FEASIBILITY OF THE LEAK-BEFORE-BREAK (LBB) APPLICATION TO THE ULCHIN 3 AND 4 PRESSURIZER SURGE LINE

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ABSTRACT

This report describes the application method, the analysis process and the results of the leak-before-break (LBB) concept for the Ulchin (UCN) 3 and 4 pressurizer surge line. The LBB analysis for the pressurizer surge line was performed for the portion of the line that has a large stress value as obtained from the static and dynamic analyses of the piping system. The hypothetical crack size was determined with the loads that are exhibited during a normal plant operational condition. The detection capability of the leak detection devices that are installed in the containment was assumed to be 1.0 gpm. The LBB analysis of the surge line was performed based on the requirements of NUREG-1061, Volume 3, and Standard Review Plan (SRP) 3.6.3. The result of the analysis showed that the LBB application satisfied all the requirements of the codes and regulations.

INTRODUCTION

The Combustion Engineering (CE) nuclear plants that were designed before 1983 adopted a double-edged-guillotine-break (DEGB) concept for a hypothetical pipe break situation in the primary coolant and the connected piping systems in accordance to the General Design Criteria (GDC)-4 which was then the U. S. licensing requirement. In the early 1980's, a study in Lawrence Livermore National Laboratory (LLNL), that was funded by the U. S. NRC and the industry, revealed that a possibility of a DEGB is very low, and as a result of this, in July 1986 NRC approved the application of LBB concept for all the high energy pipes in pressure water reactors (PWRs). Accordingly, for the first time in Korea in 1989, Yong Gwang (YGN) 3 and 4 nuclear plant in Korea adopted LBB concept for the pipes in the reactor coolant system (RCS) and the pressurizer surge line, standby cooling system (SCS) and safety injection system (SIS). In this report, the study procedure, the evaluation method and the analysis result of the LBB application to the pressurizer surge line of the Ulchin (UCN) 3 and 4 units, that were constructed after YGN 3 and 4 plant, are discussed.

PRESSURIZER SURGE LINE

The UCN 3 and 4 pressurizer surge line is a 12-inch, Schedule 160 pipe of SA-312 TP 347 material (see Figure 1). The pipe connections are shop and field welded using Gas-Tungsten-Arc-Welding (GTAW) technique. The safe-ends of the surge line were shop welded to the RCS hot leg and the pressurizer surge line using Inconel GTAW method.

REVIEW OF THE TECHNICAL FEASIBILITY

1. Evaluation Diagram

See Figure 2.

2. Major Parameters of LBB

2.1 Loads

- Normal operational load
  - 100% power operational load
  - Static mass + Operational load + 100% power linear thermal expansion + 32 thermal stratification dynamic load
- Thermal stratification dynamic load: According to the operational conditions of the plant, the thermal stratification can be classified as follows:
  - The temperature differential between the top and bottom of the pipe is 32 (during the normal operation).
  - The temperature differential between the top and bottom of the pipe at the high temperature is 320 (653 ~ 333).
  - The temperature differential between the top and bottom of the pipe at the low temperature is 320 (440 ~ 120).
- Safe Shutdown Earthquake (SSE): Specific parameters arisen as the result of the damping changes based on ASME Code Case N-411 are used.

2.2 Load Combinations

The loads during a normal operation (operational load, static load, and load due to linear thermal expansion) and those that have a temperature differential of 320 between the top and bottom of the pipe at the high temperature, are combined algebraically, which absolute value is then combined with the absolute value of the SSE load to be used for evaluation of the final safety evaluation.

2.3 Location of the Maximum Load

Analysis of the load affecting the pressurizer surge line was performed using SUPERPIPE code that is designed for analyzing a pipe load. The result shows that the limiting cases were found out to be the connections between the RCS pipe nozzle and the surge line (1F), and the connection between the surge lines (14S). The maximum loads for each point are summarized in Table 1.

Table 1

Weld Material	Location (see Figure 1)	Normal Operation (K-inch)	DW+SF+SSE (K-inch)
GTAW (Shop)	14S	680	2,162
Safe End Weld	1F	520	2,559

2.4 Leak Detection Capability (LDC)

One of the major parameters that are necessary for the LBB analysis is the leakage amount in the containment that can be detected. This value was multiplied ten times to be used for the LBB analysis as defined in NUREG-1061, Volume 3, and SRP 3.6.3.

2.5 Detectable Leaking Crack Length (DLC)

Once the LDC is determined, the DLC can be also obtained. The DLC is calculated with Pipe Crack Evaluation Program (PICEP) code by using a finite element model of the pipe. Once the information on the loads, the leaking crack area and the material characteristics are known, a Finite Element Method (FEM) technique was performed to determine the crack length for the required crack area. In order to have the crack area so as to produce a leakage amount of 10 gpm, the crack length can be obtained by applying the normal operation pressure and load to the FEM model of the pressurizer surge line. PICEP code was used for this purpose with application of a trial-and-error method.

2.6 Material Characteristics

Tensile Strength: The tensile strength characteristics of a material is expressed by the Stress-Strain Curve, which shows the material's ductility characteristics around the actual plant operation temperature (600).

Lower Limit J-R Curve (Fracture Toughness): Two types of the approximate methods were used to create the J-R Curve of the pressurizer surge line material (see Figure 2). The first method is to evaluate the J-T Curve of a sample archival material from the UCN 3 and 4 piping material. The test was performed in accordance with ASTM E1152-87. In order to use the data by extrapolating the limited data inventory, the ASTM 813-89 method was used. This method is to fit the data to the curve after applying the Power Law to the data. The second method is by using the 4T specimen in order to establish the lower limit curve. The archival material test data were compared with the other industrial test data of the materials that have the similar Power Law curves.

Table 2

Type	J-R Curve
Pipe and elbows Safe-ends Safe-ends welds	20% Side-grooved 1T-CT specimen
GTAW Field Welds	4T specimen

3. LBB Interpretation

3.1 Theoretical Aspect (FEM)

- J-a (Stress Intensity Factor-Crack Size) Curve
- For the cracks a, a+x, a-x and the cracks 2a, 2a+x, 2a-x, the J value was calculated with the FEM by applying the outside loads.
- After calculating the J value with the function of the crack length "a", the dJ/da value was calculated around "a" and "2a".
- Fitting for J and dJ/da (multiple equations were used):
  $J(a) = C_1a^2 + C_2a + C_3$
  $dJ/da = 2C_1a + C_2$(applies also to the "2a" case)
  where C_1, C_2 and C_3 is are polynomial constants
- Development of the J-T Diagram

3.2 Experimental Aspect

- Tensile Test of the Material
- Creation of the J-a Curve (Curve fitting was used by applying the Power Law)
- $J = C_1(\Delta a)^{C2}$
- $dJ/da = C_1C_2(\Delta a)^{(C2-1)}$
- Creation of the J-*d*J/*d*a diagram

3.3 Evaluation of the Crack Stability

The applied loads, the leaking crack size and the material characteristics have to be known in order to evaluate the stability of a through crack. The pipe load and the bending moment are mentioned in Table 3. The stability of a pipe that has cracks is evaluated by comparing the crack resistant factor and the J-integral by the outside loads that are applied to the pipe. The safety criteria used when a crack of a ductile material is expanding are as follows:

$$J_{applied} < J_{material}$$

and

$$dJ/da_{applied} < dJ/da_{material}$$

3.4 Evaluation Result (see Figures 3.1 and 3.2)

The static and dynamic pipe analyses for the UCN 3 and 4 surge line were performed. Based on this analysis, the possible locations of the hypothetical cracks were selected, and the LBB analyses were performed for all these locations. As indicated in Table 3, it was found out that the stability criteria are satisfied for all the hypothetical crack locations as the result of the LBB analyses.

Table 3

Location Item		**1F (Base)**	**14S**
Stress-Strain Factor		Safe End	Base
J-R		Safe End	GTAW
1/2 of Crack Length (inch)		3.29	2.89
Normal Operational Load (IN-KIPS)		529	680
Maximum Pipe Load (IN-KIPS)		2,559	2,162
Instability	A	3,800	2,900
	2a	2,730	2,220
Degree of Satisfaction		Yes	Yes

CONCLUSION

LBB analysis was performed for the UCN 3 and 4 pressurizer surge line according to the LBB analysis method as suggested in NUREG-1061, Volume 3, and SRP 3.6.3. The result shows that, under a criterion of 1.0 gpm of the allowable leakage rate, the safety criteria are satisfied for all the hypothetical crack locations. Therefore, application of LBB concept to the UCN 3 and 4 pressurizer surge line is feasible.

REFERENCES

Korea Power Engineering Company. 1996. *Leak-Before-Break Evaluation of the Ulchin Nuclear Power Plant Units 3 and 4 Surge Line Piping.* Seoul, Korea.

Combustion Engineering Calculation No. K-ME-C-230, Rev. 00, *Demonstration of Leak-Before-Break for Surge Line.* June 1989.

Combustion Engineering Calculation No. K-ME-C-230, Rev. 01, *Demonstration of Leak-Before-Break for Surge Line.* August 1989.

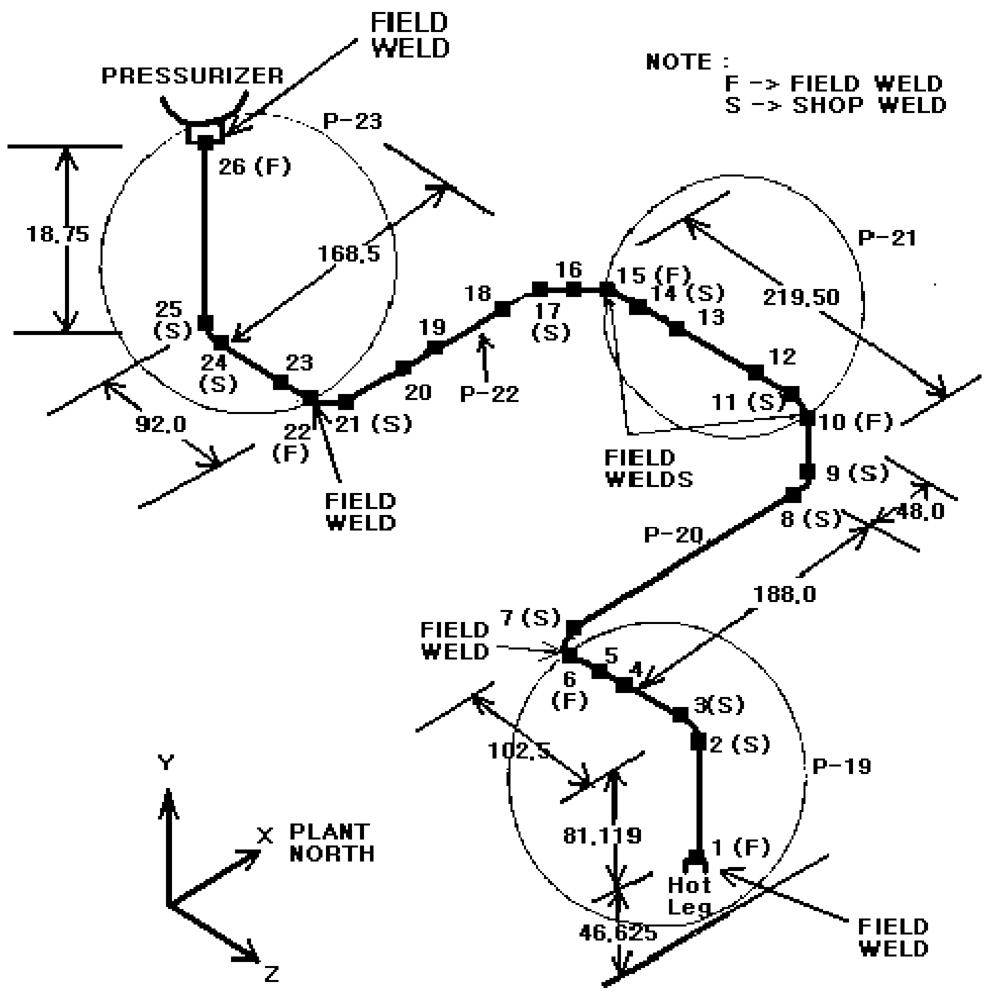
S. Nuclear Regulatory Commission NUREG-1061, Volume 3. ‘‘Evaluation of Potential for Pipe Break.’’

U. S. Nuclear Regulatory Commission Draft Standard Review Plan 3.6.3. Leak-Before-Break Evaluation Procedure.’’ March 1987.

KEY WORDS

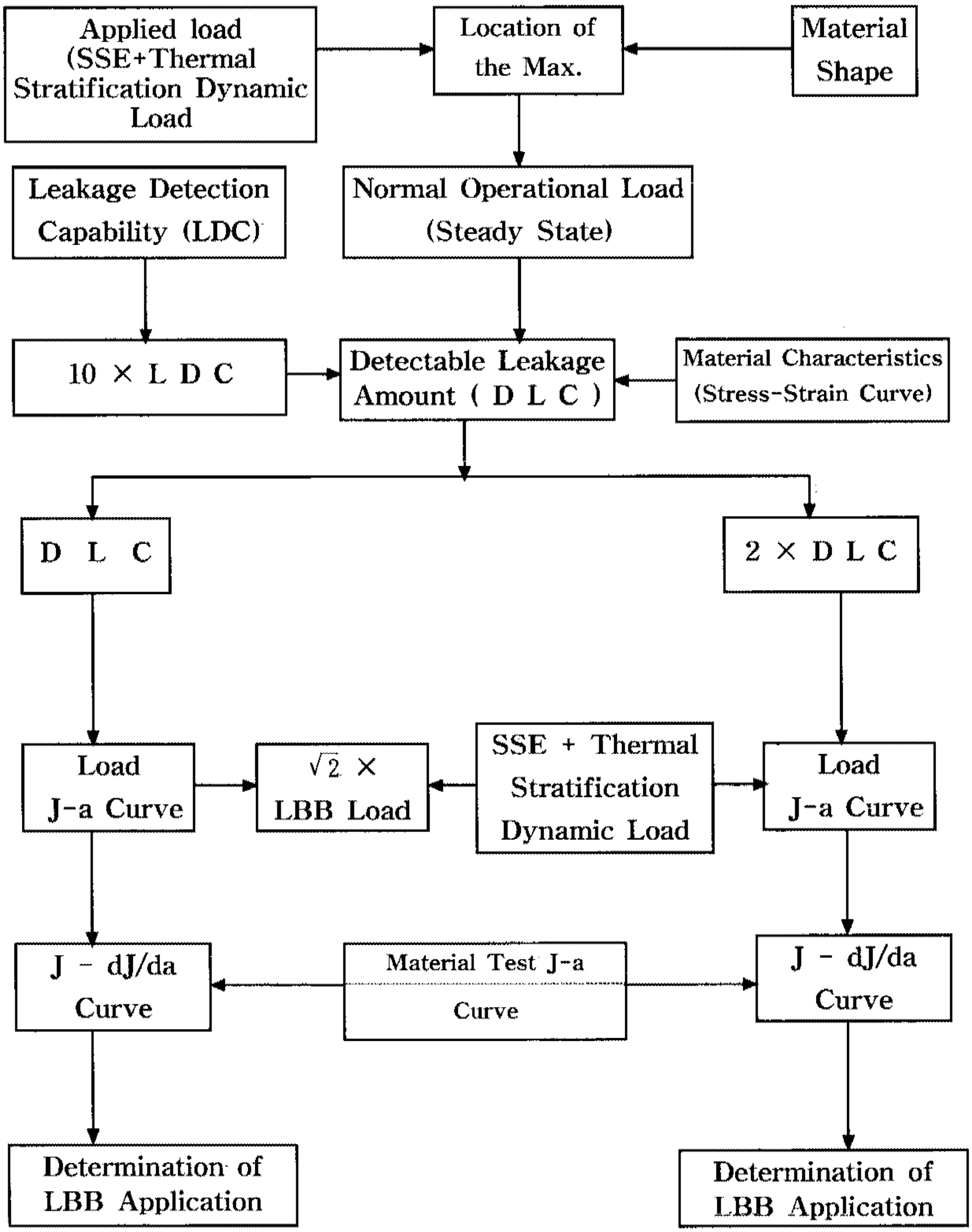
Leak-Before-Break, LBB, Surge Line, Pressurizer, Leakage, Pipe Crack, J-R Curve, J-a Curve.

Figure 1. Drawing of the ULCHIN 3&4 PZR Surge Line



ALL DIMENSIONS INCHES

Figure 2. Schematic Diagram Of The Analysis Process



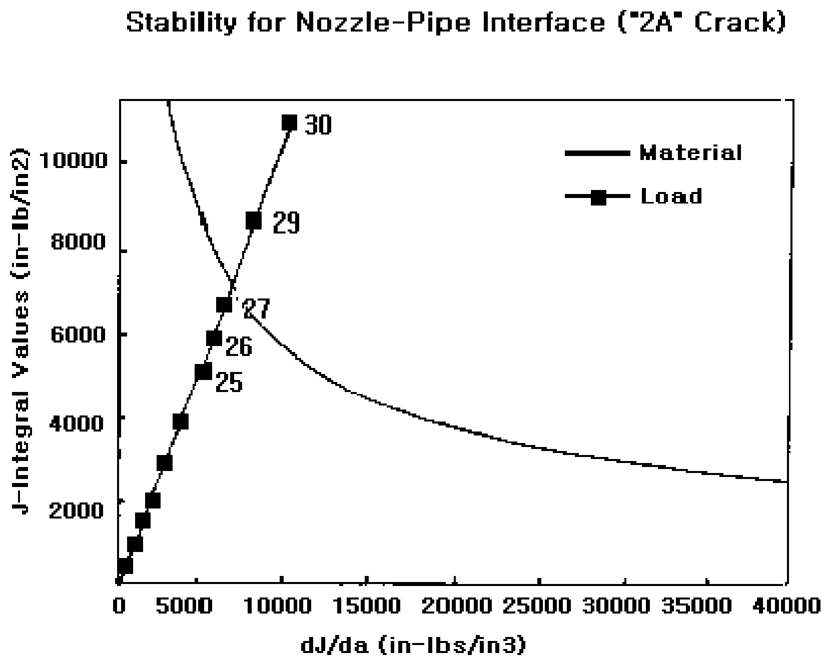


Figure 3.1 STABILITY EVALUATION FOR 2A NOZZLE END (1F)

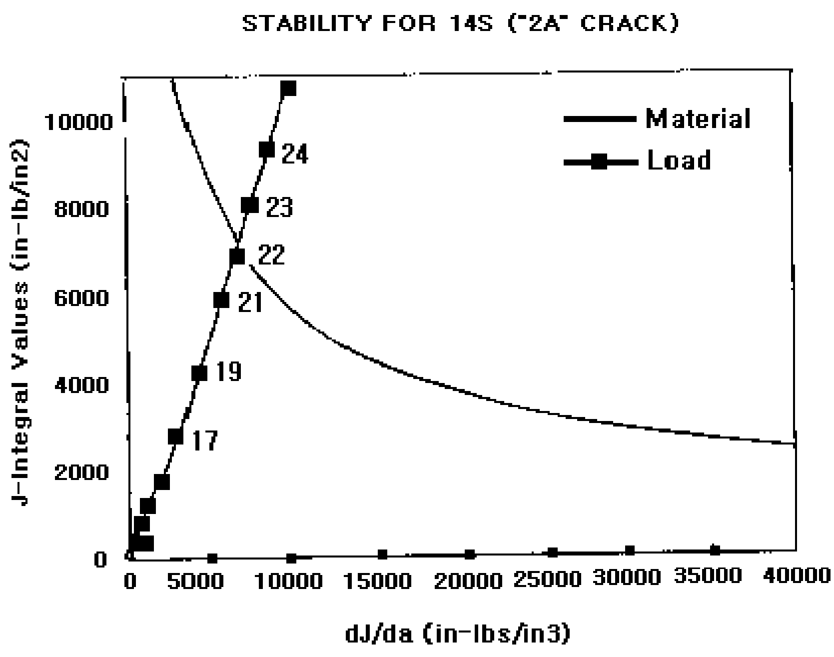


Figure 3.2 STABILITY EVALUATION FOR 2A
: INTERMEDIATE LOCATION