooling and seal water.

The logics identified continuations of specific plant safe shutdown components as being required to achieve hot standby and cold shutdown for HELBs inside or outside of containment.

3.4.4 Safe Shutdown Cable Identification

For each electrical or electromechanical component on the accident mitigation/safe shutdown component list, the cables associated with providing electrical power and/or control of the component were identified since loss of the cables would directly affect the availability of the component. The last subtask was the identification of these cables.

The applicable elementary diagram(s) for each component on the HELB safe shutdown component list was obtained and those cables whose failure could cause loss of operability or malfunction were identified and entered into the SONGS 1 HELBA data base of the CABLE program. A description of the CABLE computer program is included in Appendix D. Following identification of appropriate cables for all HELB safe shutdown components and entering the component and cable information into the CABLE program, a special sort was obtained by "VIA" (e.g., conduit or cable tray) of all "VIA"s which contained one or more HELB safe shutdown component cables.

3.4.5 Safe Shutdown Evaluations

The system interaction analysis of the pipe rupture walkdown data was performed following the development of the HELBA safe shutdown component list, the list of cable trays and conduits, and the set of the safe shutdown logic diagrams as described in the previous three sections.

The walkdown package listed targets in terms of structures, pipes, safe shutdown components, conduits and cable trays. If the pipe segment or component was on the respective safe shutdown list, then the information was transferred directly to the "safe shutdown component affected" ("SSD Comp Affected") column of the interaction evaluation forms. If the target was a conduit or cable tray, then, using the list of "VIAs" containing safe shutdown component cables, any safe shutdown cables and the corresponding safe shutdown components were listed in the "SSD Comp Affected" column. If the target was a structure and its description related it to some specific target, then the steps noted above were followed to determine whether the item being supported was safe shutdown related or not and the information was transferred to the "SSD Comp Affected" column. If the structural target could not be related to a specific safe shutdown component, then its acceptability was separately analyzed.

Having developed a list of safe shutdown components affected by the initiating line break, the list and a set of safe shutdown logic diagrams were used to evaluate whether safe shutdown was affected. The effects of jet impingement and pipe whip were combined as follows:

> Unless otherwise indicated in the evaluation of the breaks for a line, the jet impingement targets listed for the entire line were combined into one list with the break specific pipe whip interactions and an evaluation was performed. When a physical boundary, such as a wall, separated the targets, the jet impingement envelope was broken at the physical boundary and separate evaluations were performed for each area. In cases where pipe break locations were widely spaced, the pipe whip targets were combined with their corresponding jet impingement targets and analyzed.

The line evaluation then considered (1) the postulating of a single worst case active failure as stated in 3.4.1(3); and (2) determining whether both hot and cold shutdown could be achieved. Also considered was whether the plant could be safely maintained controlled in cold shutdown.

If the interaction evaluation for the line using the safe shutdown logics did not identify a method by which the plant could be safely shutdown, then the line was evaluated against a screening criteria, flowchart, developed to demonstrate that the line break and its consequences were bounded by one of the four accident scenerios analyzed in detail in Reference 49. As discussed in Section 2.4.2, the analyses in Reference 49 showed that in these scenerios core uncovery did not occur. Therefore, all lines which could be shown to be bounded by one of the four cases, were considered resolved. If the line's consequences could not be bounded by the cases in Reference 49, then the components which had to remain operational were identified for the purposes of target qualification/protection.

3.5 Target Qualification of Components

3.5.1 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) The total impingement force at any cross-section normal to the axis of the jet was assumed to be invariant with distance from the source. Energy losses due to mixing with the atmosphere were neglected.

(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.

3.5.2 Jet Impingement Load Definition

The jet thrust from the ruptured pipe was defined by:

$$T_{jet} = C_T P_O A$$

where: T_{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 44). 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.

3.5.3 Qualification Analysis

Analysis was performed in order to determine if essential structures and components 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_O	=	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 Target Qualification of Structures

Girders and columns in the turbine building and extensions 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 modification or more detailed analysis.

3.7 Leak-Before-Break

The methods and procedures applied for the leak-before-break analysis steps are described in this section.

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. Descriptions of the CRACK and IMLEAK computer programs are included in Appendix D. 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, Eqn. 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. A detailed discussion of this evaluation is provided in Appendix C.

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 (FWH)
- Feedwater (FWS)
- 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 32:

- 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 (ISA)
- Liquid Nitrogen System (LNI)
- Turbine Plant Cooling System (PSC)
- 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)

TABLE 3-3

SONGS Unit 1
SYSTEM DESIGNATION LIST/AND
SAFE SHUTDOWN CLASSIFICATION

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	SSD CLASSIFICATION*
AFW	Auxiliary Feedwater System	Both
BAS	Boric Acid System	Non-SSD
CCW	Component Cooling Water System	Both
CNA	Condenser Air Removal System	Non-SSD
CND	Condensate System	Both
CRS	Containment Spray and Recirculation System	SSD
CSS	Condensate Sampling System	Non-SSD
CVD	Condenser Vents and Drains	Non-SSD
CVS	Containment Ventilation System	SSD
CWS	Circulating Water System (Intake structure only)	Both
DCN	Diesel #2 Combustion Air Intake - Exhaust System	SSD
DCS	Diesel #1 Combustion Air Intake - Exhaust System	SSD
DFN	Diesel #2 Fuel Oil System	SSD
DFS	Diesel #1 Fuel Oil System	SSD
DIM	Diesel #2 Instrument and Control Air System	SSD
DIS	Diesel #1 Instrument and Control Air System	SSD
DLN	Diesel #2 Lube Oil System	SSD
DLS	Diesel #1 Lube Oil System	SSD
DSN	Diesel #2 Starting Air System	SSD
DSS	Diesel #1 Starting Air System	SSD
DWN	Diesel #2 Cooling Water System	SSD
DWS	Diesel #1 Cooling Water System	SSD
FES	Flash Evaporators	Non-SSD
FPH	Fire Protection Halon Systems	Non-SSD
FPS	Fire Protection Foam and Spray Systems	Non-SSD
FPW	Fire Protection Water Systems	Non-SSD
FSS	Feedwater Sampling Systems	Both
FWH	1st, 2nd, 3rd Point Feedwater Heaters	Non-SSD
FWS	Feedwater System	Both
GGS	Generator Gas System	Non-SSD
GNI	Gaseous Nitrogen System	Both
GSO	Generator Seal Oil System	Non-SSD
HSG	Circulating Water Hydraulic Stop Gates	Non-SSD

* SSD - means system is completely safe shutdown.
Non-SSD - means system is not required for any safe shutdown scenarios.
Both - means part of the system is used for safe shutdown and part is not.

TABLE 3-3
(Continued)

SONGS Unit 1
SYSTEM DESIGNATION LIST/AND
SAFE SHUTDOWN CLASSIFICATION

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	SSD CLASSIFICATION
ISA	Instrument and Service Air System (only portion from GNI tie in to safe shutdown valves)	Both
LDS	Letdown Demineralizer System	Both
LNI	Liquid Nitrogen System	Non-SSD
MCP	Mechanical Containment Penetrations	Non-SSD
MSS	Main Steam System	Both
MVS	Miscellaneous Ventilation Systems	Non-SSD
PAS	Post Accident Sampling Systems	Both
PMU	Primary Plant Make-up Water Systems	Both
PSC	Turbine Plant Sample Cooling System	Non-SSD
PZR	Pressurizer and Pressurizer Relief Tank	Both
RCP	Reactor Coolant Pump Seal Water	Both
RCS	Reactor Coolant System	Both
RHR	Residual Heat Removal System	Both
RLC	Radwaste Liquid Collection System	Both
RSS	Reactor Cycle Sampling System	Both
RWC	Radwaste Cryogenic Waste Gas System Treatment System	Non-SSD
RWD	Radwaste Drains	Non-SSD
RWG	Radwaste Gas Processing System	Non-SSD
RWL	Radwaste Liquid Processing System	Non-SSD
SCF	Secondary Chemical Feed System	Non-SSD
SDW	Service and Domestic Water System	Non-SSD
SEV	Sphere Enclosure Building Ventilation System	Non-SSD
SFP	Spent Fuel Pit Cooling System	Non-SSD
SHA	Containment Spray Hydrazine Addition System	Both
SIS	Safety Injection System	Both
SSD	Secondary Station Sumps and Drains	Non-SSD
STS	Sphere Test System	Non-SSD
SWC	Saltwater Cooling System	Both
TBN	Turbine System	Non-SSD
TCO	Turbine Control Oil System	Non-SSD
TCW	Turbine Plant Cooling Water System	Both
THP	High Pressure Turbine System	Non-SSD
TLO	Turbine Lube Oil System	Non-SSD

TABLE 3-3
(Continued)

SONGS Unit 1
SYSTEM DESIGNATION LIST/AND
SAFE SHUTDOWN CLASSIFICATION

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	SSD CLASSIFICATION
TLP	Low Pressure Turbine System	Non-SSD
VCC	Volume Control and Charging System	Both

4.0 RESULTS

Appendix A provides an itemized listing of all high energy piping, both inside and outside containment, for SONGS-1. This table is sorted by system and line identification number, and identifies which analytical approach was used to resolve each line. For each line resolved via systems interaction analysis, the transient caused by postulating a break is identified as is a proposed method of cooldown/shutdown. Appendix B shows all high energy lines graphically on SONGS-1 Piping and Instrument Diagrams. The color scheme defines the resolution approach used and is interpreted as follows:

Exclusion Criteria: Orange or Red
Systems Interaction/Target Qualification: Yellow
Leak-Before-Break: Blue
Augmented ISI Program: Green

4.1 Line Exclusion Review

Of the piping lines initially defined as high energy based on maximum operating temperatures or pressures exceeding the established criteria, 236 were excluded from further evaluation. Acceptable justifications for exclusion are described in Section 2.2 and are generally based on actual operational period at high energy levels as well as limited reservoir considerations.

4.2 Systems Interaction Evaluation/Target Qualification

426 lines were field inspected and evaluated via the systems interaction approach as described in Section 3.4. Due to plant inaccessibility, 20 lines were evaluated based on a review of plant general arrangement plan and section drawings. Therefore, a total of 446 line segments were evaluated.

4.2.1 Component Target Qualification

The approximately 2500 interaction evaluations resulted in 171 component interactions which did not meet the acceptance criteria. Table 4-1 (page 4-4) summarizes the unresolved interactions. The table identifies the source line, component target, and whether it is qualified to withstand the postulated load, unresolved, or has not been analyzed yet.

4.2.2 Structural Member Target Qualification

The structural member qualification evaluations resulted in analysis of 600 structural target interactions. Table 4-2 (page 4-6) summarizes the results of these evaluations by listing the 95 structural target interactions not shown to pass the conservative acceptance criteria. The table lists the source line, type of interaction, and structural member.

4.3 Leak-Before-Break

Nineteen large diameter piping lines inside containment were evaluated using the leak-before-break approach. Ten were evaluated as part of the HELBA project and nine reactor coolant loop lines were evaluated as part of the resolution of the asymmetric LOCA loads issue. LBB was applied to these lines due to the extensive number of modifications which would be required to alleviate postulated pipe break effects on components and structures inside containment. Appendix C provides numerical results of the LBB analyses performed for the ten lines evaluated in this project.

Prior to this effort the large diameter reactor coolant loop piping was evaluated for potential rupture to resolve the asymmetric LOCA loads issue (Reference 43). The results of that review are considered applicable to resolution of the HELBA issue for these lines. The nine large diameter lines are listed as resolved by LBB in Appendix A.

As part of the current effort, the leak-before-break condition was demonstrated for two additional RCS lines, the three feedwater lines, and the five 20- and 24-inch diameter main steam lines inside containment. Existing global leak detection was shown to be adequate except for one segment of the main steam piping (MSS-3-20). This segment did not meet the 1 gpm leak detection acceptance criteria.

4.4 Augmented Inservice Inspection Program Verification

The augmented ISI program of Technical Specification 4.10 requires inspection of specific potential break locations on twenty seven high energy lines outside containment. As part of the current HELBA effort, break locations were postulated for the twenty-seven lines and compared to the locations covered by the ISI program. If a postulated break location was included in the augmented ISI program, the break was considered resolved and further evaluation was not performed. All break locations on thirteen lines were found to be enveloped by the augmented ISI program locations and these lines are listed as resolved by ISI in Appendix A. If all postulated break locations on a line were not covered by the augmented ISI program, systems analysis and target qualification approaches were applied. The detailed analysis and specific results of the break location and ISI program coverage are provided in Reference 35.

4.5 Conclusion

This high energy line break analysis has evaluated all high energy lines at SONGS-1. This comprehensive evaluation has resolved all interactions identified during this effort with the exceptions noted in Tables 4-1 and 4-2. The report along with supporting calculations and referred documents provides a baseline for the SONGS Unit 1 HELBA program.

4.0 RESULTS

TABLE 4-1

COMPONENT TARGETS NOT MEETING ACCEPTANCE CRITERIA

Line No.	Targets	Status**
AFW-88-04-HH	71108F or 72228G	*
CND-317-14-GG[1]	49F1, 71108F, and PB799F	*
FWH-115-08-GG	SIS-6004-14-CL, 46C1, 46S2, and 46S3	*
FWH-116-10-GG	71108F, 72228G and 49B1	U
FWH-118-08-EG	PB919G and 49B1	*
FWH-11049-06-HH	(46C1 and 46C2) or (HV-854A, 72000G and 72212G)	*
FWS-321-12-EG	(49B1, 74320G, 36Q1, 36R1 and 46AF1) or (22J6, SIS-6005-14-CL, 49C4, 72009F, 79056F, 49B4, G-3B and SIS-6003-16-HK) and 7696F, 7689F, 74589	U
FWS-321-14-EG	(7592G, 7593G, and 7736F) or (7689F, 7695F and 7696F)	U
FWS-322-12-EG	46C1, 46C2, 46C4, 72000G, 10510G, 46K6, 72212G, SIS-6002-26-HK, and (PB798G)	*
FWS-325-08-EG[2]	SIS-6006-6-CL and FWS-14111-2-EG	*
FWS-326-08-EG[3]	SIS-6006-6-CL, SIS-6007-6-CL, FWS-14103-2-EG, FWS-14108-2-EG, and FWS-14111-2-EG	*
FWS-329-08-EG[4]	FWS-14103-2-EG, FWS-14108-2-EG, and FWS-14111-2-EG	*
FWS-342-02-EG[5]	T6028F, T6031F, and 7827F	*
LDS-2067-02-BH2	28H2, 28J2, 28C2, 28E2, and 28G2	*
LDS-2068-02-BH2	28H2, 28J2, 28C2, 28E2, and 28G2	*
LDS-2071-02-BH2	28H2, 28J2, 28C2, 28E2, and 28G2	*
LDS-2071-02-EG2	28J2, 28H2, and 28G2	*
LDS-3006-02-EG2	28J2 and 28H2	*
MSS-017-08-EG	PB803G, SIS-6004-14-CL, and SIS-6002-16-HK	*
MSS-064-06-EG[6]	GWPC5 and GWPC7	*
MSS-065-06-EG[7]	7681F and 7694F	
MSS-1316-08-HH	PB821F, 10521F, and SIS-6004-14-CL	*
MSS-1317-03-HH	79020G, SIS-6002-16-HK, SIS-6004-14-CL, and 39A7	*
PZR-5011-04-BH2	MSS-5-20-EG	*
PZR-5027-03-BH2	MSS-5-20-EG	*
PZR-5030-03-BH2	MSS-5-20-EG	*

NOTES:
1. CND-317-14-GG includes FWS-317-14-GG
2. FWS-325-08-EG includes FWS-393-08-EG
3. FWS-326-08-EG includes FWS-381-08-EG
4. FWS-329-08-EG includes FWS-392-08-EG
5. FWS-342-02-EG includes FWS-342-1.5-EG, MSS-342-02-EG, and MSS-342-1.5-EG
6. MSS-064-06-EG includes MSS-064-04-EG
7. MSS-065-06-EG includes MSS-065-04-EG

** LEGEND

- * Component Target Interaction is Unanalyzed
- U Component Target Interaction is Unresolved
- P Component Target Interaction is Partially Qualified

4.0 RESULTS

TABLE 4-1
(Continued)

COMPONENT TARGETS NOT
MEETING ACCEPTANCE CRITERIA

Line No.	Targets	Status**
PZR-5034-02-BH2	MSS-5-20-EG	*
PZR-5035-02-BH2	MSS-5-20-EG	*
RCS-5008-02-BH2[7]	28C2, 28G2, 28J2, 28H2, and 28E2	*
RCS-5011-03-BH2[8]	28C2, 28J2, 28E2, and 28D2	U
RCS-5037-02-BH2	28C2	*
RHR-3000-06-EG2	28J2, 28H2, and 28G2	*
RHR-3001-06-EG2	22C1	U
RHR-3001-06-EG2	28J2, 28H2, and 28G2	*
RHR-3003-04-EG2	28J2, 28H2, and 28G2	*
RHR-3015-06-EG2	28J2, 28H2, and 28G2	*
RHR-3019-02-EG2	28J2, 28H2, and 28G2	*
RHR-3019-06-EG2	28J2, 28H2, and 28G2	*
THP-021-10-GG	SIS-6002-16-HK, SIS-6004-14-CL, FWS-320-12-EG, 49B4, 79056, 72009, 72000G, 10521, 10522, 10510 and 74590F	*
THP-023-16-HH	(SIS-6004-14-CL, 10522F and 10521F) and ((46S2, 46AF1 and 46C1) or (SIS-6002-16-HK, FWS-320-12-EG, SIS-HV-853A, FWS-HV-854A, 72055G, 79102G and 10510G))	
THP-024-16-HH	7695F, 7689F, 7696F, SIS-6002-16-HK and ((49F1 and MSS-2-24-EG) or (FWS-319-12-EG, SIS-6003-16-HK, 49B4, and 79058F))	*
THP-8849-24-EG	46BB1, 46BB2, SIS-6004-14-CL and (SIS-6002-16-HK or (46C1 and MSS-17-6-EG))	*
THP-9102-36-EG	SIS-6002-16-HK and (10521F or 46AB4)	*
THP-9113-18-EG	7401F, 7474G, SIS-6004-14-CL and (10521F or 10510G)	P
VCC-2002-02-BH3	28G2, 28J2 and 31S5	*
VCC-2081-02-BH2	7807, 28E2, 28G2, 28J2 and 28H2	*

NOTES: 7. RCS-5008-02-8H2 includes LDS-5008-02-BH2
8. RCS-5011-03-BH2 includes PZR-5011-03-BH2

** LEGEND

* Component Target Interaction is Unanalyzed
U Component Target Interaction is Unresolved
P Component Target Interaction is Partially Qualified

TABLE 4-2

STRUCTURAL TARGETS NOT
MEETING ACCEPTANCE CRITERIA

Source Line	Interaction Type	Target
CND 305-12-GG	Jet Impingement	Column H9
CND 306-12-GG	Jet Impingement	Columns K1, K5, J1
CND 310-12-GG	Jet Impingement	Column L4, L5, K5
CND 311-12-GG	Jet Impingement	Column G12, H12, J12, K5, L9, L10 Girder WHP-B14, H13/J13; WHP-B16, H12/J12; WHP-B26, K9/L9; WHP-B17, L9/L10
CND 312-12-GG	Pipe Whip	Column K22
	Jet Impingement	Column H1, J1, J2, K2, L4, L5 Girder EHP-B14, H2/J2
CND 313-12-GG	Jet Impingement	Girders WHP-B14, H13/J13 WHP-B2.10, J13/K13; WHP-B26, K9/K12
CND 314-12-GG	Pipe Whip	Column K2
	Jet Impingement	Girders EHP-B8, G1/H1; EHP-B1, E1/F1; EHP-B23, E1/E3; EHP-B8, H1/J1; EHP-B13, G2/H2; EHP-B24, G1/H2; EHP-B26, J1/J2.
CND 331-1.5-GG	Pipe Whip	Column A7
CND 337-08-GG	Jet Impingement	Girder WHP-B16, G12/H12
CND 337-12-GG	Jet Impingement	Columns G12, H9, J12, Girders WHP-B16, H12/J12; WHP-B25.2 H9/H12/H13.
FWH 105-06-GG	Jet Impingement	Girder EHP-B5, E3/F2.
FWH 106-06-GG	Jet Impingement	Girder WHP-B5, E11/F12.
FWH 113-14-HH	Pipe Whip	Columns G2, F5.
FWH 115-10-GG	Jet Impingement	Girder EHP-B5, E3/F2.
FWH 116-10-GG	Jet Impingement	Column C9 & Girder WHP-B23.1, E13/E11.
FWH 203-1.5-EG	Pipe Whip	Column G2
FWS 320-12-EG	Jet Impingement	Columns E1, E3, F1, F2, & G1, Girder EHP-B23, E1/E3.
FWS 321-12-EG	Pipe Whip	Girder WHP-B5.
	Jet Impingement	Column E11, Girders WHP-B5, E11/F12; WHP-B24.1, E11/ E9.
FWS 322-12-EG	Pipe Whip	Girder EHP-B5
	Jet Impingement	Column E3, Girders EHP-B5, E3/F2; EHP-B22, E3/E5.
FWS 323-12-EG	Pipe Whip	Girder WHP-B5
	Jet Impingement	Columns E11, F12 Girder WHP-B5, E11/F12

TABLE 4-2
(Continued)

STRUCTURAL TARGETS NOT
MEETING ACCEPTANCE CRITERIA

Source Line	Interaction Type	Target
FWS 324-12-EG	Pipe Whip	Girder EHP-B5
	Jet Impingement	Columns F1, F2 Girder EHP-B5, E3/F2
FWS 326-08-EG	Jet Impingement	Girder NE-B2, A7/B7
FWS 329-08-EG	Jet Impingement	Girder NE-B2, A7/B7
FWS 6020-03-CL	Jet Impingement	Column C11
FWS 14103-03-EG	Jet Impingement	Girder NE-B4.4
FWS 14111-02-EG	Jet Impingement	Girder NE-B4.8
MSS 009-03-EG	Jet Impingement	Girder NE-B4.8, B6/B7
MSS 017-08-EG	Pipe Whip	Column E5
	Jet Impingement	Girder NE-B4.8, B6/B7
MSS 019-06-EG	Jet Impingement	Girder EHP-B5, E3/F2
TBN 1307-04-HH	Pipe Whip	Girder WHP-B2.6
TBN 1308-04-HH	Pipe Whip	Girder EHP-B20
TBN 1318-08-HH	Pipe Whip	Girder WHP-B2.6
TBN 1323-08-HH	Pipe Whip	Girder EHP-B20
THP 017-06-EG	Jet Impingement	Girder EHP-B5
THP 018-06-EG	Jet Impingement	Girder WHP-B5
THP 019-06-EG	Jet Impingement	Girder EHP-B5
THP 021-10-EG	Jet Impingement	Girder EHP-B5, E3/F2
THP 022-10-EG	Jet Impingement	Girder WHP-B5
THP 8849-24-EG	Jet Impingement	Column E9

5.0 REFERENCES

1. "Report on Effects of a Piping System Break Outside Containment," SONGS-1, AEC Docket 50-206, dated December 1973. Addendum 1, dated November 1974, Addendum 2 dated May 1975.

2. "Supplemental Study Report on Effects of a Piping System Break Outside the Containment," SONGS-1, dated March 1983. Addendum 1, dated August 1983.

3. "SEP Topic III-5.A High Energy Line Break Analysis Inside Containment," SONGS-1, dated August 1983.

4. NUREG-0829, "Integrated Plant Safety Assessment, Systematic Evaluation Program, SONGS-1," Draft Report dated April 1985, Final Report dated December 1986.

5. Letter from Robert Purple (NRC) to Jack B. Moore (SCE) dated July 15, 1975.

6. U.S. NRC Standard Review Plan 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," Revision 1, dated July 1981.

7. U.S. NRC Standard Review Plan 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," Revision 1, dated July 1981.

8. "Evaluation of Effects of Pipe Breaks on Structures, Systems, and Components Inside Containment, Topic III-5.A. for the Palisades Nuclear Power Plant," submitted by letter to Consumers Power Company dated December 4, 1981.

9. Design Criteria for Long Term Service Seismic Evaluation San Onofre Nuclear Generating Station, Unit 1, Revision 2, August 8, 1986.

10. NUREG - 1061, Volume 3, "Evaluation of Potential for Pipe Breaks," Report of the U.S. NRC Piping Review Committee, Dated November 1984.

11. 10CFR50.49

12. AISC Manual of Steel Construction, 8th Edition, 1980.

13. Return to Service Design Criteria for SONGS-1, "Impact of Pipe Support Loads on Structures," Document M-37458, Revision 1, dated October 10, 1984.

14. H. Tada and P.C. Paris, "Estimation of Stress Intensity and the Crack Opening Area of a Circumferential and Longitudinal Through-Crack in a Pipe." (Attachment to Reference 8.)

15. Southern California Edison Company, Master Line List, San Onofre Nuclear Generating Station, Unit 1. Document ID: M-37769, Rev. 2, dated March 27, 1986.

16. Impell Calculation 0310-064-201 Revision 4, "SONGS 1 Safe Shutdown Components," dated July 9, 1986.

17. SCE document CMD M Number 85003, Revision 4, "SONGS 1 EQ Master List," dated June 13, 1986.

18. "Estimation of Stress Intensity Factors and Crack Opening Area of a Circumferential and a Logitudinal Through-Crack in a Pipe", by H. Tada and P. Paris.

19. "Calculation of Leak Rates Through Cracks in Pipes and Tubes." EPRI Report NP-3395, December 1983.

20. "Study of Critical Two-Phase Flow Through Simulated Cracks", Batelle Laboratories, Interim Report - BCL-EPRI-80-1, November 25, 1980.

21. "Resolution of SEP Topics III-5.A and III-5.B for SONGS-1 Phase I," Impell Report No. 01-0310-1441, Revision 0, dated September 1985.

22. SEP Evaluation of the Pipe Break Outside Containment, Topic III-5.B, for San Onofre Nuclear Generating Station Unit 1. NRC Document, Docket No.: 50-206 LS05-84-04-047, dated April 23, 1984.

23. Impell Calculation 0310-064-903, Revision 1, Damage to Safety Related Equipment by Inadvertent Actuation of Fire Suppression System (IE 83-41).

24. Impell Calculation 0310-064-1611, Revision 0, Flooding Due to Fire Fighting Activities and FPS Pipe Rupture (IE 83-41).

25. Impell Calculation 115-1.0, Job 0310-115, "Basis for High Energy Line Exclusion," Rev. 4, February 1987.

26. Impell Calculation 115-2.0, Job 0310-115, "High Energy Line List Sort," Rev. 3, June 1987.

27. Impell Calculation 115-3.0, Job 0310-115, "High Energy Line Walkdown," Rev. 1, February 1987.

28. Impell Calculation 115-4.0, Job 0310-115, "Systems Interaction Analysis," Rev. 2, June 1987.

29. Impell Calculation 115-5.0, Job 0310-115, "Target Qualification of Components," Rev. 0, January 1987.

30. Impell Calculation 115-6.0, Job 0310-115, "Target Qualification Walkdown of Components," Rev. 0, January 1987.

31. Impell Calculation 115-7.0, Job 0310-115, "Leak-Before-Break Evaluation of Piping," Rev. 0, January 1987.

32. Impell Calculation 115-8.0, Job 0310-115, "SONGS-1 High Energy Line List," Rev. 4, June 1987.

33. Impell Calculation 115-9.0, Job 0310-115, "SONGS-1 Additional Components for HELBA Safe Shutdown," Rev. 2, February 1987.

34. Impell Calculation 0310-10.0, Job 0310-115, "SONGS-1 HELBA Safe Shutdown Logics," Rev. 1, February 1987.

35. Impell Calculation 115-11.0, Job 0310-115, "I.S.I./Break Location Comparison," Rev. 0, January 1987.

36. Impell Calculation 0310-12.0, Job 0310-115, "Safe Shutdown Circuits Evaluation," Rev. 0, February 1987.

37. Impell Calculation 115-13.0, Job 0310-115, "Generic Structural Evaluations," Rev. 0, January 1987.

38. Impell Calculation 115-14.0, Job 0310-115, "Structural Jet Impingement Evaluations," Rev. 0, January 1987.

39. Impell Calculation 115-15.0, Job 0310-115, "Target Qualification Walkdown of Structures," Rev. 0, January 1987.

40. Pipe Crack Study Group, "Investigation and Evaluation of Cracking Incident in Piping in Pressurized water Reactors," NUREG-0691, Nuclear Regulatory Commission, dated September 1980.

41. Pipe Crack Study Group, "Investigation and Evaluation of Stress-Corrosion Cracking in Piping of Light Water Reactor Plant," NUREG-0531, Nuclear Regulatory Commission, dated February 1979.

42. "A Plastic Fracture Instability Analysis of Wall Break Through in a Circumferentially Cracked Pipe Subject to Bending Loads" presented by A. Zahoor and M. F. Kanninen in Trans. ASME, Vol. 103, July 1981, p. 194-200.

43. Letter from M. O. Medford (SCE) to J. A. Zwolinski (NRC), "Generic Issue A-2, Elimination of Postulated Pipe Breaks," dated September 20, 1985.

44. Moody, F. J., "Prediction of Blowdown Thrust and Jet Forces," ASME Paper No. 69-H7-31, American Society of Mechanical Engineers (1969).

45. Impell Calculation 115-16.0, Job 0310-115, "Inside Containment Evaluations," Rev. 0, January 1987.

46. Impell Calculation 115-17.0, Job 0310-115, "Pipe Whip Structural Evaluations," Rev. 0, January 1987.

47. Impell Calculation 115-18.0, Job 0310-115, "Target Qualification Interaction Lists," Rev. 0, January 1987.

48. Impell Calculation 115-19.0, Job 0310-115, "Feed-Bleed Screening of Unresolved Lines", Rev. 0, June 1987.

49. Westinghouse Report, WCAP 11511, "Southern California Edison High Energy Line Break Evaluation for San Onofre Unit 1," Revision 0, May 1987.

APPENDIX A

HIGH ENERGY LINE BREAK RESOLUTION SUMMARY

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00069-03-EG	AFW	SYS ANA	5178221	Steam Line Break	Method #1	Notes #1, 4
00070-08-HH	AFW	2%	5178221			
00087-10-HH	AFW	SYS ANA	5178221	None	Method #1 or 3	Note #2
00088-04-HH	AFW	Unresolved	5178221	Loss of Feedwater	Method #3	Notes #8, 3, 14
00381-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater/Steam Line Break	Method #9	Notes #0, 1
00381-03-EG-4CCB	AFW	SYS ANA	5178220	Loss of Feedwater/Steam Line Break	Method #3	Note #1
00381A-03-EG-3ACB	AFW		5178220			Note #7
00381A-04-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Notes #5, 8
00381B-03-EG-3ACB	AFW		5178220			Note #7
00381C-03-EG-3ACB	AFW		5178220			Note #7
00381C-04-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Notes #5, 8
00397-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater/Steam Line Break	Method #3	Note #1
00397-03-EG-4CCB	AFW	SYS ANA	5178220	Loss of Feedwater/Steam Line Break	Method #10	Notes #0, 8
00397A-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Note #8
00397A-04-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #4	Note #8
00397B-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Note #8
00397C-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Note #8
00397C-04-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #4	Note #8
13106-03-EG	AFW	SYS ANA	5178221	None	Method #1	Note #2
14101-03-EG-3ACB	AFW	SYS ANA	5178220	Loss of Feedwater	Method #3	Note #2
00305-10-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #10	Note #1
00305-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #10	Note #1
00306-10-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #5	Note #1
00306-12-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #5	Notes #0, 1
00307-10-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00307-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00308-10-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00308-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00309-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00310-12-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #5	Notes #0, 1
00311-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1,4
00312-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #5	Notes #0, 1
00313-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #9 or 10	Note #1, 15
00314-12-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #9	Note #1
00315-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1, 4
00315-14-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #9 or 10	Notes #0, 1, 4, 15
00316-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1, 4
00316-14-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1, 4
00317-14-GG	CND	Unresolved	5178201	Loss of Feedwater/Steam Line Break	Method #5	Notes #0, 1, 3, 4, 14
00318-14-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #9	Notes #1, 4
00330-1.5-GG	CND	SYS ANA	5178201	None	Method #3	Note #2
00331-1.5-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1, 3, 6
00334-02-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00336-08-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #10	Notes #0, 1
00337-08-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #10	Notes #1
00337-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Notes #1, 4
00338-08-GG	CND	SYS ANA	5178201	Loss of Feedwater/Steam Line Break	Method #1	Notes #0, 1
00338-12-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #5	Notes #0, 1
00338-14-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #5	Notes #0, 1
00345-03-GG	CND	SYS ANA	5178201	None	Method #1	Note #2
00345-03-HP	CND	2%	5178200			
00355-04-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00355-06-GG	CND	2%	5178201			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00356-04-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #1
00356-06-GG	CND	2%	5178201			
00363-1.5-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #1	Note #2
00368-02-GG	CND	2%	5178202			
00374-03-GG	CND	SYS ANA	5178201	Loss of Feedwater	Method #5	Notes #0, 1
00396-04-HP	CND	2%	5178200			
10852-03-GG	CND	SYS ANA	5178207	Loss of Feedwater	Method #1	Note #1
00728-08-HP	CRS	2%	5178120			
00729-08-JN	CRS	2%	5178121			
00734-06-GM	CRS	2%	5178120			
00734-06-HH	CRS	2%	5178120			
00734-06-HM2	CRS	2%	5178120			
00735-04-HM2	CRS	2%	5178120			
00737-08-HP	CRS	2%	5178120			
00737-08-JN	CRS	2%	5178120			
00765-04-HH	CRS	2%	5178120			
00765-04-HM2	CRS	2%	5178120			
00876-1.5-HP	CRS	2%	5178121			
00891-02-GM	CRS	2%	5178120			
00891-02-HP	CRS	2%	5178120			
03122-02-SI	CRS	Partial 2%	5178120			
06015-04-HK	CRS	2%	5178121			
06015-06-HK	CRS	2%	5178121			
06015-08-HK	CRS	2%	5178121			
06016-04-BH3	CRS	SYS ANA	5178110	None	Method #3	Note #2
06016-04-EK	CRS	2%	5178120			
06018-04-HH9	CRS	2%	5178121			
06018-04-HM2	CRS	2%	5178121			
06018-06-HH9	CRS	2%	5178121			
06018-06-HM2	CRS	2%	5178121			
06019-04-HM2	CRS	2%	5178121			
06019-06-HH9	CRS	2%	5178121			
06019-06-HM2	CRS	2%	5178121			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
07175-02-GM	CRS	2%	5178120			
08020-06-HM2	CRS	2%	5178120			
08021-02-HP	CRS	2%	5178120			
08021-02-JN	CRS	2%	5178120			
08021-1.5-HP	CRS	2%	5178120			
08730-1.5-HM2	CRS	2%	5178120			
10371-06-GM	CRS	2%	5178120			
10375-04-GM	CRS	2%	5178120			
10375-06-GM	CRS	2%	5178120			
00241-06-HH	CVD	2%	5178245			
00242-06-HH	CVD	2%	5178245			
00181-06-HH	FES	2%	5178275			
00181-10-HH	FES	2%	5178275			
00182-06-HH	FES	2%	5178276			
00182-10-HH	FES	2%	5178276			
00214-02-HH	FES	2%	5178276			
00215-02-HH	FES	2%	5178275			
00251-06-HH9	FES	2%	5178275			
00252-03-HH9	FES	2%	5178276			
00252-06-HH9	FES	2%	5178276			
00254-03-HH9	FES	2%	5178276			
00255-03-HH9	FES	2%	5178275			
10168-03-HH	FES	2%	5178275			
10168-2.5-HH	FES	2%	5178275			
12983-03-HH	FES	2%	5178275			
01201-02-EG1	FSS	2%	5178261			
01202-02-EG1	FSS	2%	5178260			
01203-02-EG1	FSS	2%	5178260			
01207-02-EG1	FSS	2%	5178261			
01208-02-EG1	FSS	2%	5178261			
01209-02-EG1	FSS	2%	5178261			
01213-02-EG1	FSS	2%	5178261			
01214-02-EG1	FSS	2%	5178261			
00100-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00100A-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
00102-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00102A-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00103-06-EGX	FWH	SYS ANA	5178210	None	Method #1	Note #2
00103-08-EGX	FWH	SYS ANA	5178210	Loss of Feedwater	Method #9	Notes #0, 1
00103A-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
00103A-06-EGX	FWH	SYS ANA	5178210	Loss of Feedwater	Method #1	Note #2
00104-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00104-06-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00104-06-EGX	FWH	SYS ANA	5178212	None	Method #3	Note #2
00104-08-EGX	FWH	SYS ANA	5178212	Loss of Feedwater/Steam Line Break	Method #10	Notes #0, 1
00104A-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00104A-06-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00104A-06-EGX	FWH	SYS ANA	5178212	None	Method #1	Note #2
00105-06-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Note #1
00105-10-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00106-06-GG	FWH	SYS ANA	5178213	Loss of Feedwater	Method #9 or 10	Notes #1, 4, 15
00106-10-GG	FWH	SYS ANA	5178213	None	Method #3	Note #2
00107-04-GGX	FWH	SYS ANA	5178211	None	Method #3	Note #2
00107-08-GGX	FWH	SYS ANA	5178211	None	Method #3	Note #2
00107-12-GGX	FWH	SYS ANA	5178211	None	Method #3	Note #2
00108-04-GGX	FWH	SYS ANA	5178213	None	Method #3	Note #2
00108-08-GGX	FWH	SYS ANA	5178213	None	Method #3	Note #2
00108-12-GGX	FWH	SYS ANA	5178213	None	Method #3	Note #2
00109-08-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Notes #0, 1
00109-14-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Notes #1, 4
00110-08-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #9 or 10	Notes #1, 4, 15
00110-14-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00111-06-HHX	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00111-10-HHX	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00111-14-HHX	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00112-06-HHX	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00112-10-HHX	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00112-14-HHX	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00113-10-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00113-14-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Notes #1
00113-18-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
00114-10-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00114-14-HH	FWH	SYS ANA	5178213	Loss of Feedwater/Steam Line Break	Method #9 or 10	Notes #1, 4, 15
00114-18-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00115-08-GG	FWH	Unresolved	5178211	Loss of Feedwater	Method #5	Notes #1, 14
00115-10-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Notes #0, 1
00116-08-GG	FWH	SYS ANA	5178213	Loss of Feedwater	Method #9	Notes #0, 1
00116-10-GG	FWH	Unresolved	5178213	Loss of Feedwater	Method #1	Notes #1, 14
00117-08-EG	FWH	SYS ANA	5178210	Loss of Feedwater	Method #9	Notes #0, 1
00118-08-EG	FWH	Unresolved	5178212	Loss of Feedwater	Method #5	Notes #0, 1, 4, 14
00119-08-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
00120-08-EG	FWH	SYS ANA	5178212	Loss of Feedwater	Method #1	Note #2
00121-06-HH	FWH	SYS ANA	5178210	Loss of Feedwater	Method #1	Note #2
00121-08-HH	FWH	SYS ANA	5178210	None	Method #3	Note #2
00122-06-HH	FWH	SYS ANA	5178212	Feedwater Line Break	Method #1	Note #2
00122-08-HH	FWH	SYS ANA	5178212	None	Method #1	Note #1
00123-08-HH	FWH	SYS ANA	5178210	None	Method #3	Note #2
00124-08-HH	FWH	SYS ANA	5178212	None	Method #3	Note #2
00127-06-HHX	FWH	SYS ANA	5178210	None	Method #1	Note #2
00127-10-HHX	FWH	SYS ANA	5178210	Loss of Feedwater	Method #9	Note #1
00127-14-HHX	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Note #1
00128-06-HHX	FWH	SYS ANA	5178212	Loss of Feedwater	Method #1	Note #1
00128-10-HHX	FWH	SYS ANA	5178212	Loss of Feedwater	Method #9 or 10	Notes #0, 1, 4, 15
00128-14-HHX	FWH	SYS ANA	5178213	None	Method #3	Note #2
00129-14-HH	FWH	SYS ANA	5178211	None	Method #3	Note #2
00130-14-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #5	Notes #0, 1
00131-12-HHX	FWH	2%	5178211			
00131-16-HHX	FWH	2%	5178211			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00131-24-HHX	FWH	2%	5178211			
00132-12-HHX	FWH	2%	5178213			
00132-16-HHX	FWH	2%	5178213			
00132-24-HHX	FWH	2%	5178213			
00155-03-EG	FWH	Partial 2%	5178210			
00155-04-EG	FWH	SYS ANA	5178210			Included in FWH-11093-4-EG
00155-06-EG	FWH	2%	5178210			
00155-06-HHX	FWH	2%	5178210			
00155-08-HHX	FWH	2%	5178210			
00156-03-EG	FWH	Partial 2%	5178212			
00156-04-EG	FWH	SYS ANA	5178212			Included in FWH-11100-4-EG
00156-06-EG	FWH	2%	5178212			
00156-06-HHX	FWH	2%	5178212			
00156-08-HHX	FWH	2%	5178212			
00157-08-HHX	FWH	Partial 2%	5178211			
00158-08-HHX	FWH	Partial 2%	5178213			
00181-10-HH	FWH	2%	5178211			
00182-10-HH	FWH	2%	5178213			
00182-12-HH	FWH	2%	5178213			
00183-03-HH	FWH	SYS ANA	5178211	None	Method #3	Note #2
00183-04-HH	FWH	2%	5178211			
00183-06-HH	FWH	2%	5178211			
00184-04-HH	FWH	SYS ANA	5178213	None	Method #3	Note #2
00184-06-HH	FWH	2%	5178213			
00185-03-HH	FWH	SYS ANA	5178211	None	Method #3	Note #2
00185-04-HH	FWH	2%	5178211			
00185-06-HH	FWH	2%	5178211			
00186-03-HH	FWH	SYS ANA	5178213	None	Method #3	Note #2
00186-04-HH	FWH	2%	5178213			
00186-06-HH	FWH	2%	5178213			
00187-04-HH	FWH	SYS ANA	5178211	None	Method #3	Note #2
00187-06-HH	FWH	2%	5178211			
00188-04-HH	FWH	SYS ANA	5178213	None	Method #3	Note #2

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00188-06-HH	FWH	2%	5178213			
00189-02-HH	FWH	SYS ANA	5178211	None	Method #3	Note #2
00190-02-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00191-02-EG	FWH	SYS ANA	5178210	Loss of Feedwater	Method #1	Note #1
00192-02-EG	FWH	SYS ANA	5178212	Loss of Feedwater	Method #1	Notes #1, 4
00193-02-EG	FWH	SYS ANA	5178210	Loss of Feedwater	Method #1	Note #1
00194-1.5-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00194-1.5-HH	FWH	2%	5178212			
00195-1.5-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
00195-1.5-HH	FWH	2%	5178210			
00196-1.5-EG	FWH	SYS ANA	5178212	Loss of Feedwater/Steam Line Break	Method #9	Notes #0, 1, 4
00197-1.5-HH	FWH	2%	5178213			
00198-1.5-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
00199-1.5-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
00200-1.5-EG	FWH	SYS ANA	5178213	None	Method #3	Note #2
00200-1.5-HH	FWH	2%	5178213			
00201-1.5-EG	FWH	SYS ANA	5178211	None	Method #3	Note #2
00201-1.5-HH	FWH	2%	5178211			
00202-1.5-GG	FWH	SYS ANA	5178213	Loss of Feedwater/Steamline Break	Method #5	Notes #1, 4
00203-1.5-EG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #5	Notes #0, 1, 4
00203-1.5-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #5	Note #1
00204-06-HHX	FWH	2%	5178212			
00204-10-HHX	FWH	2%	5178212			
00205-08-HH	FWH	SYS ANA	5178210	None	Method #3	Note #2
00206-06-HH	FWH	SYS ANA	5178212	None	Method #3	Note #2
00206-08-HH	FWH	SYS ANA	5178212	None	Method #3	Note #2
00208-02-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #9 or 10	Notes #1, 4, 15
00209-06-HHX	FWH	2%	5178210			
00209-10-HHX	FWH	2%	5178245			
00212-02-HH	FWH	2%	5178213			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00213-02-HH	FWH	2%	5178211			
00235-02-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Notes #0, 1, Included in FWH 0235-03-GG
00235-03-GG	FWH	SYS ANA	5178211	Loss of Feedwater	Method #9	Notes #0, 1
00236-02-GG	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
00236-03-GG	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
11000-12-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #1	Note #1
11000-12-HHX	FWH	2%	5178213			
11001-12-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
11001-12-HHX	FWH	2%	5178211			
11018-06-HH	FWH	SYS ANA	5178213	Loss of Feedwater	Method #3	Note #1
11018-06-HHX	FWH	SYS ANA	5178213	None	Method #3	Note #2
11019-06-HH	FWH	SYS ANA	5178211	Loss of Feedwater	Method #1	Note #1
11019-06-HHX	FWH	SYS ANA	5178211	None	Method #3	Note #2
11023-03-GG	FWH	SYS ANA	5178211	None	Method #3	Note #2
11023-03-GGX	FWH	SYS ANA	5178211	None	Method #3	Note #2
11023-08-GGX	FWH	SYS ANA	5178211	None	Method #3	Note #2
11024-03-GG	FWH	SYS ANA	5178213	None	Method #3	Note #2
11024-03-GGX	FWH	SYS ANA	5178213	None	Method #3	Note #2
11049-06-HH	FWH	Unresolved	5178210	Loss of Feedwater	Method #5	Notes #1, 0, 14
11049-06-HHX	FWH	2%	5178210			
11052-06-HH	FWH	SYS ANA	5178212	Loss of Feedwater	Method #1	Note #1
11052-06-HHX	FWH	2%	5178212			
11085-04-EG	FWH	SYS ANA	5178210	Loss of Feedwater	Method #9	Note #1
11087-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11088-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11089-04-HH	FWH	2%	5178210			
11090-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11091-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11091-04-EGX	FWH	SYS ANA	5178210	None	Method #3	Note #2
11091-06-EGX	FWH	SYS ANA	5178210	None	Method #3	Note #2
11092-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11092-04-EGX	FWH	SYS ANA	5178212	None	Method #3	Note #2
11093-03-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
11093-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11094-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11095-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11095-04-HHX	FWH	2%	5178210	None	Method #3	Note #2
11096-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11096-04-HHX	FWH	2%	5178212			
11097-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11097-04-EGX	FWH	SYS ANA	5178210	None	Method #3	Note #2
11098-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11098-04-EGX	FWH	SYS ANA	5178212	None	Method #3	Note #2
11099-03-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11099-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
11100-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11101-04-EG	FWH	SYS ANA	5178210	None	Method #9	Note #1
11101-04-HHX	FWH	2%	5178210			
11102-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
11102-04-HHX	FWH	2%	5178212			
11199-1.5-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
12643-04-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
12643-06-EG	FWH	SYS ANA	5178210	None	Method #3	Note #2
12643-06-EGX	FWH	SYS ANA	5178210	None	Method #3	Note #2
12644-1.5-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
12644-1.5-HH	FWH	2%	5178212			
14303-03-EG	FWH	Partial 2%	5178210			
14303-04-EG	FWH	SYS ANA	5178210			Included in FWH 11099-4-EG
14303-06-EG	FWH	2%	5178210			
14303-06-HHX	FWH	2%	5178210			
14304-03-EG	FWH	Partial 2%	5178212			
14304-04-EG	FWH	SYS ANA	5178212	None	Method #3	Note #2
14304-06-EG	FWH	2%	5178212			
14304-06-HHX	FWH	2%	5178212			
00180-16-HH	FWS	2%	5178206			
00317-14-GG	FWS	Unresolved	5178205			Included in CND-317-14-GG

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00317-16-GG	FWS	ISI	5178205			
00318-14-GG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #1	Note #1
00319-12-EG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Notes #1, 4
00319-14-EG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #10	Note #1
00320-12-EG	FWS	SYS ANA	5178205	Loss of Feedwater/ Small Break LOCA	Method #9	Notes #0, 1
00320-14-EG	FWS	SYS ANA	5178205	Loss of Feedwater/ Small Break LOCA	Method #9	Notes #1, 4
00321-12-EG	FWS	Unresolved	5178205	Loss of Feedwater	Method #5	Notes #0, 1, 4, 14
00321-14-EG	FWS	Unresolved	5178205	Loss of Feedwater	Method #1	Notes #1, 4, 14
00322-12-EG	FWS	Unresolved	5178205	Loss of Feedwater/Steam Line Break	Method #5	Notes #0, 1, 4, 14
00322-14-EG	FWS	SYS ANA	5178205	Loss of Feedwater/ Small Break LOCA	Method #1	Notes #1, 4
00323-12-EG	FWS	SYS ANA	5178205	Loss of Feedwater/Steam Line Break	Method #9 or 10	Notes #0, 1, 4, 15
00324-12-EG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Notes #0, 1
00325-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/Steam Line Break	Method #5	Note #1, 14
00325-10-EG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Notes #1, 4
00325-18-EG	FWS	ISI	5178205			
00326-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/Steam Line Break	Method #5	Note #1, 14
00326-10-EG	FWS	SYS ANA	5178206	Loss of Feedwater/Steam Line Break	Method #9	Note #1
00329-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/Steam Line Break	Method #5	Note #1, 14
00329-10-EG	FWS	SYS ANA	5178206	Loss of Feedwater/Steam Line Break	Method #9	Note #1
00339-03-EG	FWS	SYS ANA	5178205	Loss of Feedwater/Steam Line Break	Method #9 or 10	Notes #0, 1, 4, 15
00340-03-EG	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Note #1
00341-02-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Notes #0, 1
00341-1.5-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00342-02-EG	FWS	Unresolved	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9, 14
00342-1.5-EG	FWS	Unresolved	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9, 14, Included in FWS 342-02-EG
00343-02-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Note #1
00343-1.5-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Note #1
00347-02-EGX	FWS	SYS ANA	5178206	None	Methods #3, 4	Note #2
00347-03-EGX	FWS	SYS ANA	5178206	Steam Line Break	Method #3	Note #2
00348-02-HH	FWS	SYS ANA	5178206	None	Method #3	Note #2
00349-02-HH	FWS	SYS ANA	5178157	None	Method #3	Note #2
00350-04-HH	FWS	SYS ANA	5178206	None	Method #3	Note #2
00350-04-KNI	FWS	2%	5178330			
00351-02-EG	FWS	SYS ANA	5178205	None	Method #3	Note #2 (Partial 2%)
00351-04-EGX	FWS	2%	5178205			
00352-02-EG	FWS	SYS ANA	5178205	None	Method #3	Note #2 (Partial 2%)
00352-04-EGX	FWS	2%	5178205			
00374-02-GG	FWS	SYS ANA	5178207	Loss of Feedwater	Method #1	Note #1
00374-03-GG	FWS	SYS ANA	5178207	Loss of Feedwater	Method #1	Note #1
00375-02-GG	FWS	SYS ANA	5178207	Loss of Feedwater/ Steam Line Break	Method #9	Notes #0, 1
00389-06-EGX	FWS	2%	5178200			
00390-06-EGX	FWS	2%	5178205			
00391-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/ Steam Line Break	Method #5	Note #1 (Included in FWS 326-08-EG)
00391-10-EG	FWS	LBB/ISI	5178206			
00392-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/ Steam Line Break	Method #5	Note #1 (Included in FWS 329-08-EG)
00392-10-EG	FWS	LBB/ISI	5178206			
00393-08-EG	FWS	Unresolved	5178206	Loss of Feedwater/ Steam Line Break	Method #5	Note #1 (Included in FWS 325-08-EG)
00393-10-EG	FWS	LBB/ISI	5178206			
00462-3-HH	FWS	2%	5178206			
06004-14-CL	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Note #1
06005-14-CL	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Notes #1, 3, 6
06020-03-BH4	FWS	2%	5178205			
06020-03-CL	FWS	SYS ANA	5178205	Loss of Feedwater	Method #1	Notes #1, 4

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
06020-04-BH4	FWS	2%	5178205			
06021-03-BH4	FWS	2%	5178205			
06021-03-CL	FWS	SYS ANA	5178205	Loss of Feedwater	Method #9	Note #1
10852-03-GG	FWS	SYS ANA	5178207	Loss of Feedwater	Method #1	Note #1, 14
14103-02-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Method #10	Note #1
14104-04-EG	FWS	ISI	5178206			
14108-02-EG	FWS	SYS ANA	5178206	Loss of Feedwater	Method #10	Note #1
14109-04-EG	FWS	ISI	5178206			
14111-02-EG	FWS	SYS ANA	5178206	Loss of Feedwater/Steam Line Break	Method #9	Note #1
14114-04-EG	FWS	ISI	5178206			
14115-02-EG	FWS	SYS ANA	5178206	None	Method #3	Note #2
14115-03-EG	FWS	SYS ANA	5178206	None	Method #3	Note #2
14115-04-EG	FWS	2%	5178206			
02067-02-BH2	LDS	Unresolved	5178130	Small Break LOCA	Method #7	Notes #1, 14
02068-02-BH2	LDS	Unresolved	5178130	Small Break LOCA	Method #7	Notes #1, 14
02071-02-BH2	LDS	Unresolved	5178130	Small Break LOCA	Method #7	Notes #1, 14
02071-02-EG2	LDS	Unresolved	5178130	Small Break LOCA	Method #7	Notes #1, 14
03006-02-EG2	LDS	Unresolved	5178130	Small Break LOCA	Method #9	Notes #0, 1, 14
05008-02-BH2	LDS	Unresolved	5178130	Small Break LOCA	Method #7	Notes #1, 14 Same as RCS-5008-02-BH2
00001-16-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
00001-24-EG	MSS	ISI	5178226			
00002-16-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
00002-24-EG	MSS	ISI	5178226			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00003-20-EG	MSS	LBB	5178225			
00004-20-EG	MSS	LBB	5178225			
00005-20-EG	MSS	LBB	5178225			
00006-24-EG	MSS	LBB	5178225			
00007-24-EG	MSS	LBB	5178225			
00008-02-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #9	Notes #0, 1, 4
00008-04-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #9	Notes #0,1,4 (included in MSS-8-2"-EG)
00009-03-EG	MSS	SYS ANA	5178226	Loss of Feedwater/Steam Line Break	Method #5	Note #1
00010-1.5-EG	MSS	SYS ANA	5178226	None	Method #2	Note #1
00013-12-EGX	MSS	2%	5178226			
00014-20-EG	MSS	ISI	5178226			
00015-04-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
00015-06-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
00015-06-EGX	MSS	2%	5178226			
00015-08-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
00015-10-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Notes #0, 1
00017-06-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #9	Note #1
00017-08-EG	MSS	Unresolved	5178226	Steam Line Break	Method #5	Notes #1, 14
00018-06-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #9	Notes #0, 1
00018-10-EG	MSS	ISI	5178226			
00019-06-EG	MSS	SYS ANA	5178226	Steam Line Break/Loss of Feedwater	Method #9	Note #1
00020-06-EG	MSS	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
00020-08-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Notes #0, 1
00050-24-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #5	Note #1
00051-24-EG	MSS	ISI	5178225			
00052-10-HH	MSS	2%	5178225			
00052-14-HH	MSS	2%	5178225			
00053-10-HH	MSS	2%	5178225			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00053-14-HH	MSS	2%	5178225			
00054-10-HH	MSS	2%	5178225			
00054-14-HH	MSS	2%	5178225			
00055-10-HH	MSS	2%	5178225			
00055-14-HH	MSS	2%	5178225			
00056-10-HH	MSS	2%	5178225			
00056-14-HH	MSS	2%	5178225			
00057-10-HH	MSS	2%	5178225			
00057-14-HH	MSS	2%	5178225			
00058-10-HH	MSS	2%	5178225			
00058-14-HH	MSS	2%	5178225			
00059-10-HH	MSS	2%	5178225			
00059-14-HH	MSS	2%	5178225			
00060-10-HH	MSS	2%	5178225			
00060-14-HH	MSS	2%	5178225			
00061-10-HH	MSS	2%	5178225			
00061-14-HH	MSS	2%	5178225			
00062-04-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #6	Note #1
00062-06-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #6	Note #1
00062-10-HH	MSS	2%	5178225			
00063-04-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #5	Note #1
00063-06-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #5	Note #1
00063-10-HH	MSS	2%	5178225			
00064-04-EG	MSS	Unresolved	5178225	Steam Line Break	Method #6	Notes #1, 4, 14 Included in MSS 64-06-EG
00064-06-EG	MSS	Unresolved	5178225	Steam Line Break	Method #6	Notes #1, 4, 14
00064-10-HH	MSS	2%	5178225			
00065-04-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #8	Note #1 Included in MSS 65-06-EG
00065-06-EG	MSS	SYS ANA	5178225	Steam Line Break	Method #8	Note #1
00065-10-HH	MSS	2%	5178225			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00069-03-EG	MSS	SYS ANA	5178221	Steam Line Break	Method #10	Notes #0, 1, 4
00341-02-EG	MSS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Notes #0, 1
00341-1.5-EG	MSS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9
00342-02-EG	MSS	Unresolved	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9, 14 included in FWS 342-02-EG
00342-1.5-EG	MSS	Unresolved	5178206	Loss of Feedwater	Methods #1, 2	Notes #1, 9, 14 included in FWS-1.5-EG
00343-02-EG	MSS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Note #1
00343-1.5-EG	MSS	SYS ANA	5178206	Loss of Feedwater	Methods #1, 2	Note #1
01300-04-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
01301-04-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
01312-08-HH	MSS	SYS ANA	5178226	Steam Line Break	Method #5	Note #1
01313-12-HH	MSS	2%	5178213			
01314-02-EG	MSS	2%	5178226			
01315-02-EG	MSS	2%	5178226			
01316-03-HH	MSS	SYS ANA	5178226	Loss of Feedwater/Steam Line Break	Method #5	Note #1
01316-06-HH	MSS	SYS ANA	5178226	Steam line Break	Method #5	Notes #0, 1
01316-08-HH	MSS	Unresolved	5178226	Steam line Break	Method #5	Notes #0, 1, 6, 14
01317-03-HH	MSS	Unresolved	5178226	Steam line Break	Method #6	Notes #1, 14
01319-10-HH	MSS	2%	5178226			
01319-12-HH	MSS	2%	5178226			
08594-1.5-EG	MSS	SYS ANA	5178226	None	Method #3	Note #2
08599-04-EGX	MSS	2%	5178226			
08599-06-EGX	MSS	2%	5178226			
08599-08-EGX	MSS	2%	5178226			
08603-1.5-EG	MSS	SYS ANA	5178226	None	Method #2	Note #1
10521-02-EG	MSS	SYS ANA	5178226	Steam Line Break	Method #1	Notes #0, 2
10521-02-HH	MSS	SYS ANA	5178226	Steam Line Break	Method #1	Notes #0, 2
12591-02-HH	MSS	SYS ANA	5178226	Steam line Break	Method #1	Notes #0, 2
13388-16-EG	MSS	SYS ANA	5178226	Steam line Break	Method #5	Note #1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
13390-16-EG	MSS	SYS ANA	5178226	Steam line Break	Method #5	Note #1
13399-06-HH	MSS	SYS ANA	5178226	Steam line Break	Method #1	Note #1
13400-06-HH	MSS	SYS ANA	5178226	Steam line Break	Method #1	Note #1
13403-06-HH	MSS	SYS ANA	5178226	Steam line Break	Method #1	Note #1
05011-03-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14 included in RCS 5011-03-BH2
05011-04-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14
05025-03-BH2	PZR	SYS ANA	5178105	Small Break LOCA	Method #7	Note #1
05027-03-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14
05028-06-EG3	PZR	2%	5178105			
05030-03-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14
05031-06-EG3	PZR	2%	5178105			
05034-02-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14
05034-02-EG2	PZR	2%	5178105			
05034-02-EG3	PZR	2%	5178105			
05034-03-BH2	PZR	SYS ANA	5178105	Small Break LOCA	Method #7	Note #1
05034-04-EG3	PZR	2%	5178105			
05035-02-BH2	PZR	Unresolved	5178105	Small Break LOCA	Method #7	Notes #1, 14
05035-02-EG2	PZR	2%	5178105			
05035-02-EG3	PZR	2%	5178105			
05035-04-EG3	PZR	2%	5178105			
05035-10-EG2	PZR	2%	5178105			
05035-10-EG3	PZR	2%	5178105			
08315-03-EG2	PZR	2%	5178105			
02005-02-BH2	RCP	SYS ANA	5178110	Small Break LOCA	Method #7	Note #2
02005-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #2	Notes #0, 2
02005-2.5-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #1	Note #2
02005-04-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #5	Note #2
02006-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02008-02-BH2	RCP	SYS ANA	5178110	Small Break LOCA	Method #7	Note #2
02008-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #1	Notes #2, 10

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
02009-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02011-02-BH2	RCP	SYS ANA	5178110	Small Break LOCA	Method #2	Note #2
02011-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #2	Notes #0, 2
02012-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02014-02-BH2	RCP	SYS ANA	5178111	Small Break LOCA	Method #2	Note #1
02018-02-BH2	RCP	SYS ANA	5178111	Small Break LOCA	Method #2	Note #1
02020-02-BH2	RCP	SYS ANA	5178111	Small Break LOCA	Method #1	Note #1
02090-02-BH2	RCP	SYS ANA	5178115	Small Break LOCA	Method #2	Note #1
02090-02-BH3	RCP	SYS ANA	5178115	Loss of RCP Transient	Method #2	Note #1
02091-02-BH2	RCP	SYS ANA	5178115	Small Break LOCA	Method #6	Note #1
02091-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #7	Note #2
02092-02-BH2	RCP	SYS ANA	5178115	Small Break LOCA	Method #2	Note #1
02092-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #2	Note #2
02105-02-BH3	RCP	SYS ANA	5178110	None	Method #3	Notes #2, 11
02105-03-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02105-04-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02106-04-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02108-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Notes 2, 11
02108-03-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Notes #2, 11
02109-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02109-03-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02109-04-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02110-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02110-03-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #3	Note #2
02121-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #4	Notes #0, 2
02122-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient	Method #4	Notes #0, 2
02123-02-BH3	RCP	SYS ANA	5178110	Loss of RCP Transient/ Small Break LOCA	Method #7	Note #2
05000-1.5-DG	RCS	2%	5178100			
05001-27.5-BH2	RCS	LBB	5178100			
05002-08-BH2	RCS	LBB	5178100			
05003-02-BH2	RCS	SYS ANA	5178100	Small Break LOCA	Method #7	Note #1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
05003-02-HP	RCS	2%	5178100			
05005-29-BH2	RCS	LBB	5178100			
05006-27.5-BH2	RCS	LBB	5178100			
05007-27.5-BH2	RCS	LBB	5178100			
05008-02-BH2	RCS	Unresolved	5178200	Small Break LOCA	Method #7	Notes #1, 14
05009-29-BH2	RCS	LBB	5178200			
05010-27.5-BH2	RCS	LBB	5178200			
05011-03-BH2	RCS	Unresolved	5178110	Small Break LOCA	Method #7	Notes #1, 14
05012-27.5-BH2	RCS	LBB	5178110			
05013-10-BH2	RCS	LBB	5178110			
05015-29-BH2	RCS	LBB	5178110			
05016-02-BH2	RCS	SYS ANA	5178100	Small Break LOCA	Method #7	Note #1
05016-02-HP	RCS	2%	5178100			
05017-27.5-BH2	RCS	LBB	5178100			
05019-02-HK	RCS	2%	5178100			Note #12
05025-03-BH2	RCS	SYS ANA	5178100	Small Break LOCA	Method #7	Note #1
05037-02-BH2	RCS	Unresolved	5178100	Small Break LOCA	Method #7	Notes #1, 14
05037-02-HP	RCS	2%	5178100			
03000-06-EG2	RHR	Unresolved	5178130	LOCA	Method #6	Notes #2, 14
03001-06-BH2	RHR	Unresolved	5178100	LOCA	Method #7	Notes #2, 14
03001-06-EG2	RHR	Unresolved	5178130	Small Break LOCA	Method #6	Notes #0, 2, 14
03003-04-EG2	RHR	Unresolved	5178130	Small Break LOCA	Method #6	Notes #0, 2, 14
03004-04-HK	RHR	2%	5178130			
03004-2.5-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2	Notes #0, 2
03015-06-EG2	RHR	Unresolved	5178130	Small Break LOCA	Method #2	Notes #0, 2, 14
03016-06-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2	Notes #0, 2
03019-02-EG2	RHR	Unresolved	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2, 14
03019-06-EG2	RHR	Unresolved	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2, 14
05002-06-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2	Notes #0, 2
05002-08-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
05038-06-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2
05038-08-EG2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2
05056-02-S2	RHR	SYS ANA	5178130	Small Break LOCA	Method #2 or 7	Notes #0, 2
00349-02-HH	RLC	2%	5178157			
07037-02-HP2	RLC	2%	5178158			
07076-2-HP2	RLC	2%	5178158			
07170-03-HP2	RLC	2%	5178156			
07027-02-HH6	RWL	2%	5178165			
07028-02-HH6	RWL	2%	5178166			
07039-03-HH6	RWL	2%	5178166			
07177-02-HP2	RWL	2%	5178156			
01104-1.5-HH5	SCF	2%	5178270			
01100-1.5-HH5	SCF	2%	5178210			
06004-03-CL	SIS	SYS ANA	5178115	Loss of Feedwater	Method #9	Note #1 (Included in SIS-6004-14-CL)
06004-14-CL	SIS	SYS ANA	5178115	Loss of Feedwater	Method #9	Note #1 (Included in FWS-6004-14-CL) (Partial 2%)
06005-03-CL	SIS	SYS ANA	5178115	Loss of Feedwater	Method #9	Notes #1,3,6 (Included in SIS-6005-14-CL)
06005-14-CL	SIS	SYS ANA	5178115	Loss of Feedwater	Method #9	Notes #1,3,6 (Included in FWS-6005-14-CL) (Partial 2%)
06006-06-BH2	SIS	SYS ANA	5178100	LOCA	Method #7	Note #1
06006-06-CL	SIS	2%	5178115			
06007-06-BH2	SIS	SYS ANA	5178100	LOCA	Method #7	Note #1
06007-06-CL	SIS	2%	5178115			
06008-06-BH2	SIS	SYS ANA	5178100	LOCA	Method #7	Note #1
06008-06-CL	SIS	2%	5178115			
06009-02-CL	SIS	2%	5178115			
06010-02-CL	SIS	2%	5178115			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
06011-02-CL	SIS	2%	5178115			
06011-02-HK	SIS	2%	5178115			
06012-02-CL	SIS	2%	5178115			
06012-02-HK	SIS	2%	5178115			
06028-02-CL	SIS	2%	5178115			
01302-1.5-EGX	TBN	SYS ANA	5178240	Loss of Feedwater	Method #9	Notes #0, 1
01303-1.5-EGX	TBN	SYS ANA	5178240	Loss of Feedwater	Method #9	Notes #0, 1
01304-1.5-EGX	TBN	SYS ANA	5178240	Loss of Feedwater	Method #9	Notes #0, 1
01305-1.5-EGX	TBN	SYS ANA	5178240	Loss of Feedwater	Method #9	Notes #0, 1
01307-04-HH	TBN	SYS ANA	5178240	None	Method #3	Note #2
01308-04-HH	TBN	SYS ANA	5178240	Loss of RCP Transient	Method #1	Notes #0, 1
01311-1.5-EGX	TBN	SYS ANA	5178240	Loss of Feedwater	Method #9	Notes #0, 1
01316-06-HH	TBN	SYS ANA	5178226	Loss of RCP Transient	Method #5	Notes #0, 1
01318-04-HH	TBN	SYS ANA	5178240	None	Method #3	Note #2
01318-08-HH	TBN	SYS ANA	5178251	None	Method #3	Note #2
01323-04-HH	TBN	SYS ANA	5178240	None	Method #3	Note #2
01323-08-HH	TBN	SYS ANA	5178251	Loss of Load Transient	Method #1	Notes #0, 1, 13
11416-1.25-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
11417-1.25-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
11421-1.5-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13382-16-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13383-16-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13386-16-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13387-16-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13392-1.5-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13393-1.5-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13394-03-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13394-1.25-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13394-1.5-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13395-04-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13 (Partial 2%)
13396-04-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13 (Partial 2%)

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
13397-1.25-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13 (Partial 2%)
13397-1.5-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13397-03-EG	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13398-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #0, 1, 13
13399-06-HH	TBN	SYS ANA	5178240	Steam Line Break	Method #1	Notes #1, 13
13400-06-HH	TBN	SYS ANA	5178240	Steam Line Break	Method #5	Notes #1, 13
13401-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #0, 1, 13
13402-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #0, 1, 13
13403-06-HH	TBN	SYS ANA	5178240	Steam Line Break	Method #5	Notes #1, 13
13404-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #0, 1, 13
13427-02-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13428-04-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13429-2.5-HH	TBN	SYS ANA	5178240	None	Method #3	Notes #2
13431-04-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13434-02-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13435-2.5-HH	TBN	SYS ANA	5178240	None	Method #3	Note #2
13445-1.25-EG	TBN	SYS ANA	5178240	None	Method #3	Note #2
13446-1.25-EG	TBN	SYS ANA	5178240	None	Method #3	Note #2
13447-1.25-EG	TBN	SYS ANA	5178240	None	Method #3	Note #2
13448-04-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13448-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13449-04-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
13449-06-HH	TBN	SYS ANA	5178240	Loss of Load Transient	Method #1	Notes #1, 13
00012-10-GG	THP	SYS ANA	5178240	Steam Line Break	Method #9 or 10	Notes #0, 1, 15
00016-16-HH	THP	SYS ANA	5178240	Steam Line Break	Method #9	Notes #0, 1
00017-06-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of Feed Water	Method #9	Notes #0, 1
00018-06-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
00019-06-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
00020-06-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
00021-10-GG	THP	Unresolved	5178230	Steam Line Break	Method #5	Notes #0, 1, 4, 14
00022-10-GG	THP	SYS ANA	5178213	Steam Line Break/ Loss of Feed Water	Method #10	Notes #0, 1, 4
00023-16-GG	THP	SYS ANA	5178211	Steam Line Break	Method #9	Notes #1, 0
00023-16-HH	THP	Unresolved	5178211	Steam Line Break/ Small Break LOCA	Method #5	Notes #0, 1, 4, 14
00024-16-GG	THP	SYS ANA	5178213	Loss of Feed Water/ Steam Line Break	Method #9	Note #1
00024-16-HH	THP	Unresolved	5178213	Loss of Feed Water/ Steam Line Break/ Small Break LOCA	Method #5	Notes #1, 4, 14
00078-04-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
00079-04-EG	THP	SYS ANA	5178231	Loss of Feedwater/ Steam Line Break	Method #9	Notes #0, 1
00945-18-EG	THP	SYS ANA	5178231	Steam Line Break	Method #1	Note #1
08824-36-EG	THP	SYS ANA	5178231	Loss of Feed Water	Method #1	Notes #0, 1
08825-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08825-22-HH	THP	2%	5178232			
08826-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08826-22-HH	THP	2%	5178232			
08827-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08827-22-HH	THP	2%	5178232			
08828-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08828-22-HH	THP	2%	5178232			
08829-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08829-22-HH	THP	2%	5178232			
08830-02-HH	THP	2%	5178232			
08836-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08836-22-HH	THP	2%	5178232			
08837-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08837-22-HH	THP	2%	5178232			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
08838-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08838-22-HH	THP	2%	5178232			
08839-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08839-22-HH	THP	2%	5178232			
08840-18-EG	THP	SYS ANA	5178232	None	Method #3	Notes #0, 2
08840-22-HH	THP	2%	5178232			
08841-02-HH	THP	2%	5178232			
08847-36-EG	THP	SYS ANA	5178231	None	Method #3	Notes #0, 2
08849-24-EG	THP	Unresolved	5178231	Steam Line Break/ Loss of Feed Water	Method #5	Notes #1, 14
09092-24-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of Feed Water	Method #9	Note #1
09093-24-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of Feed Water	Method #9	Note #1
09094-24-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of Feed Water	Method #9	Notes #0, 1
09095-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
09096-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Note #1
09097-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Note #1
09098-24-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of Feed Water	Method #9	Note #1
09099-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Note #1
09100-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Note #1
09101-24-EG	THP	SYS ANA	5178231	Steam Line Break	Method #5	Note #1
09102-30-EG	THP	SYS ANA	5178231	Steam Line Break	Method #5	Note #1, Included in THP 9102-42-EG
09102-36-EG	THP	Unresolved	5178231	Steam Line Break/ Loss of Feed Water	Method #6	Notes #0, 1, 5, 14
09102-42-EG	THP	SYS ANA	5178231	Steam Line Break	Method #5	Note #1
09102-54-EG	THP	SYS ANA	5178235	None	Method #1	Notes #0, 1
09103-36-EG	THP	SYS ANA	5178231	Steam Line Break/ Loss of RCP Transient	Method #9	Notes #0, 1

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
09103-42-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1
09104-30-EG	THP	SYS ANA	517231	Steam Line Break/ Loss of Feedwater	Method #1	Notes #0, 1
09104-36-EG	THP	SYS ANA	517231	Steam Line Break/ Loss of Feed Water	Method #9	Note #1
09104-42-EG	THP	SYS ANA	517231	Steam Line Break	Method #5	Note #1
09104-54-EG	THP	SYS ANA	517235	None	Method #1	Notes #0, 1
09105-36-EG	THP	SYS ANA	517231	Steam Line Break	Method #5	Note #1
09106-24-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1, 6
09107-18-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1
09108-18-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1
09109-18-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1
09110-18-EG	THP	SYS ANA	517231	Steam Line Break	Method #1	Notes #0, 1
09111-02-EG	THP	SYS ANA	517231	None	Method #3	Note #2
09112-02-EG	THP	SYS ANA	517231	None	Method #3	Note #2
09113-18-EG	THP	Unresolved	5178231	Steam Line Break	Method #1	Notes #0, 1
09114-18-EG	THP	SYS ANA	5178231	Steam Line Break	Method #1	Notes #0, 1
09116-18-EG	THP	SYS ANA	5178231	Steam Line Break	Method #1	Note #1
09117-02-EG	THP	SYS ANA	5178231	Steam Line Break	Method #3	Note #2
09118-02-EG	THP	SYS ANA	5178231	None	Method #3	Note #2
09119-28-GG	THP	SYS ANA	5178230	Steam Line Break	Method #9	Notes #0, 1
09120-28-GG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Notes #0, 1
09123-03-GG	THP	SYS ANA	5178231	None	Method #3	Note #2
09123-2.5-GG	THP	SYS ANA	5178231	None	Method #3	Note #2
09123-28-GG	THP	SYS ANA	5178231	Steam Line Break	Method #9	Note #1
09124-28-GG	THP	SYS ANA	5178230	Steam Line Break	Method #9	Note #1
09140-1.5-HH	THP	2%	5178232			
09141-1.5-HH	THP	2%	5178232			
12195-1.5-HH	THP	2%	5178232			
12196-1.5-HH	THP	2%	5178232			
12197-1.5-HH	THP	2%	5178232			

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
12203-1.5-HH	THP	2%	5178232			
12204-1.5-HH	THP	2%	5178232			
12205-1.5-HH	THP	2%	5178232			
12206-1.5-HH	THP	2%	5178232			
12207-1.5-HH	THP	2%	5178232			
00025-18-HH	TLP	SYS ANA	5178235	Loss of Feed Water	Method #9 or 10	Notes #0, 1, 4, 15
00026-18-HH	TLP	SYS ANA	5178235	Loss of Feed Water	Method #9 or 10	Notes #0, 1, 4, 15
00027-20-HH	TLP	2%	5178235			
00028-20-HH	TLP	2%	5178235			
00029-20-HH	TLP	2%	5178235			
00030-20-HH	TLP	2%	5178235			
00039-16-HH	TLP	2%	5178235			
00040-16-HH	TLP	2%	5178235			
00043-16-HH	TLP	2%	5178235			
00044-16-HH	TLP	2%	5178235			
00213-02-HH	TLP	2%	5178235			
08500-16-HH	TLP	2%	5178235			
08508-16-HH	TLP	2%	5178235			
08509-16-HH	TLP	2%	5178235			
02002-02-BH2	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02002-02-BH3	VCC	Unresolved	5178135	Loss of RCP Transient	Method #7	Notes #2, 10, 14
02002-03-BH2	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02002-03-BH3	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02003-02-BH2	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02003-02-BH3	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02003-03-BH2	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02004-03-BH2	VCC	SYS ANA	5178135	None	Method #3	Notes #0, 2, 10
02005-02-BH2	VCC	SYS ANA	5178135	None	Method #7	Note #2
02005-02-BH3	VCC	SYS ANA	5178110	None	Method #3	Notes #0, 2, 10
02005-04-BH3	VCC	SYS ANA	5178110	None	Method #3	Notes #0, 2, 10
02005-2.5-BH3	VCC	SYS ANA	5178110	Loss of RCP Transient	Method #1	Note #2

Appendix A
HELB Resolution Summary

LINE NO.	SYSTEM	RESOLUTION METHOD	REFERENCE DRAWING	RESULTING TRANSIENT	SHUTDOWN METHOD	REMARKS
02010-02-HN1	VCC	2%	5178135			
02031-02-BH3	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02033-02-BH3	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02033-02-HK	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
02080-02-BH2	VCC	SYS ANA	5178105	Small Break LOCA	Method #5	Note #1
02080-04-BH2	VCC	SYS ANA	5178135	Small Break LOCA	Method #5	Note #1
02081-02-BH2	VCC	Unresolved	5178100	Small Break LOCA	Method #5	Notes #1, 14
02093-1.5-HK	VCC	SYS ANA	5178315	None	Method #3	Notes #2, 10
02094-1.5-HK	VCC	SYS ANA	5178135	None	Method #3	Notes #2, 10
08936-1.25-BH2	VCC	2%	5178135			
08941-1.25-BH2	VCC	2%	51781356			

LEGEND:

SHUTDOWN METHOD:

Method # 1 - Auxiliary feed to steam generators, residual heat removal for long term heat removal
Method # 2 - Auxiliary feed to steam generators, single phase cooldown for long term heat removal
Method # 3 - Main feed and condensate to steam generators, residual heat removal for long term heat removal
Method # 4 - Main feed and condensate to steam generators, single phase cooldown for long term heat removal
Method # 5 - Safety injection together with auxiliary feed to steam generators, residual heat removal for long term heat removal
Method # 6 - Safety injection together with auxiliary feed to steam generators, single phase cooldown for long term heat removal
Method # 7 - Safety injection together with recirculation pumps and charging for long term heat removal
Method # 8 - Safety injection for RCS inventory until break isolation, then main feed and condensate to steam generators and residual heat removal for long term heat removal
Method # 9 - Charging for RCS inventory makeup, auxiliary feed to steam generators, then single phase cooldown
Method #10 - Charging for RCS inventory makeup. Open PORV for RCS pressure relief and to establish primary heat sink flow path to containment sump. Water from containment sump via Recirculation Pump and Recirculation HX to Charging Pump suction to complete primary heat removal path.

REMARKS:

Note # 0 - Initial break or subsequent interaction target isolated
Note # 1 - Reactor trip/turbine trip occurs
Note # 2 - No reactor trip and no turbine trip occurs
Note # 3 - Loss of both diesel generator backed buses occurs
Note # 4 - Dedicated shutdown diesel generator and auxiliary feedwater pump G-10W used
Note # 5 - Dedicated shutdown diesel generator and pressurizer heater group D used
Note # 6 - Dedicated shutdown diesel generator and all loads used
Note # 7 - This line is being modified. HELB concerns will be addressed in the auxiliary feedwater modification design change package (DCP) to be implemented during the cycle 10 outage
Note # 8 - A reactor trip but no turbine trip since turbine not on line in mode 2
Note # 9 - Lose all RCS pressure transmitters
Note #10- Lose charging pump for RCS inventory control, use will be made of the safety injection system for RCS inventory control
Note #11- This line is located inside the RCP seal filter vault and is unaccessible. If ruptured it would only affect that seal filter
Note #12- This is the reactor vessel seal ring leakage measurement gage glass standpipe. It will not fail
Note #13- Turbine Trip on high vibration followed by an ATWS trip of the reactor
Note #14- Shutdown method is contingent upon target qualification or alternate resolution.
Note #15- Shutdown method depends upon choice of Single Active Failure component.

APPENDIX B

HIGH ENERGY LINE BOUNDARY DRAWINGS

(TAKEN FROM REFERENCE 32)

NOTE: The color drawings are available for review by calling G. E. Hammond at PAX 22978.

DRAWING LEGEND

EXCLUSION CRITERIA: ORANGE (ALSO RED)

SYSTEM INTERACTION/TARGET QUALIFICATION: YELLOW

LEAK-BEFORE-BREAK: BLUE

AUGMENTED ISI PROGRAM: GREEN

D.1 SUPERPIPE

SUPERPIPE is a comprehensive computer code for the structural analysis and design checking of piping systems. In addition to a wide array of static analysis options, SUPERPIPE performs dynamic response spectral analyses, force time history and acceleration time history analysis.

For response spectral analyses, a 'missing mass' correction is available to account for dynamic effects represented by higher modes not computed in the eigensolution. In addition to the traditional in-phase, single-level analysis method using eveloped spectra, SUPERPIPE uses a multilevel response spectral analysis technique to analyze piping subjected to dynamic excitations which vary significantly between different anchor/support locations. For appropriate applications, the multilevel method can provide reduced analysis conservatism.

SUPERPIPE can also perform the dynamic, multilevel excitation option as a time history modal superposition analysis, with seismic loading represented by an acceleration time history record. Force time history analysis options are available with SUPERPIPE using the modal superposition methodology as well as the direct integration method.

A comprehensive series of design checking options are available for Class 1 and Class 2 stress checking, Class 2 break locations, and support load summaries.

SUPERPIPE was benchmarked by comparison with results published by the NRC in NUREG/CR-1677 for seven sample problems. The comparison was performed in accordance with the NRC request for additional verification of computer codes used for analysis of nuclear piping systems. The verification specifically addressed the response spectrum method of dynamic analysis commonly used in seismic qualification of nuclear piping.

The program has also been thoroughly tested and verified for a comprehensive set of sample problems, including extensive comparison with several publicly available programs and ASME benchmark problems. All verification analyses have been documented in accordance with established Impell Quality Assurance procedures. SUPERPIPE is widely used and has been audited by many clients. SUPERPIPE was previously used in SEP for the RTS seismic reevaluation of SONGS-1.

D.2 CRACK

CRACK is a computer code that performs fracture mechanics calculations for leak-before-break analyses. The code calculates the stress intensity factor and the opening area of cracks in piping.

The cracks considered are through-wall and may be oriented axially or circumferentially. The input required is the pipe section geometry, crack size, and loads. The loads used for circumferential cracks are axial load, internal pressure, and bending moment. For longitudinal cracks, only internal pressure is required.

Linear elastic fracture mechanics formulations are used. Since material near the crack tip yields, a plastic-zone correction to the effective crack length is included. An interative calculation scheme is used to ensure a stable solution. The code is based on the methodology of Tada and Paris, Reference 18, and has been verified in accordance with Impell Quality Assurance procedures.

The stress intensity factor calculated by CRACK is used to determine local stability of the flawed piping. The opening area of the crack is used, along with other data on the piping system, by the program IMLEAK to calculate fluid flow through the crack.

D.3 IMLEAK

IMLEAK is a computer code developed to evaluate the leak rate of pressurized fluids through narrow cracks. The code is used in leak-before-break analyses to estimate leak rates from postulated cracks to determine whether the crack is detectable. The program is based on References 19 and 20 and has been verified against experimental data. The program has been verified in accordance with Impell Quality Assurance procedures.

The analytical model in IMLEAK is a modified version of Henry's non-equilibrium two-phase flow model. The model accounts for non-equilibrium effects in the flow due to flashing within the flow path. The model also includes pressure drops due to entrance losses, friction, and fluid acceleration.

The model handles complex crack geometry, including turns in the flow path, variable flow area, and crack surface roughness. The program also contains its own steam properties subroutines.

D.4 CABLE

Impell Corporation's CABLE program is a microcomputer-based system designed to assist in gathering and correlating data concerning safe shutdown components and their circuits. CABLE performs the following major functions:

- Maintains a list of all circuits, reported by schedule or combined into one report.
- Maintains a report of safe shutdown components and their required systems and circuits.
- Maintains lists of enclosures (vias, conduits, raceways, etc.) and the plant areas (fire area(s)/zone(s)) in which they are located.
- Cross-references, sorts, and issues reports from these databases, sorting on various fields, including the routing of safe shutdown circuits by plant areas (fire area/zone).

The program is entirely menu driven and error trapped to reduce possible operator errors. For example, if a circuit that has been entered to the components database contains a typographical error, the reports will identify these errors.

Sixteen reports are available from CABLE. The first ten are "input" reports that sort and print out the typed-in data. The last six are "output" reports that are issued after a maintenance program has been run to cross-reference the databases and sort the information on various criteria.

The CABLE program has been fully verified in accordance with Impell Corporation's Quality Assurance procedures.

APPENDIX D

COMPUTER PROGRAMS

TABLE C-1

LEAK BEFORE BREAK RESULTS

Line Number	Break[1] Location	Leak Rate Under Normal Operating Conditions (Size/gpm)	Crack Stability Under Normal & 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	1,1W	7t/1.13	7t/51.3	168.4	3.67
	22,22W	6t/1.09	6t/40.2	168.4	4.33
FWS-392-10	Term. ends.	7.5t/0.95	7.5t/75.8	168.4	2.55
FWS-393-10	1,1W	7t/0.93	7t/62.4	168.4	2.99
	23,23W	6t/1.44	6t/47.2	168.4	3.56
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) Break locations refer to piping stress analysis nodes as noted in Reference 31.

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 PWRs and review of analysis of circumferential cracks, it was determined that the LBB scenario is applicable to the piping considered in this evaluation.

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.

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

Leak-Before-Break Numerical Results

Leak-before-break (LBB) evaluations were performed for three feedwater lines, five main steam lines, and two reactor coolant system lines. Table C-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 2t was evaluated.

The 1 gpm criteria is met for all lines except MSS-3-20. The support configuration of the main steam piping near the MSS-3-20 branch connection accounts for the different results for the three 20-inch diameter MSS lines.

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 4t 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.

APPENDIX C

LEAK-BEFORE-BREAK NUMERICAL RESULTS