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Millstone Unit 3 Pressurizer, Relief, and Surge Nozzles Structural Weld Overlay Qualification

Westinghouse

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NOMENCLATURE

ΔK_I	stress intensity factor range, ksi√in (MPa√m)
A	constant in crack growth law for Alloy 82/182 welds
A	cross-section area, in^2
A_i	polynomial coefficients in through-wall stress distributions
C	scaling parameter for temperature effects in crack growth law
da	crack growth, inches
$\left(\frac{da}{dN}\right)_{air}$	crack growth rate in air, inch/cycle (m/cycle)
F_{env}	environmental factor for stainless steel welds
F_x, F_y, F_z	forces along x, y, and z-directions, kips
G_j	boundary correction factors in stress intensity factor
h	weld overlay wall thickness, inches
K_I	stress intensity factor, ksi√in (MPa√m)
K_{max}	maximum stress intensity factor range, ksi√in (MPa√m)
K_{min}	minimum stress intensity factor range, ksi√in (MPa√m)
m	exponent in crack growth law for Alloy 82/182 welds
M_x, M_y, M_z	moments about x, y and z-axis, in-kips
n	material property slope in crack growth law
P	primary stress component, ksi
Q	secondary stress component, ksi
Q	shape factor in stress intensity factor formulae
R	stress intensity factor ratio, K_{min} / K_{max}
R_i	inside radius, inches
R_o	outside radius, inches
S	scaling factor for load ratio
S_m	ASME Code allowable stress intensity, ksi
S_y	yield strength, ksi
S_u	ultimate tensile strength, ksi
T	metal temperature, °F (°C)
t	wall thickness, inches
Z	section modulus, in^3
σ	stress perpendicular to the plane of the crack
σ_m, σ_b	membrane and bending stresses, ksi
Φ	elliptical angle in crack shape definition

LIST OF ABBREVIATIONS

ASME	American Society of Mechanical Engineers
ASN	analysis section number
BWR	boiling water reactor
CGR	crack growth rate
DM	dissimilar metal
DNC	Dominion Nuclear Connecticut Inc.
DO	dissolved oxygen
DW	deadweight
EOP	end of evaluation period
EPU	extended power uprate
FCG	fatigue crack growth
FEA	finite element analysis
GMAW	gas-metal arc welding
GTAW	gas-tungsten arc welding
HAZ	heat-affected zone
HU	heatup
ID	inside diameter
IGSCC	intergranular stress corrosion cracking
ISI	in-service inspection
LOCA	loss-of-coolant accident
LWR	light water reactor
MOPCD	modified operating procedure cooldown
MOPHU	modified operating procedure heatup
NRC	Nuclear Regulatory Commission
OBE	operating basis earthquake
P	pressure
PDI	Performance Demonstration Initiative
PT	penetration testing
PWR	pressurized water reactor
PWSCC	primary water stress corrosion cracking
RCL	reactor coolant loop
RCS	reactor coolant system
RSS	root-sum-of-the-squares
RV	relief valve
RVT	relief valve thrust
SAW	submerged arc weld
SI	safety injection
SMAW	shielded-metal arc welding
SS	stainless steel
SST	stainless steel
SSE	safe shutdown earthquake
SV	safety valve
SVT	safety valve thrust
SWOL	structural weld overlay
TGSCC	transgranular stress corrosion cracking
TH	thermal
UT	ultrasonic testing
WOL	weld overlay

1 INTRODUCTION

Weld overlay is a repair and/or mitigation technique used to reinforce nozzle safe-end regions and pipes susceptible to primary water stress corrosion cracking (PWSCC). In this report, the term "repair" is used to describe the application of weld overlay as either a pre-emptive or repair activity. ASME Code Case N-740 [1] was used for the weld overlay design. ASME Code Case N-740 permits the use of weld deposit on austenitic stainless steel piping to increase the wall thickness of the affected region. This demonstrates acceptability of the repaired defects in accordance with ASME Code Section XI IWB-3640 [6]. Use of Code Case N-740 prior to Nuclear Regulatory Commission (NRC) approval of the case has required a relief request [3] for their approval.

The process identified in this Code Case may be used to design either a pre-emptive or repair overlay. The weld overlay involves both the application of a specified thickness and length of weld material over the region of interest in a configuration that ensures structural integrity is maintained. The weld material, Alloy 52/52M, is applied by the gas-tungsten arc welding (GTAW) process. Alloy 52/52M is considered highly resistant to intergranular stress corrosion cracking (IGSCC), transgranular stress corrosion cracking (TGSCC), and PWSCC. The reinforcement material forms a structural barrier to stress corrosion cracking and produces a compressive residual stress condition at the inner portion of the pipe that mitigates future crack initiation and/or propagation.

The approach outlined in ASME Code Case N-740, ASME Code Section XI IWB-3640, and the Millstone relief requests is also consistent with the requirements set forth in NUREG-0313, Revision 2 [4] for boiling water reactor (BWR) coolant pressure boundary piping. The design must consider limitations on the welding process and control, as well as accommodate the need for ultrasonic testing (UT) examinations of the weld overlay and the original weld. Additionally, the impact of the resulting weld overlay repair on the existing design qualification of the piping system and nozzle safe-end must be addressed.

Due to the proximity of the safe-end-to-piping stainless steel (SS) butt-weld to the nozzle-to-safe-end dissimilar-metal (DM) butt-weld, the weld overlay will not only cover the nozzle-to-safe-end weld, but will cover and extend past the safe-end-to-piping weld. Therefore, this report describes the geometry of the weld overlay repairs for the stainless steel butt-welds, as well as the dissimilar-metal butt-welds of the pressurizer relief nozzle, safety nozzles and surge nozzle. Furthermore, this report provides the technical basis for application of the overlay. A summary of the finite element analyses (FEA) that were performed to determine the residual stresses that result from the structural weld overlay (SWOL) is also provided. Also provided are both the methodology used in the weld overlay design qualification and the results that demonstrate the acceptability of the design.

Several locations in this report contain proprietary information. Proprietary information is identified and bracketed. For each of the bracketed locations, the reason for the proprietary classification is provided, using a standardized system. The proprietary brackets are labeled with three different letters, a, c, and e, that provide this information. The explanation for each letter is given here:

a. The information reveals the distinguishing aspects of a process or component, structure, tool, method, etc. The prevention of its use by Westinghouse's competitors, without license from Westinghouse, gives Westinghouse a competitive economic advantage.

c. The information, if used by a competitor, would reduce the competitor's expenditure of resources or improve the competitor's advantage in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

e. The information reveals aspects of past, present, or future Westinghouse- or customer-funded development plans and programs of potential commercial value to Westinghouse.

2 BACKGROUND

The Westinghouse Series 84 pressurizer for Millstone Unit 3 was designed for use in the primary loop of a closed-cycle, pressurized light water nuclear power plant. Figure 2-1 is a schematic view of the pressurizer. Its function is to maintain the required Reactor Coolant System (RCS) pressure during steady-state operation, limit the pressure changes caused by RCS thermal expansion and contraction during normal power plant load transients, and prevent the pressure in the RCS from exceeding the design pressure. The vessel has one spray nozzle connecting the pressurizer spray piping to the upper, steam-filled region of the pressurizer. The spray piping is connected to the main and auxiliary spray valves, which in turn are connected to various RCS cold legs.

Self-actuating safety valves are designed to both accommodate large volume insurges that are beyond the pressure-limiting capability of the spray system and to prevent RCS pressure from exceeding the design pressure by more than 10%. To minimize the use of the safety valves, a power-operated relief valve is set to open at a pressure that is slightly below design pressure. The primary system is maintained in a water-solid condition by the pressurizer, which is connected to the hot leg piping by the surge line.

The pressurizer controls RCS pressure by maintaining the temperature of the pressurizer liquid at the saturation temperature corresponding to the desired system pressure. Pressurizer temperature is controlled and maintained by both the internal heaters and the pressurizer spray system. The spray system acts to reduce pressurizer pressure, should it increase during a transient, by injecting cold leg water into the steam space.

In September 2003, a small leak was discovered from an Alloy 132 (similar to Alloy 182) butt-weld on a pressurizer relief nozzle in Tsuruga Unit 2. Samples removed for destructive examination contained the entire weld and a portion of the base metal on each side of the weld. Metallurgical failure analysis showed that the cracks initiated from the inside surface, were axially oriented, and were intergranular or interdendritic in nature. The metallurgical analysis concluded that the nozzle failure was caused by PWSCC in the nozzle weld [5]. Similar indications were found in the D. C. Cook Unit 1 safety nozzle in the spring of 2005. In 2006, circumferential indications consistent with PWSCC were found at Wolf Creek prior to performing an overlay repair.

Weld overlay repairs were first applied to address IGSCC in weld heat-affected zones (HAZs) of BWR stainless steel piping as an alternative to pipe replacement. Since 1982, weld overlay repairs have been used extensively in BWR stainless steel piping and safe-end welds (over 1,000 in service) to repair flawed weldments, and have produced favorable compressive residual stresses on the inner portion of the pipe wall [4], thereby minimizing further crack growth. Many BWR weld overlays were applied using stainless steel. However, in recent years, Alloy 52/52M material has been used.

Dominion Nuclear Connecticut Inc. (DNC) has decided to install a SWOL on five of the pressurizer nozzles, the surge nozzle and the four safety/relief nozzles, beginning in the spring of 2007. This report documents the technical basis for these weld overlay mitigations.

Figures 2-2 and 2-3 show the typical safety/relief nozzle and surge nozzle configurations, respectively.

In accordance with ASME Code Case N-740, weld metal is applied circumferentially around the affected region and in its vicinity to restore ASME Code Section XI margins. An analysis of the repaired/mitigated weld is performed to ensure that any remaining flaws in the affected region will not further propagate to an unacceptable condition. According to ASME Code Case N-740, the weld overlay is designed to maintain all the structural requirements by conservatively assuming that a through-wall defect has penetrated 360 degrees of the circumference of the original nozzle-to-safe-end dissimilar-metal butt-weld and the original safe-end-to-piping similar-metal butt-weld. The weld overlay provides a replacement pressure boundary and an effective barrier to any further crack growth because of the excellent corrosion resistance inherent in the chemistry of the Alloy 52/52M weld deposits. The weld metal to be used as the overlay filler wire will be ERNiCrFe-7 (Alloy 52, UNS06052) or ERNiCrFe-7A (Alloy 52M, UNS06054). Both Alloy 52 and Alloy 52M are listed in the ASME Code, Section II and Section IX, and is acceptable for use under the ASME Code. Alloy 52/52M nickel-based weld repair material is used rather than austenitic stainless steel, because stainless steel welds cannot be effectively applied over Alloy 82/182 buttering and welds. The use of Alloy 52/52M nickel-based repair material is also consistent with the Millstone Relief Requests.

All welding will be accomplished using the GTAW process. The requirements specified in the Relief Requests will be used for the repair examinations. The impact of the structural weld overlay on the original Code of Construction qualifications for these nozzles is evaluated. The original Codes of Construction and design specifications are:

- Pressurizer
  - ASME Section III, 1971 Edition through Summer 1973 Addenda [28] for Unit 3 for the Code of Construction and stress and fatigue analyses.
  - Design Specifications 955285, Rev 0 [30], 952371, Rev. 4 [33]
  - Millstone Unit 3 Stretch Power Uprate Transients [35 through 37]

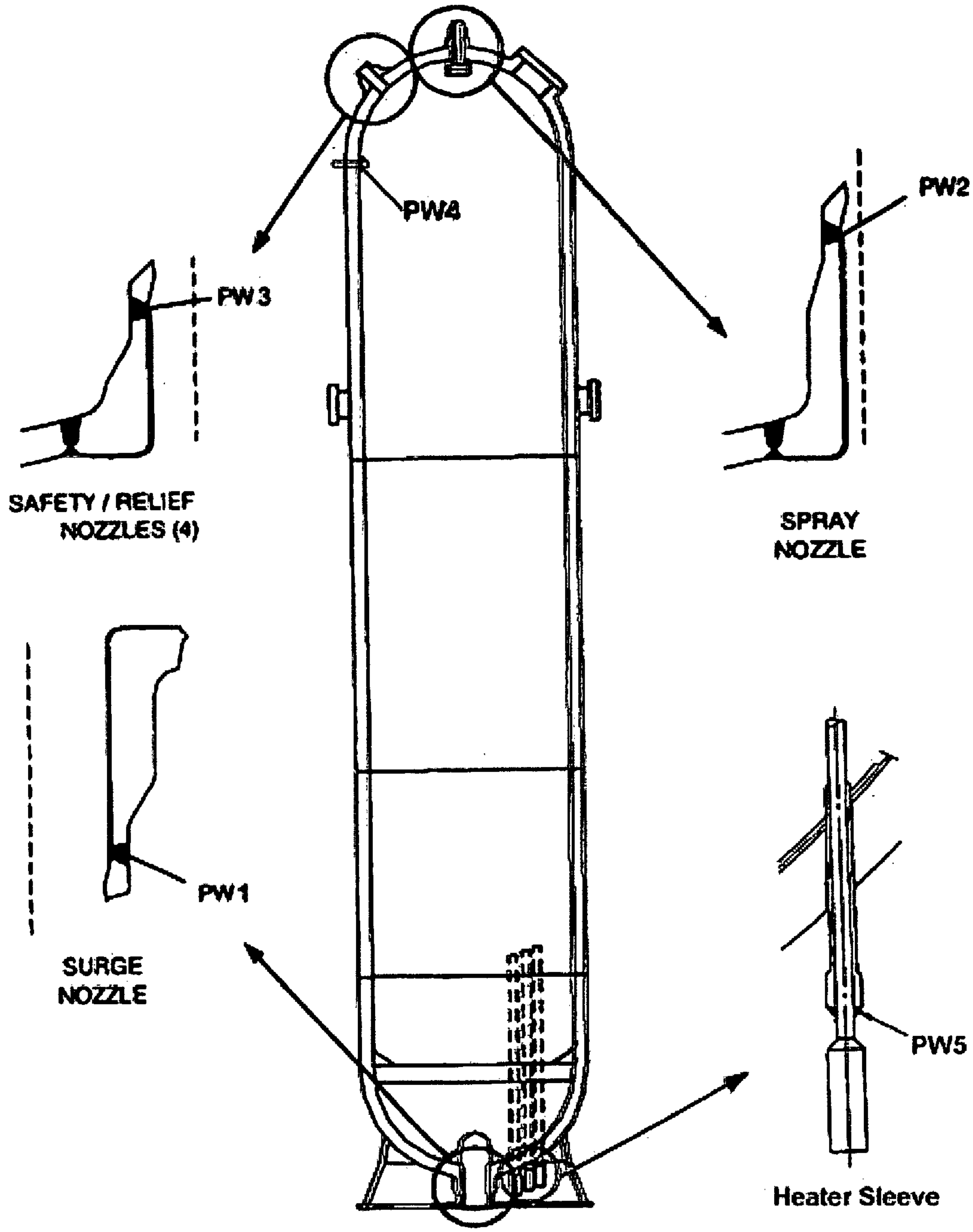

Figure 2-1: Sketch of a Typical Westinghouse Pressurizer Configuration

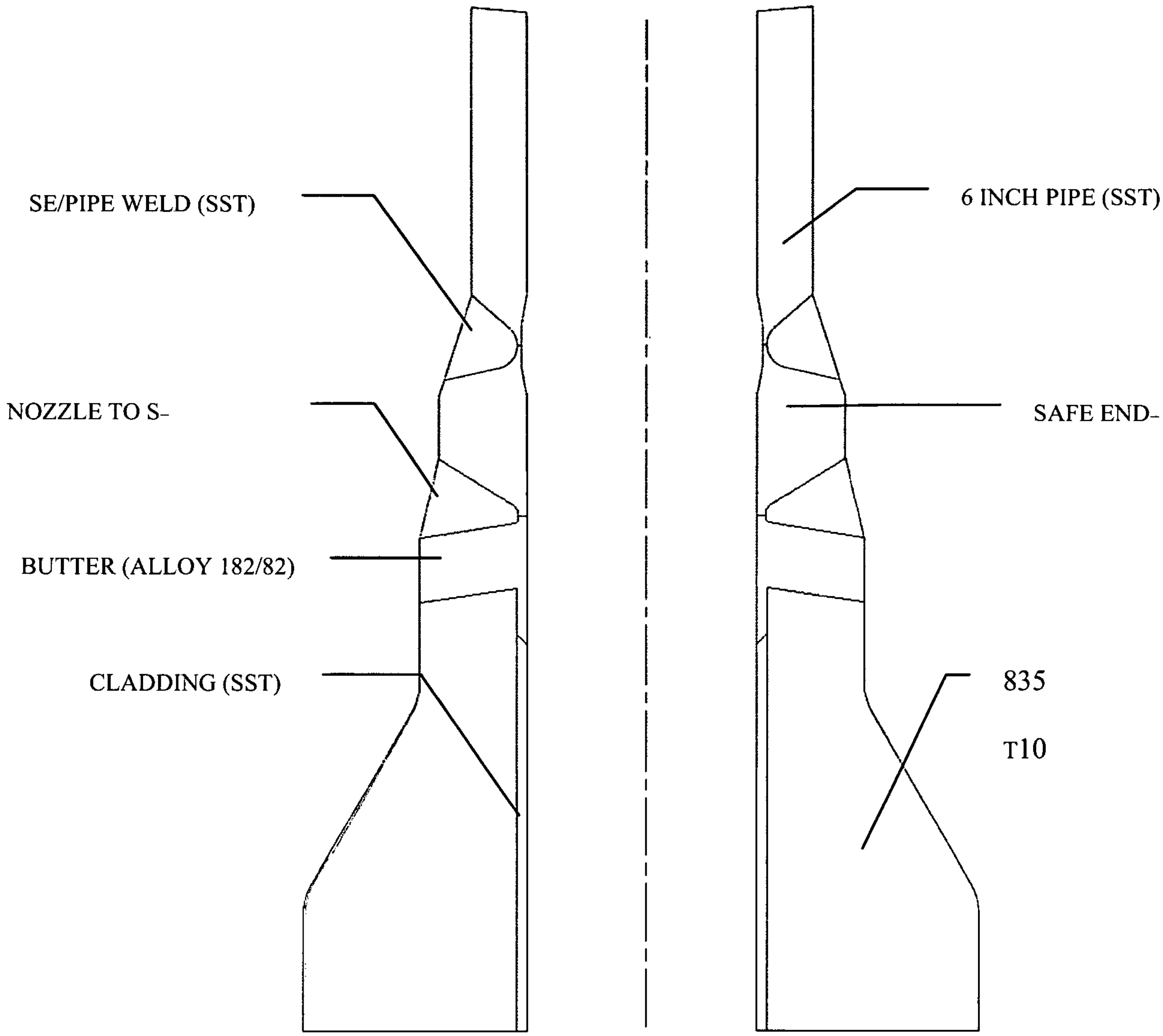

Figure 2-2: Typical Pressurizer Safety and Relief Nozzle Configuration for Millstone

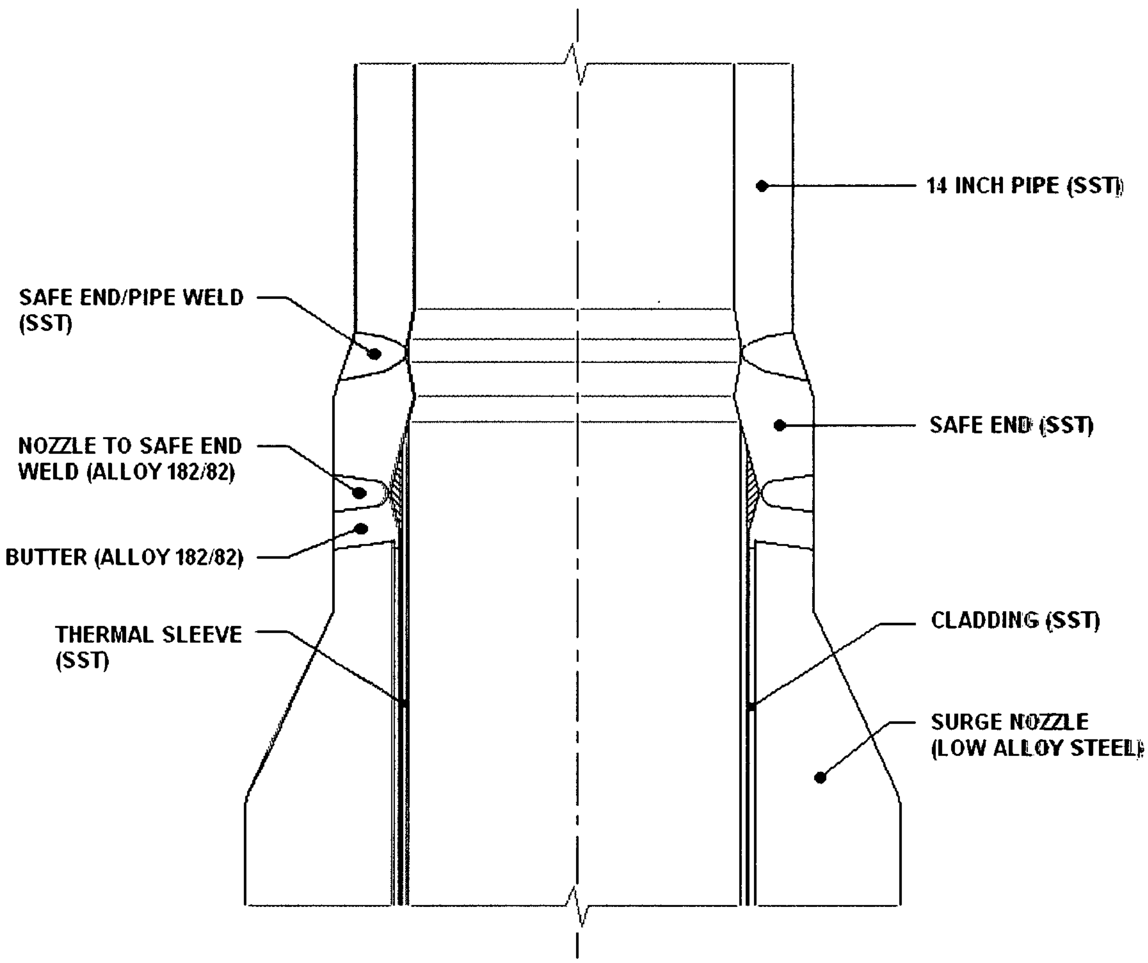

Figure 2-3: Typical Pressurizer Surge Nozzle Configuration for Millstone

3 WELD OVERLAY DESIGN METHODOLOGY

The design of the SWOL thickness/length is performed in accordance with ASME Code Cases N-740, Section XI and ASME Section XI IWB-3640 to demonstrate that the pressurizer nozzle weld overlays will provide a structural barrier that is reliable and durable. A flaw that is 100% through the original weld thickness for the entire circumference of the weld has been assumed in the weld overlay design.

The lifetime of the overlay is evaluated using the actual size of the flaw that is discovered by the UT examination. A series of flaw sizes was evaluated, and plots of design life versus flaw depth were created in advance. When the examinations are complete, these figures can be used to determine the remaining design life for each overlay. The figures are provided in the following sections.

The methodology discussed in this section is applied to the SWOL evaluation of the pressurizer nozzles. The weld overlay design sizing calculations are documented in [2].

3.1 CODE CASE N-740 WELD OVERLAY DESIGN

The weld overlays will extend around the full circumference of the dissimilar-metal butt-weld region and safe-end-to-piping similar-metal butt-weld region for the required length and thickness. In accordance with ASME Section XI IWB-3640 [6], the maximum allowable flaw depth for axial and circumferential flaws is 75 % of the wall thickness for wrought base metals, cast stainless steel, GTAW, and gas-metal arc welds (GMAW). The maximum allowable flaw size for shielded-metal arc welds (SMAW) and submerged arc welds (SAW) is 60 % of the wall thickness. This 60 % limitation is included primarily for conservatism due to the low toughness value of the stainless steel flux welds and is not directly applicable to the high toughness of the Alloy 82/182 weld, which is the weld of interest. This limitation has been removed from Section XI IWB-3640 in later Code editions. Therefore, the maximum allowable depth of 75 % of the wall thickness is used in the weld overlay design. Using this maximum flaw depth as the upper limit, the actual allowable flaw size is then calculated in accordance with the flaw evaluation procedures of ASME Section XI Appendix C [6], and acceptance criteria based on plant-specific loadings at the nozzle. This is an iterative calculation and the overlay thickness is increased until the flaw evaluation criteria are satisfied for all applicable loadings.

For the Millstone pressurizer nozzle safe-end regions, the maximum allowable flaw depth, based on plant-specific nozzle loadings and geometry, is 75 % of the wall thickness. Therefore, the required weld overlay repair thickness can be determined by the following equation:

$$\frac{t}{(t+h)} = 0.75$$

Where,

t = wall thickness at the location of indication
h = thickness of weld overlay repair

According to ASME Code Case N-740, the axial length and end slope of the weld reinforcement are specified to provide smooth load redistribution from the nozzle to the weld overlay and back to the pipe.

This demonstrates that the applicable stress limits of the ASME Section III Code of Construction are met. The full length of the weld overlay was extended axially at least $0.75\sqrt{Rt}$ beyond each end of the postulated flaws, prior to deposition of the weld overlay. (R and t are the outer radius and nominal wall thickness of the pipe/nozzle, respectively) Since crack growth can occur anywhere within the susceptible Alloy 82/182 weld material, the length of the weld overlay is assumed to be measured from the base metal/weld interface on the outside surface of the affected weld region. To avoid stress risers, the weld overlay material was blended into the pipe and nozzle side. The maximum end slope was specified as 30 degrees, which provides a transition consistent with the recommendation of MRP-169 [27]. The weld overlay repair is to be applied 360 degrees around the component to provide a full structural barrier. The weld overlay repair designs for the pressurizer nozzles are shown schematically in Figures 3-1 through 3-2 [8].

3.2 WELD OVERLAY DESIGN FOR EXAMINATION

Examination requirements are a controlling factor in the weld overlay repair design. Based on the current industry examination techniques, the radius of curvature at any geometric transition must be at least 4 inches to ensure proper operation of the examination probes. The stainless steel safe-end-to-pipe weld is located very close to the Alloy 82/182 weld; therefore the SWOL was designed for both welds. This was done to provide for the inspectability of both welds. The length of the weld overlay must be sufficient to examine an area that is 0.5 inches beyond each weld toe and as deep as the outer 25 % of wall thickness; otherwise, full examination coverage cannot be claimed in accordance with the examination procedure. Penetrant testing (PT) examination of the nozzle and pipe surface shall occur prior to application of the weld overlay.

The length of the weld overlay was extended and blended into the low-alloy steel nozzle outer diameter taper to permit UT examination of the adjacent weld and minimize stress concentration on the nozzle outer diameter. Since the outside diameter of the nozzle is larger than that of the safe-end, the weld overlay thickness on the safe-end is increased to allow a smooth-transition surface for UT examination. The final weld overlay length and thickness, after considering the UT examination requirements, may exceed the length and thickness required for a full SWOL repair in accordance with ASME Code Case N-740.

The minimum weld overlay design thickness required to meet structural requirements is shown in the weld overlay design drawings (Figures 3-1 through 3-2) [8]. The cross-hatched areas represent weld deposits that are added to facilitate volumetric examination. Therefore, the weld overlay design values (thickness and length) provided in this report are considered minimum values. Additional weld passes or a larger weld overlay thickness within the specified tolerance on the drawings will not invalidate the design.

a,c,e

Figure 3-1: Pressurizer Safety and Relief Nozzles Typical Weld Overlay Design

a,c,e

Figure 3-2: Pressurizer Surge Nozzle Weld Overlay Design

4 MATERIAL PROPERTIES AND FRACTURE ANALYSIS METHODS

4.1 MATERIALS

All pressurizer nozzles are made of SA-508 Class 2 material. The safe-ends for all nozzles are made of SA-182 F316L. The stainless steel piping for all lines is made of SA-376 TP304. The safe-end-to-nozzle weld material is Alloy 82/182. The safe-end-to-piping weld material is ER308/E308 for the safety/relief and surge lines. The materials for these components are specified in the Millstone Relief Requests. The physical properties used for these materials are based on available data provided in the ASME Code [9, 10] and other publications and reports [11 through 15, 18]. All Section III evaluations used the original Code of Construction stress allowables to determine the impact of the weld overlay.

4.2 WELD OVERLAY MATERIAL PROPERTIES

The weld overlay material, Alloy 52/52M, is a nickel-based alloy that is highly resistant to stress corrosion cracking. The substantial chromium content also gives Alloy 52/52M outstanding resistance to oxidizing chemicals, which makes it an ideal weld material for weld overlay repairs. Alloy 52/52M has properties similar to SB-166 and SB-167 (N06690) ASME Code materials. The material properties used in the design calculations for the weld overlay were obtained from [9].

4.3 ALLOWABLE FLAW SIZE METHODOLOGY

The allowable flaw size is not directly calculated as part of the flaw evaluation process for stainless steels [6]. Instead, the failure mode and allowable flaw size are incorporated directly into the flaw evaluation technical basis; therefore they are used in the tables of "Allowable End-of-Evaluation Period Flaw Depth to Thickness Ratio," in paragraph IWB-3640 of [6]. A more accurate determination of the allowable depth can be made using the methodology of ASME Section XI [6], Appendix C.

Rapid, nonductile failure is possible for ferritic materials at low temperatures, but is not applicable to stainless steels. In stainless steel and nickel-based alloy materials, the higher ductility leads to two possible modes of failure, plastic collapse or unstable ductile tearing. The second mechanism can occur when the applied J integral exceeds the J_{Ic} fracture toughness, and some stable tearing occurs prior to failure. If this mode of failure is dominant, the load-carrying capacity is less than that predicted by the plastic collapse mechanism.

The allowable flaw sizes of paragraph IWB-3640 of [6] for the high-toughness base materials were determined based on the assumption that plastic collapse would occur and would be the dominant mode of failure. All repair welding will be accomplished using the GTAW process. Therefore, the appropriate failure bending stress equation for P_b' from ASME Code Section XI [6], Appendix C, paragraph C-3320, was used for the evaluation.

4.4 CRACK GROWTH METHODOLOGY

The fatigue crack growth (FCG) analysis involves postulating a flaw at the region of concern. The objective of this analysis is to determine the service life required for the flaw to propagate through the original wall thickness to an allowable depth. The determination of this process was previously discussed. The flaw is subjected to cyclic loads due to the applicable design thermal transients. The design thermal transients considered in the analysis were distributed equally over the plant design life. Figures 6-10, 6-11, 7-10 and 7-11 provide examples of remaining service life based on % of design transient cycles. This representation was selected to enable the curves to be used to predict the remaining life, regardless of how the fatigue cycles are handled in license renewal. This is valid for the stainless steel weld, which is not susceptible to PWSCC, and to those portions of the 82/182 weld where a compressive stress field has been established by the weld overlay process. This topic and the results will be discussed further in the applicable sections for each nozzle.

The input required for a fatigue crack growth analysis is essentially the same information necessary to calculate the range of stress intensity factor (ΔK_I), which depends on the crack size, crack shape, geometry of the structural component where a crack is postulated, and the applied cyclic stresses.

Once ΔK_I is calculated, the fatigue crack growth due to a particular stress cycle can be calculated based on the fatigue crack growth model published in [19 through 22]. The incremental growth is then added to the original crack size, and the analysis proceeds to the next cycle or transient. The procedure is repeated until all the transients predicted to occur in the remaining design life of operation have been analyzed.

Stress Intensity Factor

One of the key elements of the fatigue crack growth calculation is the determination of the driving force or crack tip stress intensity factor (K_I). In all cases, the crack tip stress intensity factor for the fatigue crack growth calculation utilized a representation of the actual stress profile rather than a linearization. The stress profile was represented by a cubic polynomial:

$$\sigma(x) = A_0 + A_1 \frac{x}{t} + A_2\left(\frac{x}{t}\right)^2 + A_3\left(\frac{x}{t}\right)^3$$

Where,

x	=	distance into the wall from inside surface
t	=	wall thickness
σ	=	stress perpendicular to the plane of the crack
A_i	=	coefficients of the cubic polynomial fit

The stress intensity factor calculation for a semi-elliptical surface flaw in a cylinder was carried out using the expressions from [22, 23]. The boundary correction factors for the loading conditions utilized for surface flaws are provided in these references. The boundary correction factors for various locations along the crack front (Φ) can be obtained using an interpolation method. Stress intensity factors for a semi-elliptical surface flaw in a cylinder can be expressed using the general form:

$$K_I(\Phi) = \left[\frac{\pi a}{Q}\right]^{0.5} \sum_{j=0}^{3} G_j \left(a/c,\, a/t,\, t/R_i,\, \Phi\right) A_j$$

Where,

- a/c = ratio of crack depth (a) to half-crack length (c)
- a/t = ratio of crack depth (a) to thickness of a cylinder (t)
- t/R_i = ratio of thickness (t) to inside radius (R_i)
- Φ = elliptical angle along the crack front
- G_j = G_0, G_1, G_2, G_3 are boundary correction factors
- Q = shape factor $= \int_0^{\pi/2} \left(\cos^2 \Phi + \frac{a^2}{c^2} \sin^2 \Phi \right)^{1/2} d\Phi$

Fatigue Crack Growth Rate Reference Curves for Nickel-Based Alloys

Crack growth rate (CGR) reference curves for Alloy 52/52M, 82, and 182 materials have not been developed in the ASME Code Section XI; therefore, information available from the literature [19 through 22] was used. Based on the results reported in [19 through 22], a crack growth rate curve was developed for application in the air environment for INCONEL® Alloy 600 material, as shown below. The crack growth rate is a function of both stress ratio R (K_{min}/K_{max}) and the range of the applied stress intensity factor (ΔK_I).

$$\left(\frac{da}{dN}\right)_{air} = CS(\Delta K)^n \, (F_{weld})(F_{env})$$

$$C_{A600} = 4.835 \times 10^{-14} + (1.622 \times 10^{-16})T - (1.490 \times 10^{-18})T^2 + (4.355 \times 10^{-21})T^3$$

$$S = [1 - 0.82R]^{-2.2}$$

$$n = 4.1$$

Where,

- T = operating temperature (°C)
- ΔK = stress intensity factor range, MPa$\sqrt{m}$
- R = stress ratio, K_{min}/K_{max}
- $\left(\frac{da}{dN}\right)_{air}$ = crack growth rate, m/cycle

F_{weld} = Factor for weld

F_{env} = environmental factor

According to [19], the fatigue CGR of high-nickel alloys in the light water reactor/pressurized water reactor (LWR/PWR) environment can be correlated to that in the air environment using:

$$CGR_{env} = CGR_{air} + A(CGR_{air})^m$$

By performing a least-square curve fitting of the FCG data on Alloy 600 in high-purity water with ~300 ppb DO (dissolved oxygen), it was concluded in [22] that the best values of A and m for CGR of Alloy 600 in LWR/PWR environment are:

$A = 4.4 \times 10^{-7}$
$m = 0.33$

This model was proposed by Chopra et al. in [22]. It was judged conservative for this application since it includes data for water environments with oxygen contents up to 10 ppb, as shown in Figure 4-1. The typical PWR water chemistry has an oxygen level that is too low to measure, since it is scavenged by the presence of a hydrogen overpressure.

The fatigue CGR in a water environment for an Alloy 182 weld is a factor of 10 higher than that for Alloy 600 material. This CGR is assumed to be also applicable to the Alloy 82 weld material in the dissimilar-metal weld region.

Fatigue Crack Growth Rate Reference Curves for Stainless Steel

The reference crack growth law shown in Figure 4-2 was used for the stainless steel material, and appears in Section XI, Appendix C for air environments. Its basis is provided in [25]. For water environments, an environmental factor of two was used, based on the crack growth tests in PWR environments reported in [26].

$$\frac{da}{dN} = CS\left(\Delta K\right)^n F_{env}$$

Where,

$\frac{da}{dN}$ = CGR, inches per cycle

C = material coefficient $C = 10^{\left[-10.009+812E-04T-1.13E-06T^2+1.02E-09T^3\right]}$

S = 1.0 for R = 0

$S = 1 + 1.8R$ for $0 < R \leq 0.79$

$S = -43.35 + 57.97R$, for $0.79 < R < 1.0$)

n = material property slope = 3.30

ΔK = stress intensity factor range, $\text{ksi}\sqrt{\text{in}}$

F_{env} = environmental factor (= 1.0 for air environment, and = 2.0 for PWR environment)

Fatigue Crack Growth Curves for Alloy 52/52M SWOL Material

Since the SWOL will be applied before any inspections can be completed, the possibility of discovering an almost through-wall flaw during the final Performance Demonstration Initiative (PDI) qualified UT inspection of the completed weld overlay needs to be addressed. Based on the residual stress distributions at the Alloy 82/182 weld that the residual stresses under normal operating condition do not remain compressive through 100% of the original wall thickness, PWSCC may become an active crack growth mechanism at the Alloy 82/182 weld if an existing flaw propagates under fatigue crack growth mechanism to the portion of the original wall where the residual stresses become tensile. Using the current PWSCC crack growth rate, the service life required for such a flaw to propagate under PWSCC to reach 100% through the original wall would be quite short. Even though this is an unlikely scenario, additional FCG analyses were performed at the Alloy 82/182 weld location for a postulated 100% through the original wall flaw. If crack growth continues beyond the original Alloy 82/182 weld metal, it will grow into the Alloy 52/52M SWOL. No primary water stress corrosion crack growth needs to be considered for the postulated 100% through-wall flaw because the weld overlay material, Alloy 52/52M, is considered highly resistant to PWSCC. In accordance with the test data for Alloy 52 weld material, the fatigue crack growth rate in the water environment is similar to that for Alloy 600 in a water environment and is therefore it is assumed applicable to the Alloy 52/52M weld overlay material. To model this effect, the scaling factor for temperature effects is:

$$C_{A690} = 5.423 \text{ X } 10^{-14} + (1.83 \text{ x } 10^{-16})T - (1.725 \text{ x } 10^{-18})T^2 + (5.49 \text{ x } 10^{-21})T^3.$$

Scaling factor for load ratio effects, S(R) parameter, for Alloy 52/52M is the same as for the case of Alloy 82/182 material.

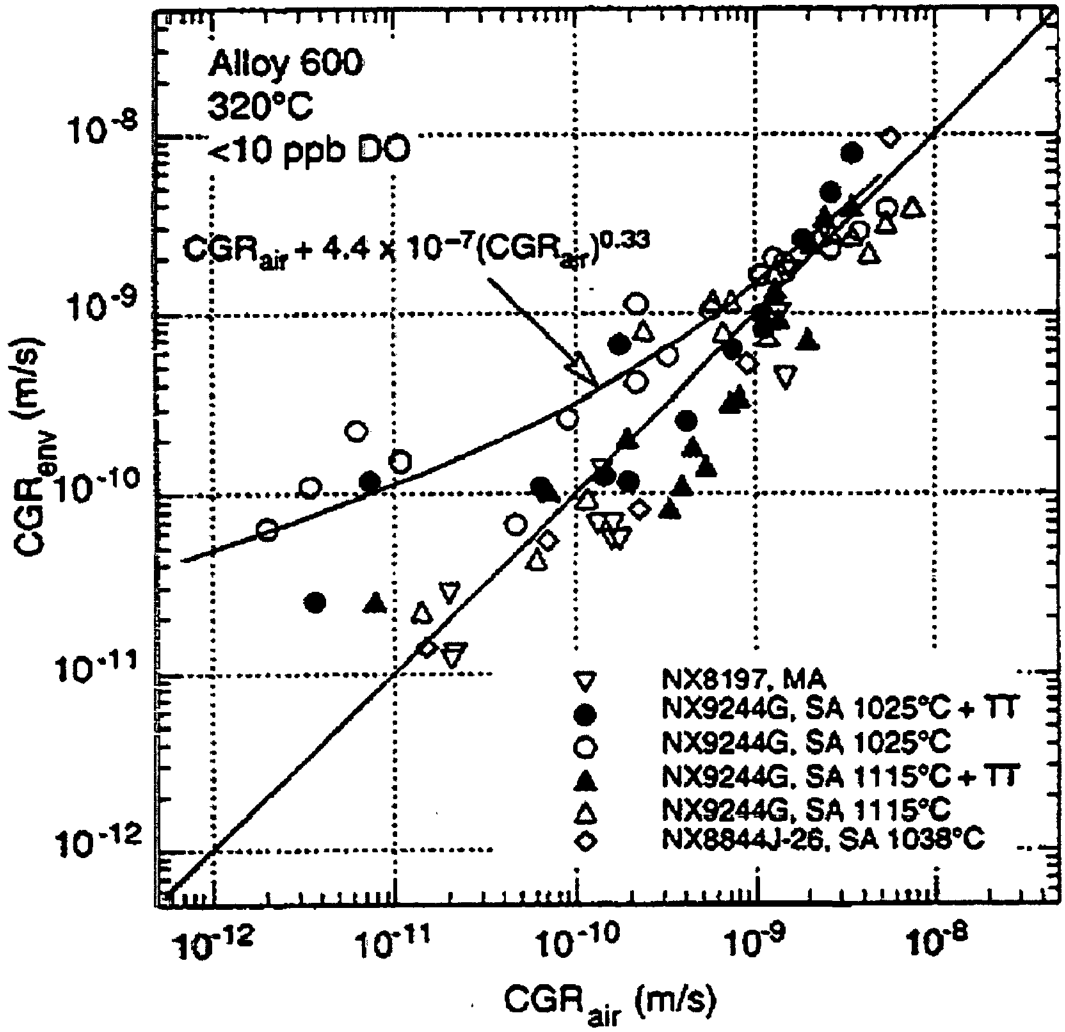

Figure 4-1: Fatigue Crack Growth Model Development for Alloy 600 and Associated Welds in PWR Water Environment

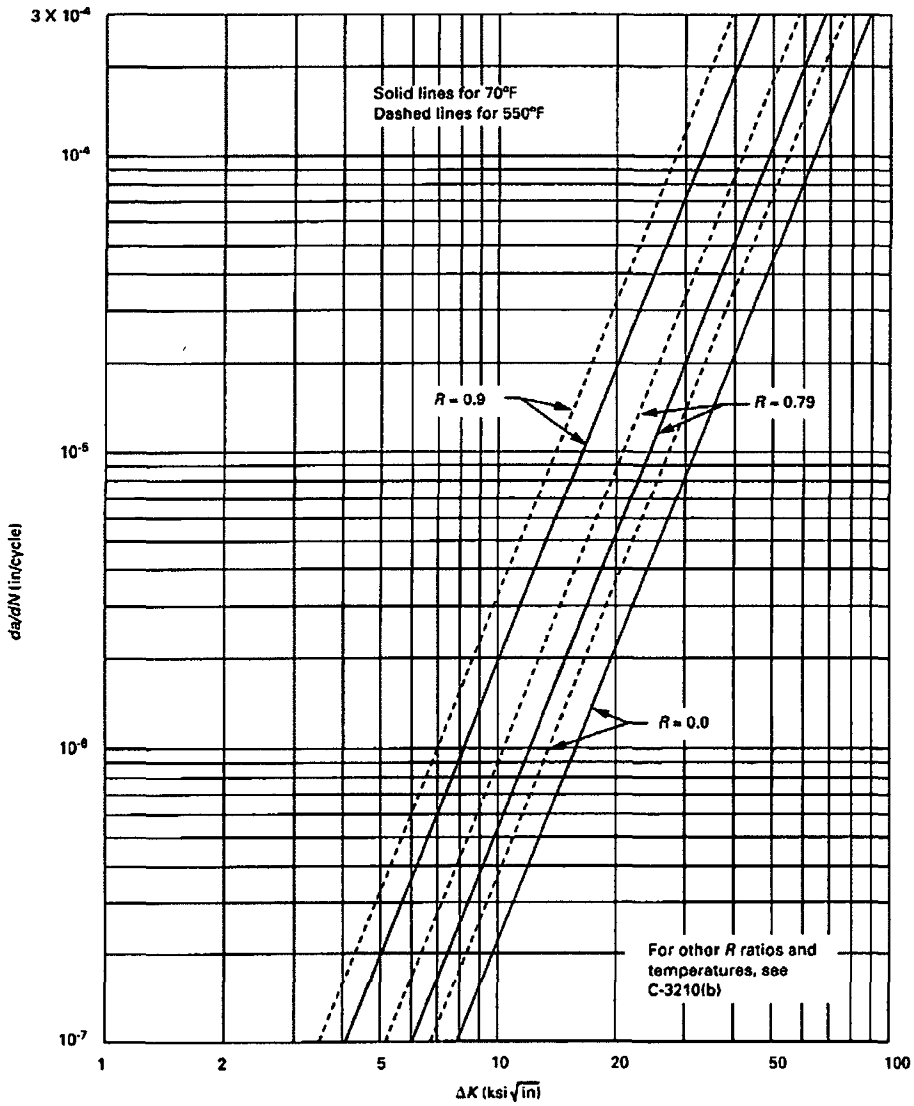

FIG. C-8410-1 REFERENCE FATIGUE CRACK GROWTH CURVES FOR AUSTENITIC STAINLESS STEELS IN AIR ENVIRONMENTS

Figure 4-2: Reference Crack Growth Rate Curves for Stainless Steel in Air Environments

5 WELD OVERLAY FINITE ELEMENT ANALYSIS

5.1 OBJECTIVE OF THE ANALYSIS

The objective of this analysis was to determine the stresses produced by the pressurizer nozzle SWOLs that will be used to demonstrate the acceptability of the mitigation/repair in accordance with Section XI requirements. Finite element analyses were performed to simulate the weld overlay process and obtain the resulting residual weld stresses. These finite element analyses were performed using the ANSYS®[1] finite element analysis program [16]. Then crack growth evaluations were performed using the finite element stress results to demonstrate that the SWOL is sized adequately and within allowable crack growth limits.

5.2 FINITE ELEMENT MODELS

The finite element models use PLANE42 for the structural elements and PLANE55 for the thermal elements, each with four nodes. The models are axisymmetric and use isotropic, temperature-dependent material properties, as summarized in Section 4. Higher-order elements are not used in this application because the plasticity treatment in the elements derives no significant benefit from the higher-order shape functions. The typical analysis sequence involves a heat transfer analysis that determines applicable heat flow and temperatures (steady-state or transient). The same model is used for the structural analysis, with the element type changed from PLANE55 to PLANE42 and the appropriate structural boundary conditions applied. The nodal temperatures were read into the structural model to capture the steady-state or transient thermal stresses. The results for each particular nozzle type (safety/relief and surge) are documented in Sections 6 and 7.

5.3 WELD OVERLAY SIMULATION

Analyses were performed to determine residual weld stresses in the pressurizer nozzle dissimilar-metal and stainless steel butt-weld regions, to support the ASME Section XI evaluations. [

]a,c,e

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The structural analysis was performed using a similar process. Each area was applied using the "birth option" and the temperatures were read into the model. A time-history elastic-plastic analysis was performed for the entire weld overlay application. Once the weld overlay simulation was completed, the normal operating loads (temperature and pressure) were applied to the model. Several cycles of ambient temperature and normal operating loads were applied until the stresses achieved "shakedown," meaning that subsequent cycles did not produce significant stress changes.

The surge and safety/relief nozzles were conservatively analyzed assuming a 50 % through-wall ID weld repair of the Alloy 82/182 weld to simulate the initial stress state due to either weld repair or as-fabricated weld stresses. The ID repair was applied as four radial layers, each repair layer consisting of one weld area. [

]a,c,e The approaches used for the safety/relief and surge nozzles have been shown to produce a conservative simulation of residual weld stresses as compared to test data [17].

6 WELD OVERLAY DESIGN QUALIFICATION ANALYSIS: SAFETY AND RELIEF NOZZLES

6.1 INTRODUCTION

This section provides the weld overlay design qualification analysis to demonstrate the adequacy of the SWOL design for the pressurizer safety/relief nozzle. The effectiveness of a weld overlay with Alloy 52/52M weld material is demonstrated using crack growth analysis per IWB-3640 [6], to ensure that the weld overlay does not deteriorate during service. Using the residual weld stresses developed by the finite element model of the weld overlay process, future crack growth was evaluated at the safety/relief nozzle safe-end weld locations using the operational design transients affecting the weld overlay region. The advantage of the Alloy 52/52M material is its high resistance to PWSCC, which minimizes the possibility for future PWSCC crack growth. Since the purpose of the SWOL is to mitigate/repair a potentially cracked dissimilar-metal butt-weld, performing crack growth analyses using the ASME Code Section XI methodology is the accepted method to address the fatigue qualification of the weld overlay region for the pressurizer safety/relief nozzle.

The effect of the SWOL on the existing fatigue qualification of the pressurizer safety/relief nozzle outside the weld overlay region is addressed in accordance with ASME Section III requirements considering the effect of the applicable thermal transient stresses, structural discontinuities, and bimetallic effects resulting from the SWOL. The impacts of weld shrinkage from the overlay are also addressed.

6.2 LOADS

The loads used for the design of the safety and relief nozzle weld overlay are listed in Table 6-1. These loads are listed in [2] and specified in [32]. The load combinations considered in the design are listed in Table 6-2. The transients considered in the safety and relief nozzle FCG evaluation are shown in Table 6-3 and the nozzle loads considered are shown in Table 6-4. The FCG loads are specified in [32]. The nozzle loads and transients used for the design and FCG analysis are bounding for the actual nozzle loads and the plant-specific transients specified in [7], [32], and [33].

Table 6-1: Enveloping Safety and Relief Nozzle Loads Used for Weld Overlay

Load Type	Axial F_x (kips)	Torsion M_x (in-kips)	Bending	
			M_y (in-kips)	M_z (in-kips)
DW	0.20	16.14	11.78	15.79
TH	7.81	57.17	86.65	253.16
RVT	0.58	12.01	18.37	3.34
SVT	0.39	3.74	5.88	26.40
OBE	0.27	9.28	14.23	9.86
SSE	0.30	11.09	17.90	7.70

Notes:
1. The loads used in the safety and relief nozzle design calculations bound the Millstone specific design loads [32] for Unit 3, which remain unchanged as a result of the application of the weld overlay.
2. F_x = axial force; M_x = torsion moment; M_y, M_z = bending moments

Table 6-2: Load Combinations		
Load	**Pressurizer**[(1)]	**Safety/Relief Piping**[(2)]
Design	P + DW + MAX (RV, SV, OBE)	P + DW
Normal	P_A + TH + DW	P_A + TH + DW
Upset	P_B + TH + DW + OBE	P_B + DW + TH + OBE + MAX (RV, SV)
	P_B + TH + DW + MAX (RV, SV)	
Faulted	P_D + DW + RSS[(3)] (LOCA, SSE)	P_D + DW + TH + SSE + MAX (RV, SV)
	P_D + DW + MAX (RV, SV)	
Test	P + DW	P + DW

Notes:
1. Based on pressurizer stress report [7]
2. Based on pipe end loads [32]
3. RSS indicates that the root-sum-of-the-squares method is to be used

P = Internal Pressure (subscripts A, B, C, and D indicate service levels)
DW = Deadweight
RV = Relief Valve Thrust
SV = Safety Valve Thrust
TH = Thermal
OBE = Operating Basis Earthquake
LOCA = Loss of Coolant Accident
SSE = Safe Shutdown Earthquake

Table 6-3: Summary of Design Transients for Reference Safety and Relief Nozzles

Transient ID	Transient Title	Total Events
1	Heatup	200
2	Cooldown	200
3	Unit Loading	13,200
4	Unit Unloading	13,200
5	Reduced Temp Return to Power	2,000
6	Step Load Increase	2,000
7	Step Load Decrease	2,000
8	Large Step Decrease	200
9	Steady-State Fluctuation - Initial	150,000
10	Steady-State Fluctuation - Random	3,000,000
11	Feedwater Cycling	2,000
12	Loop Out of Service Normal Shutdown	80
13	Loop Out of Service Normal Startup	80
14	Turbine Roll Test	20
15	Loss of Load	80
16	Loss of Power	40
17	Partial Loss of Flow	80
18	Reactor Trip-No Cooldown	230
19	Reactor Trip-with Cooldown and No SI	160
20	Reactor Trip-with Cooldown and SI	10
21	Inadvertent RCS Depressurization	20
22	Inadvertent Startup Inactive Loop	10
23	Control Rod Drop	80
24	Inadvertent SI Actuation	60
25	Excessive Feedwater Flow	30
26	Primary-Side Leak Test	200
27	Primary Hydrostatic Pressure Test	10
28	Boron Concentration Equalization	26,000
29	OBE	20[1]

Note:

1. 20 occurrences, each with 20 stress cycles

Table 6-4: Enveloping Safety/Relief Nozzle Loads for Fatigue Crack Growth						
				Torsion	Bending	
Load Condition	**F_x (kips)**	**F_y (kips)**	**F_z (kips)**	**M_x (in-kips)**	**M_y (in-kips)**	**M_z (in-kips)**
Thermal	13	38	38	365	198	198
Pressure	59	0	0	0	0	0
Weight	4	4	4	25	30	30
Seismic OBE and Valve Thrust	4	4	4	50	59	59

Notes:
1. The loads used in the safety and relief nozzle fatigue crack growth calculations are bounding for the Millstone specific design loads [32], which remain unchanged as a result of the application of the weld overlay. Fatigue crack growth is not significantly impacted by the OBE and valve thrust loads.
2. F_x = axial force; M_x = torsion moment; M_y, M_z = bending moments

6.3 WELD OVERLAY DESIGN SIZING

The minimum weld overlay thickness was determined based on a through-wall flaw in the original pipe. The methodology used to determine the weld overlay design thickness and length is discussed in Section 3. Using this methodology, radii from the design geometry, shown in Table 6-5, are used to design the minimum SWOL parameters. As-designed inside and outside radii at the thickest portion of the Alloy 82/182 and stainless steel welds are presented here. The thickest portion results from considering the smallest inner radius ($R_{i\text{-}min}$) and the largest outer radius ($R_{o\text{-}max}$). Using the thickest section in sizing the overlay results in a conservative design thickness and length. The weld overlay length was based conservatively on the recommended length, per Code Case N-740, of:

$$L_{WOL} = 0.75\sqrt{Rt}$$

Where,

$R = R_{o\text{-}max}$ = outside radius
$t = R_{o\text{-}max} - R_{i\text{-}min}$ = wall thickness at the location of indication

It should be noted that the weld overlay length (L_{WOL}) will extend from the weld/base metal interface on either side of the Alloy 82/182 and stainless steel welds as shown in Figure 6-1. The weld overlay thickness (t_{WOL}) was determined using the following equation:

$$t_{WOL} = t/0.75 - t$$

The minimum weld overlay design dimensions are shown in Table 6-6.

In accordance with ASME Section XI IWB-3640, the criterion from Section XI, Appendix C is used to evaluate the maximum post-weld-overlay stresses resulting from the actual applied loadings. To determine the applied post-weld-overlay stresses, the minimum post-weld-overlay thicknesses are considered. This produces a conservative method to determine stresses for comparison to the allowable stress criterion. The thinnest portion of the Alloy 82/182 and stainless steel welds results from considering the largest inner radius ($R_{i\text{-max}}$) and the smallest outer radius post-weld-overlay ($R_{o\text{-min-WOL}}$). These parameters and also the resulting geometric section properties are presented in Table 6-7.

The applied bending stresses were calculated by:

$$\sigma_b = \frac{\sqrt{M_x^2 + M_y^2 + M_z^2}}{Z}$$

Where,

M_x, M_y, and M_z are per Table 6-1 and

Z is per Table 6-7

$$Z = \frac{\pi(R_{o-\min-wol}^4 - R_{i-\max}^4)}{4(R_{o-\min-wol})}$$

Where,

$R_{i\text{-max}}$ and $R_{o\text{-min-wol}}$ are per Table 6-7

The applied membrane stresses were calculated by:

$$\sigma_m = \sigma_p + \frac{F_x}{A_x}$$

Where,

$$\sigma_p = \frac{\pi R_{i-\max}^2}{\pi\left(R_{o-\min-wol}^2 - R_{i-\max}^2\right)} P$$

F_x is per Table 6-1, Table 6-4

A_x is per 6-7

$A_x = \pi\ (R_{o\text{-min-wol}}^2 - R_{i\text{-max}}^2)$.

Where,

$R_{i\text{-max}}$ and $R_{o\text{-min-wol}}$ are per Table 6-7

P = 2,485 psig, see Table 6-2

The allowable stress intensity S_m (at 650°F) used in the sizing of the Alloy 52/52M (N06690) overlay is 23.3 ksi [9]. This allowable is based on the annealed condition of SB-167. The normal operating pressure and design pressure are 2,235 psig and 2,485, respectively. The applicable service condition pressure is required; however, the design pressure is conservatively used to determine all applied loads.

The resulting stresses, determined by using the previous equations and the loads and load combinations from Tables 6-1 and 6-2, respectively, are listed and compared to the Code allowable in Table 6-8.

Table 6-5: Safety/Relief Nozzle Geometry for WOL Design Calculations [2]					
Alloy 82/182 Weld			Stainless Steel Weld		
Inside Radius R_{i-min} (in)	Outside Radius R_{o-max} (in)	Wall Thickness t_{design} (in)	Inside Radius R_{i-min} (in)	Outside Radius R_{o-max} (in)	Wall Thickness t_{design} (in)
2.575	4.015	1.440	2.659	3.645	0.987

Table 6-6: Safety/Relief Nozzle Minimum Weld Overlay Repair Design Dimensions [2]			
Alloy 82/182 Weld		Stainless Steel Weld	
t_{WOL} (in)	L_{WOL} (in)	t_{WOL} (in)	L_{WOL} (in)
0.48	1.81	0.33	1.43

Table 6-7: Safety/Relief Nozzle Geometry for Stress Check in Post-Weld-Overlay Condition [2]							
Alloy 82/182 Weld				Stainless Steel Weld			
Inside Radius R_{i-max} (in)	Outside Radius $R_{o-min-WOL}$ (in)	Cross-Sect. Area A_x (in^2)	Section Modulus Z (in^3)	Inside Radius R_{i-max} (in)	Outside Radius $R_{o-min-WOL}$ (in)	Cross-Sect. Area A_x (in^2)	Section Modulus Z (in^3)
2.595	4.215	34.659	50.365	2.669	3.640	19.254	26.938

Table 6-8: Applied and Allowable Post-WOL Bending Stress Comparison for Safety and Relief Nozzles [2]		
Location	Applied Stress σ_b (ksi)	Allowable Stress(1) P_b (ksi)
Alloy Weld	1.530	9.914
SS Weld	2.912	8.210
Note: 1. The allowable stress is a function of the applied piping membrane stress per ASME Section XI, Appendix C, 3320.		

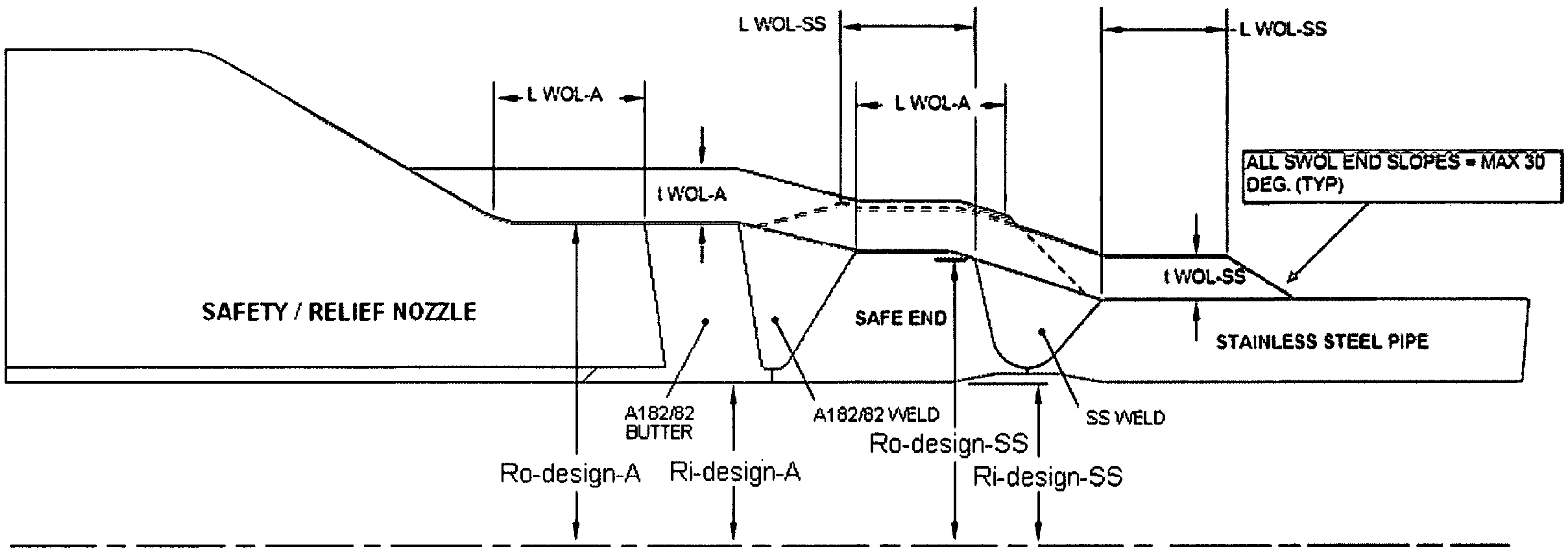

Figure 6-1: Sketch Showing Weld Overlay Design Parameters for the Safety/Relief Nozzles

6.4 WELD OVERLAY RESIDUAL WELD STRESS RESULTS

As described in Section 5.3, the finite element model was developed to capture the parts of the structure in the vicinity of the safety/relief nozzle safe-end with the SWOL. This includes a portion of the safety and relief nozzle attached to the nozzle safe-end and a length of stainless steel pipe attached to the safe-end. An ID weld repair was considered in the finite element model. The overall finite element model is shown in Figures 6-2 and 6-3. The nozzle is fixed in the axial direction to simulate the rest of the nozzle. The stainless steel piping is coupled in the axial direction to simulate the remaining portion of the stainless steel piping not included in the model.

The final residual weld stresses, including normal operating pressure and temperature conditions, are shown in Figures 6-4 through 6-7 for selected stress cuts in the Alloy 82/182 and stainless steel welds. The locations of the stress cuts are provided in Figure 6-3. The stress contours in the pressurizer safety/relief nozzle after the weld overlay application are provided in Figures 6-8 and 6-9.

From Figures 6-4 and 6-5, both the axial and hoop residual weld stresses at normal operating conditions resulting from the SWOL are compressive up to about 80 % of the original pipe wall thickness. This stress distribution is favorable due to the generally compressive stress field because it minimizes the potential for crack growth in the dissimilar-metal weld region. For the stainless steel weld, both the axial and hoop residual weld stresses shown in Figures 6-6 and 6-7, respectively, remain compressive at normal operating conditions for nearly the entire original pipe wall thickness. Therefore, the potential for FCG in the stainless steel weld is also minimized.

Acceptable post-weld-overlay residual stresses (i.e., stresses that satisfy the requirements for mitigating PWSCC) are those that are sufficiently compressive over the entire length and circumference of the inside surface of the Alloy 82/182 weld (at operating temperature, but prior to applying operating pressure and loads) that the resulting total stress, after application of operating pressure and loads, remains less than 10 ksi tensile [27]. This target level has been selected as a conservatively safe value, below which PWSCC initiation, or growth of small initiated cracks, is very unlikely. Additionally, the residual plus operating stresses must remain compressive through some portion of the weld thickness away from the inside surface. The residual stresses in the Alloy 82/182 weld of the safety/relief nozzle, resulting from the weld overlay, are well below this stress level through at least 80 % of the original weld thickness. Additionally, the maximum bending moment in the safety/relief nozzle under normal operating conditions is approximately 287 in-kips and the resulting maximum bending stress in the 82/182 weld is approximately 5.7 ksi. Therefore, the combination of normal operating and residual weld stresses in the axial direction is compressive through at least 80 % of the original weld thickness and the flaws in this region are not susceptible to PWSCC. Thermal transient stresses need not be considered since only steady-state conditions are applicable for determining PWSCC susceptibility.

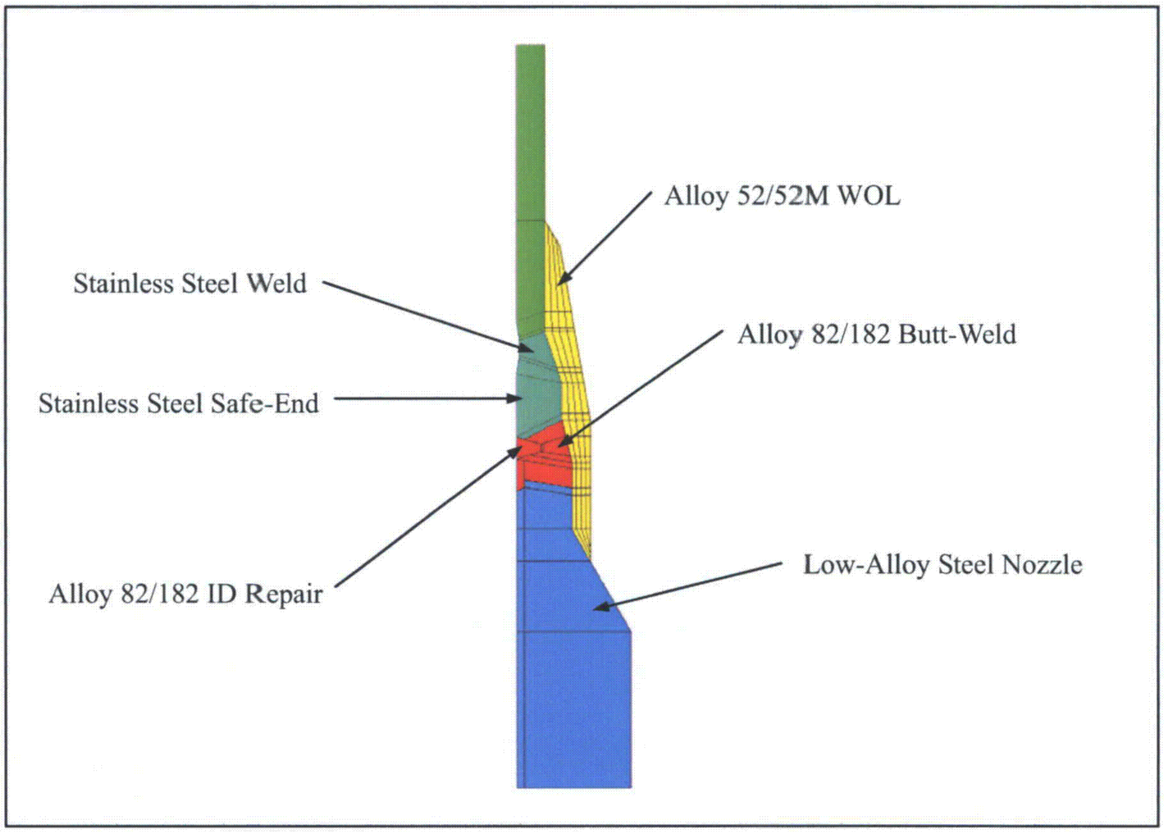

Figure 6-2: ANSYS Model of Safety and Relief Nozzle

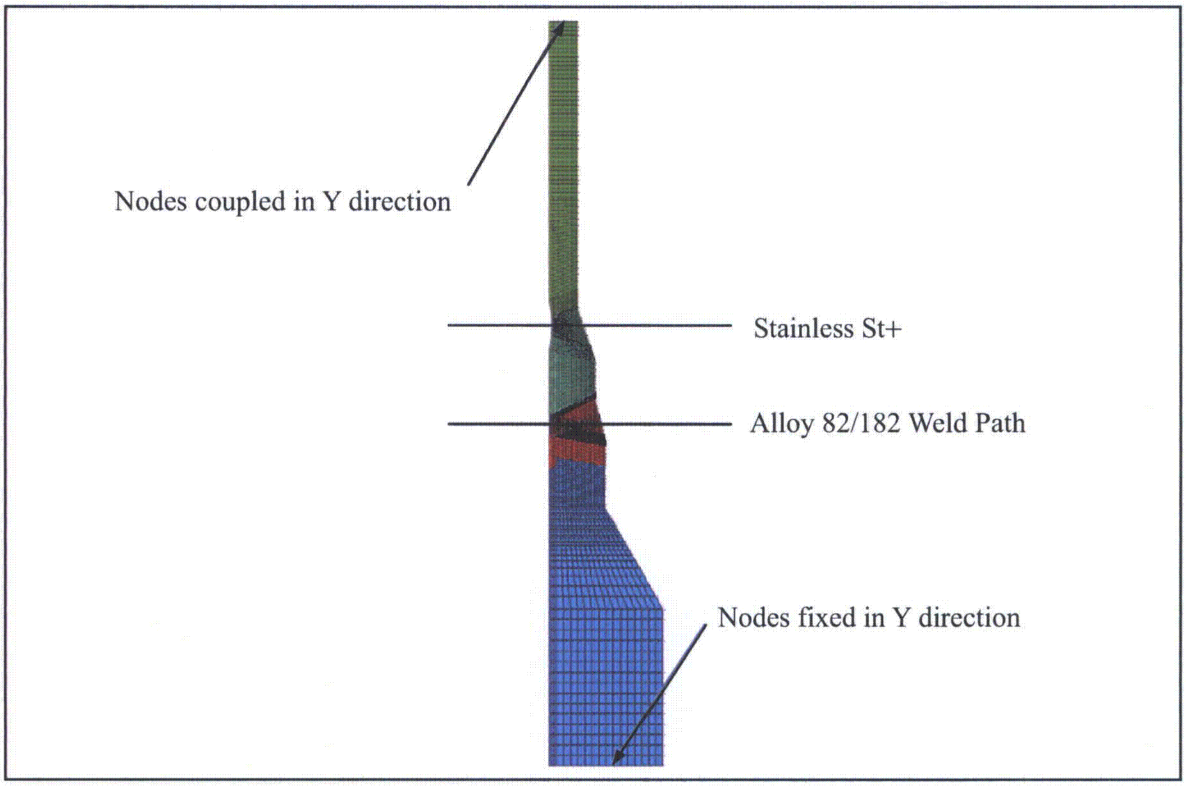

Figure 6-3: View of the Mesh and Path Locations: Safety/Relief Nozzle

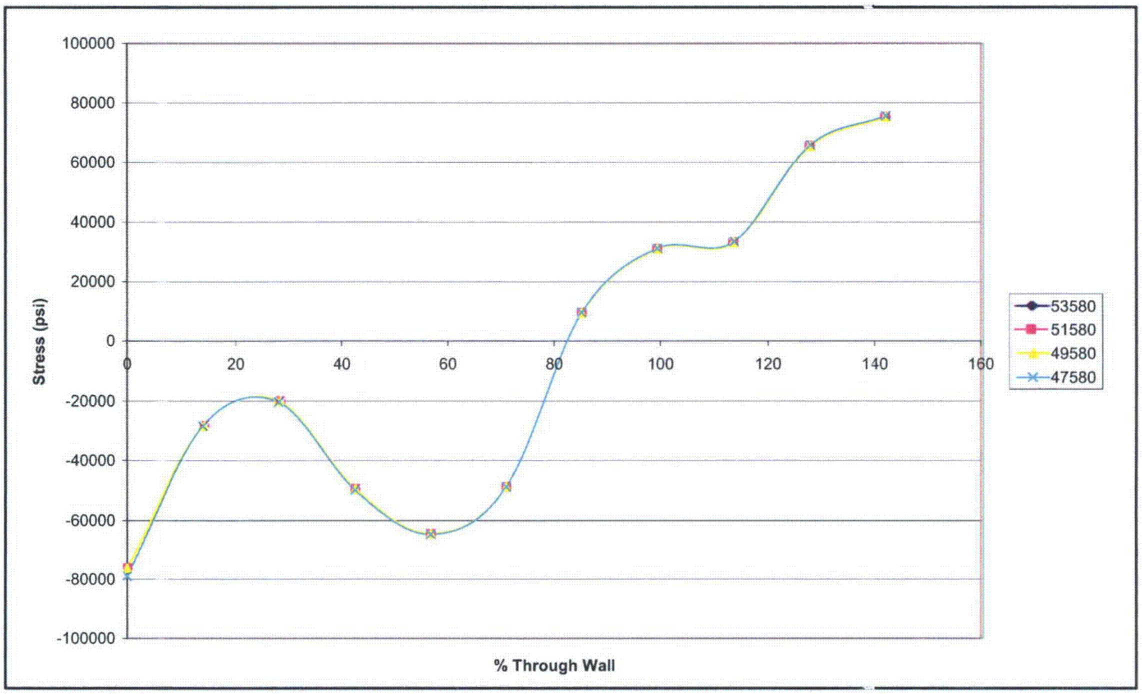

Figure 6-4: Axial Residual Stresses in the Alloy 82/182 Weld at Operating Conditions*

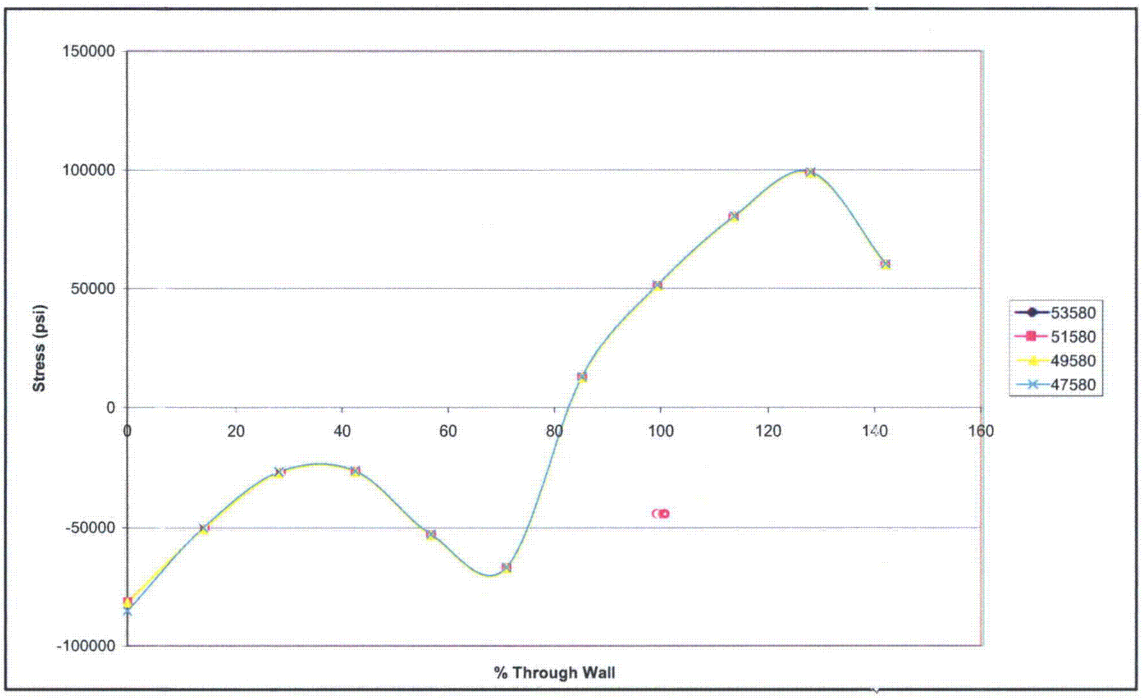

Figure 6-5: Hoop Residual Stresses in the Alloy 82/182 Weld at Operating Conditions*

*Note: The percent through-wall indicated on the horizontal axis is expressed in terms of the original pipe wall thickness. The weld overlay region is the region beyond 100 % wall thickness.

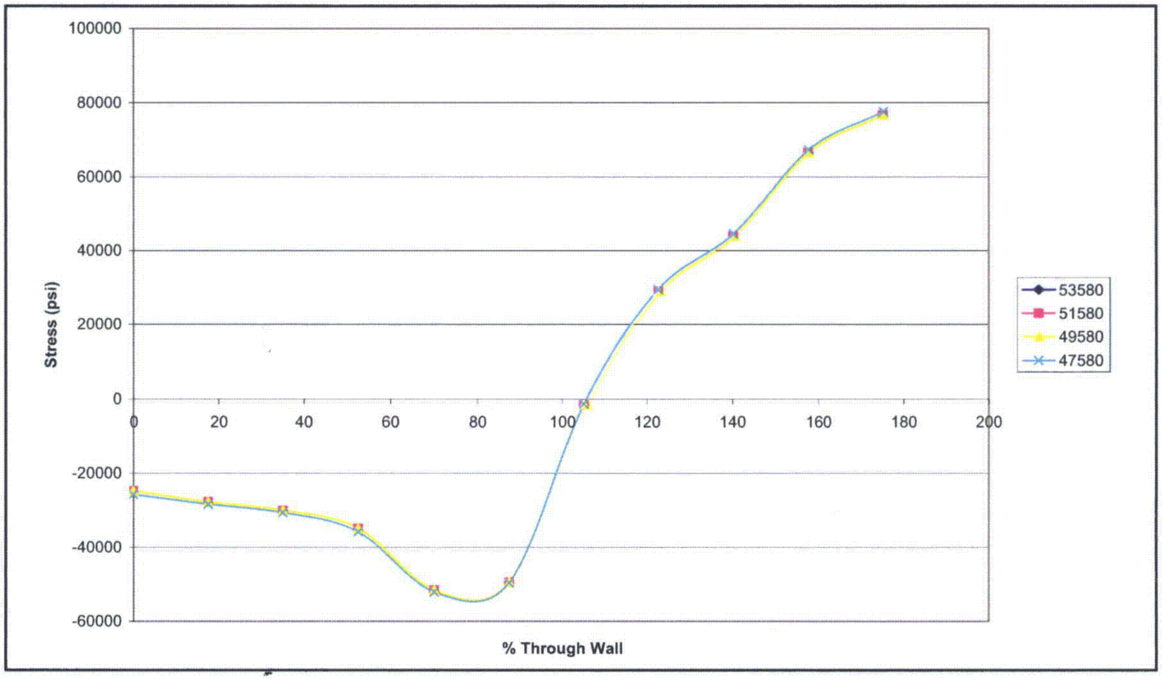

Figure 6-6: Axial Residual Stresses in the Stainless Steel Weld at Operating Conditions*

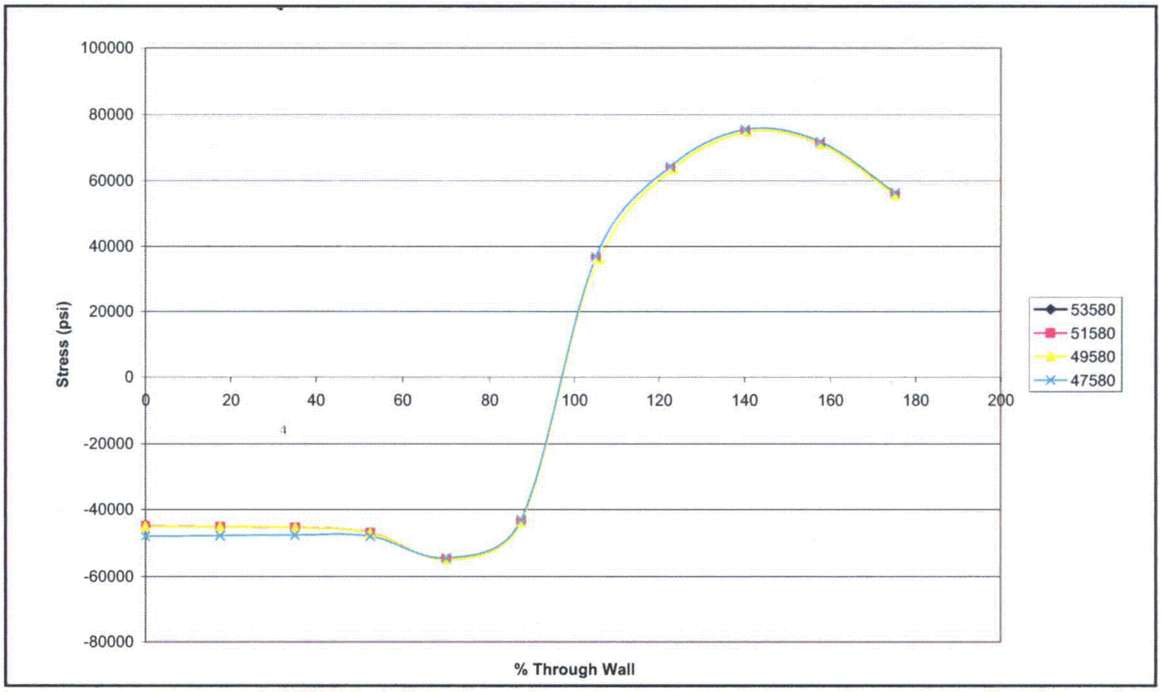

Figure 6-7: Hoop Residual Stresses in the Stainless Steel Weld at Operating Conditions*

*Note: The percent through-wall indicated on the horizontal axis is expressed in terms of the original pipe wall thickness. The weld overlay region is the region beyond 100 % wall thickness.

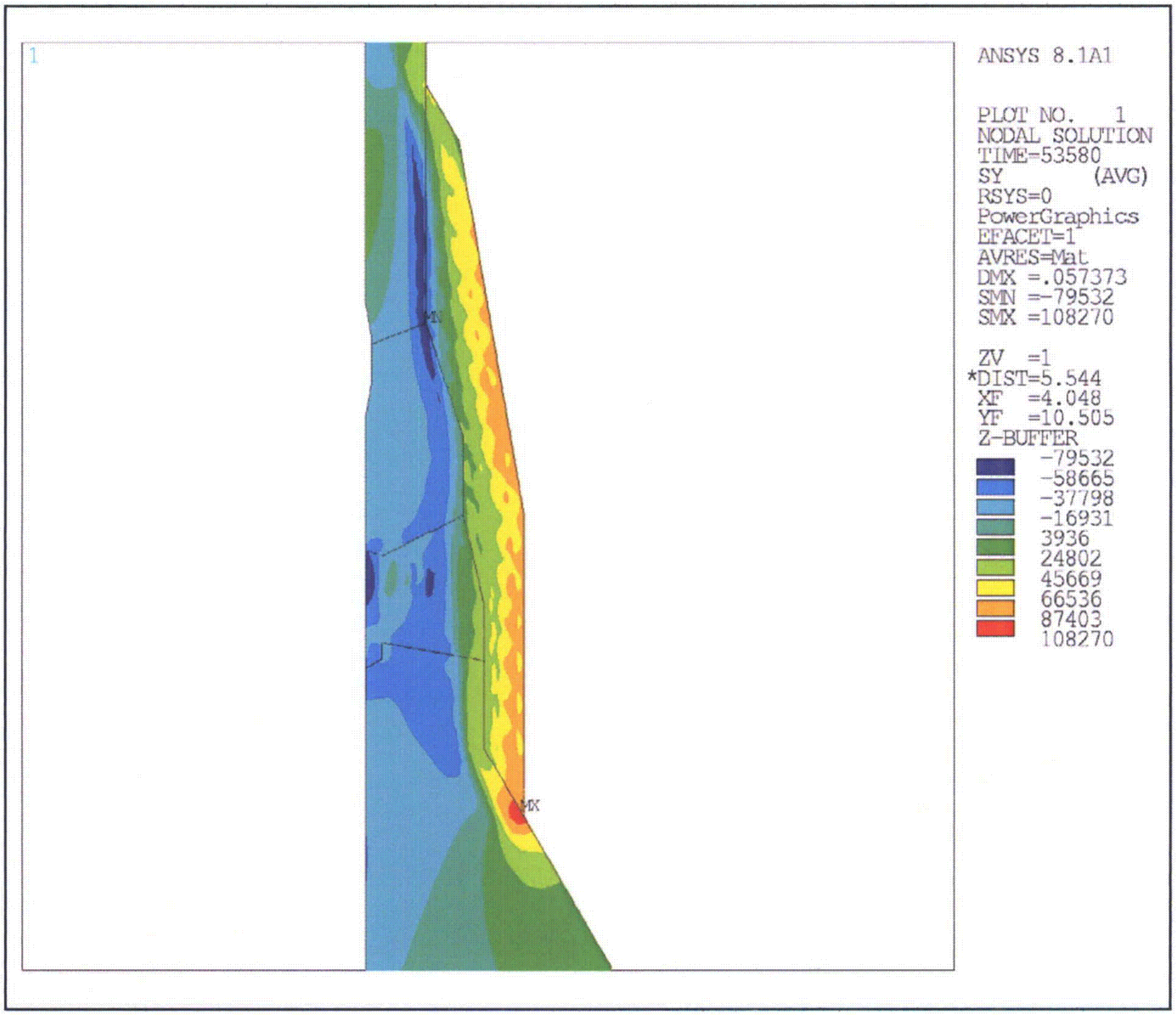

Figure 6-8: Axial Stress (psi) Contour Plot at Operating Conditions after the Weld Overlay

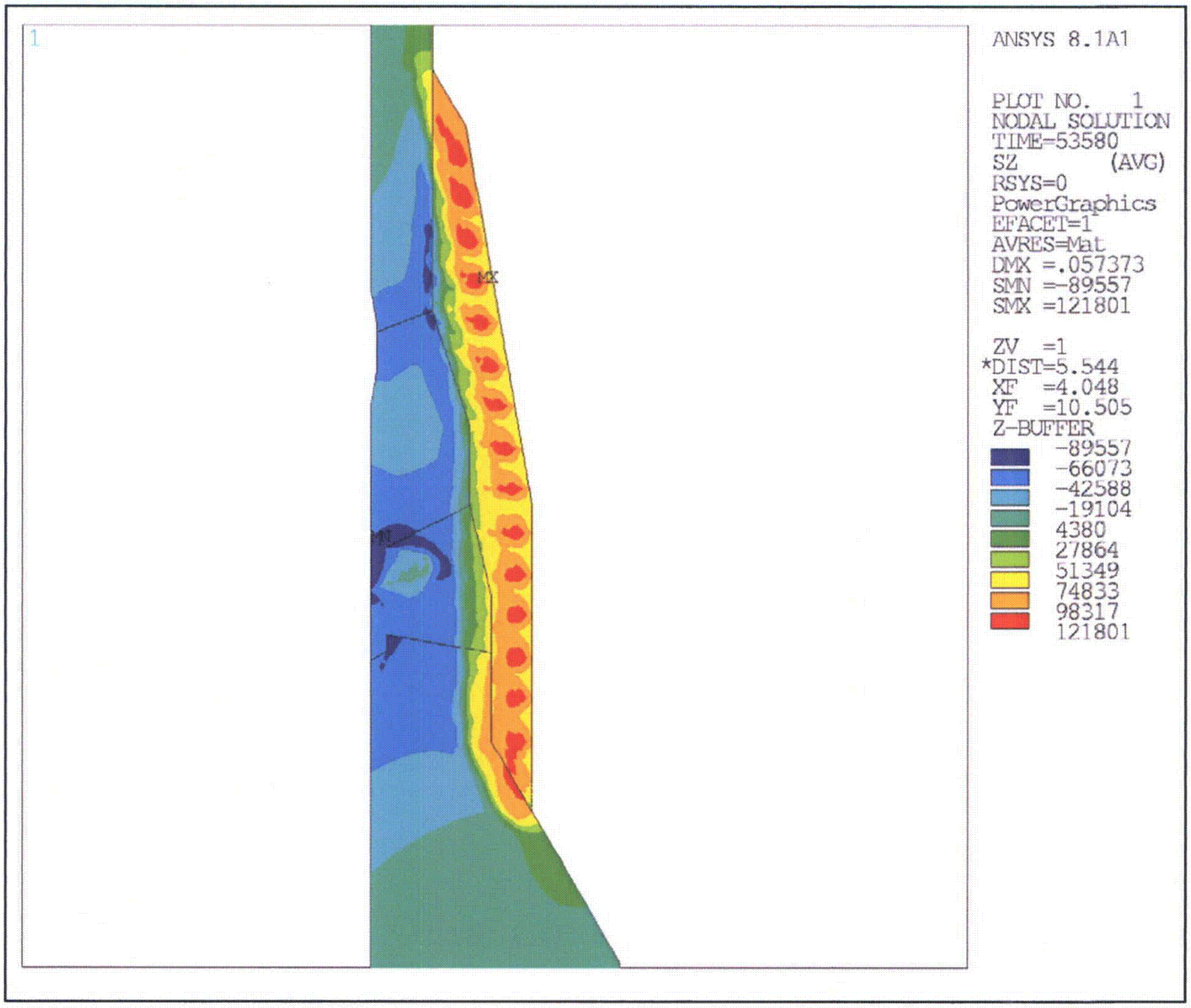

Figure 6-9: Hoop Stress (psi) Contour Plot at Operating Conditions after the Weld Overlay

6.5 FATIGUE CRACK GROWTH RESULTS AND ESTIMATE OF WELD OVERLAY DESIGN LIFE: SAFETY AND RELIEF NOZZLE REGION

The methodology used to determine fatigue crack growth is described in Section 4.4. Fatigue crack growth analyses were performed for the safety and relief nozzles using the through-wall stress distribution including residual stresses generated from the weld overlay mitigation/repair process and the thermal transient stresses.

The weld overlay service life is a function of the flaw depth found in the region being overlaid, and the projected growth of that flaw. The limitation on the maximum flaw depth is 75 % of the piping wall thickness (including the weld overlay thickness), per Section XI, IWB 3640 [6].

A range of possible flaw sizes, ranging from small depths of 5% of the original wall depth on the inside surface to a maximum depth of 100% of the original design wall thickness, were postulated in the fatigue crack growth evaluations. The results of these evaluations for the flaw depths less than the original design wall thickness have been plotted, in Figures 6-10 and 6-11, in the form of expected time for these flaws to reach the interface between the original wall and the newly laid weld overlay material. Figure 6-10 shows results for the Alloy 82/182 weld, and Figure 6-11 shows results for the stainless steel weld. For the maximum possible flaw depths of 100% of the original design wall thickness propagating into the Alloy 52/52M weld overlay material, results are shown in Figure 6-12. This figure shows the estimated flaw depth with time for the design cycles spread over either the original design life or the extended life of the plant.

Figures 6-10 and 6-11 provide expected time in years for the initial flaw depth to reach the weld metal interface based on 100% of the original design transient cycles for 40 years of plant operation. In Figure 6-10, the vertical axis is the estimated time in years, and the horizontal axis is the initial flaw depth to the original wall thickness ratio. The initial flaw depth is determined based on examination. The curves show the maximum estimated time for the flaw to reach the weld metal interface for a specified initial flaw depth. Results are provided for both axial and circumferential flaws. For example, if a circumferential flaw with a depth of 70% of the original wall thickness was found, the estimated time for it to reach the weld metal interface, and, therefore, the remaining service life, would be 100% of the original design cycles.

For the case of an initial flaw depth of 100% of the original wall thickness, which is essentially a through-wall flaw, Table 6-9 and Figure 6-11 show that the total flaw growth into the newly laid Alloy 52/52M welds material in one 10-year inspection interval is less than 10 mils. The final flaw depth after the 10-year period with the fatigue crack growth considered is still within 75% of the total post-WOL wall thickness, as required by SWOL criteria.

Two examination scenarios exist: a pre-overlay examination and a post-overlay examination. If an examination found no flaws, the overlay service life would be governed by the largest flaw that might have been missed by the examination. For an examination performed prior to the weld overlay installation, a conservative approach would be to assume that the flaw depth is 10% of the original wall thickness. Alternatively, this would be 75% of the original wall for an examination performed after the weld overlay installation. This is because the area required to be inspected after the overlay is only the outer 25% of the original pipe thickness plus the overlay thickness itself. The PDI qualification blocks do not contain any flaws in the inner 75 % of the pipe wall; therefore, it would be conservative to assume such a flaw for the qualification. As shown in Figure 6-10, a circumferential flaw as deep as 75% would result in a remaining service life of 100% of the original design cycles. If the design cycles are assumed to be spread over 40 years of plant operation, the remaining life of the SWOL would be 40 years. This is well beyond the required 10-year in-service inspection (ISI) interval. If, after the next ISI, no flaws are detected in the outer 25% of the original welds, the SWOL life is 40 years from the time of the latest inspection.

In the unlikely event that the post-overlay inspection detected a flaw that is as large as the full depth of the original design wall thickness, the expected service life of the weld overlay is at least one 10-year inspection interval period. For the safety and relief nozzles, flaw growth rate into the weld overlay material is small or negligible, indicating that the expected service life of the repair would be 100% of the original design cycles.

As an example, if an axial flaw that is 95% through the original Alloy 82/182 wall thickness is detected as a result of the post weld overlay inspection, and conservatively assuming that the current 40-year design transient cycles are spread evenly for only 40 years, the expected time for the flaw to reach the weld metal interface or 100% of the original wall thickness, from Figure 6-10, is approximately 19 years. If it is assumed that the design transient cycles are spread evenly for 60 years, the time to reach the weld metal interface would be 29 years. This can also be determined by applying a factor of 1.5 to the service life, based on the 40-year design cycles. For a similar size circumferential flaw, the expected time to reach the weld metal interface is approximately two years, based on current 40-year design transient cycles assumed to be spread evenly over 40 years. Then, the flaw would propagate in to the Alloy 52/52M weld overlay material at a significantly lower rate, and would have a total growth of just under 10 mils during the 40-year original design or the 60-year extended life period. Since the typical in-service inspection interval is 10 years for this initial flaw depth of 95%, it can be concluded that the sizing of the structural weld overlay is adequate up to and beyond the next inspection period, based on the current 40-year design transient cycles spread evenly over the next 40 years.

PWSCC is not an issue for the stainless steel weld, and no adjustment of Figure 6-11 is necessary.

The actual time required to use the remaining design cycles depends on plant operating practice.

Table 6-9: Safety/Relief Nozzle Alloy 52/52M FCG Data – Circumferential Flaw

Nozzle Thickness (in)	Initial Flaw Depth (in)	Final Flaw Depth in 10 years (in)	Total Flaw Growth in 10 years (in)
1.731	1.321	1.327	0.007

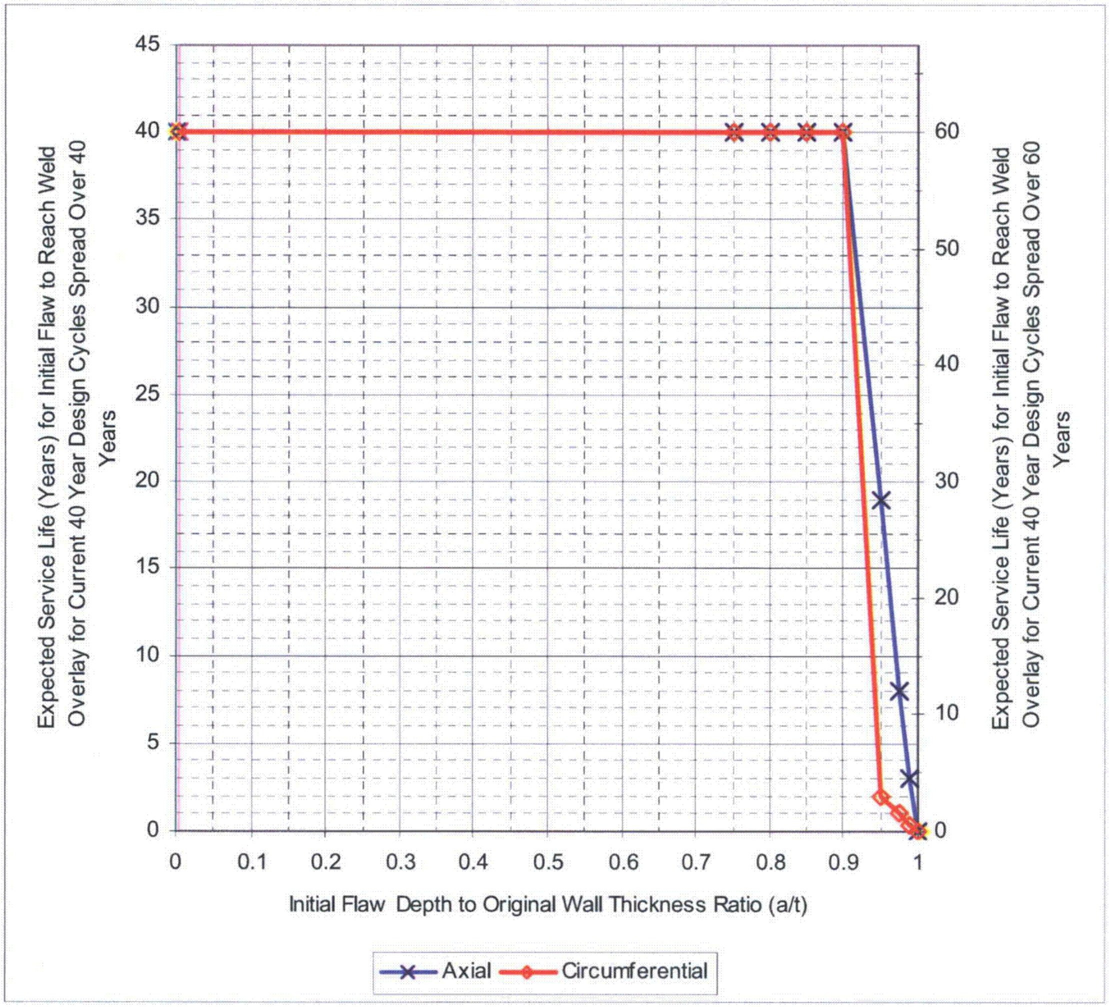

Figure 6-10: Expected Time for the Initial Flaw Depth to Reach the Weld Metal Interface for Safety/Relief Nozzles Alloy 82/182 Weld

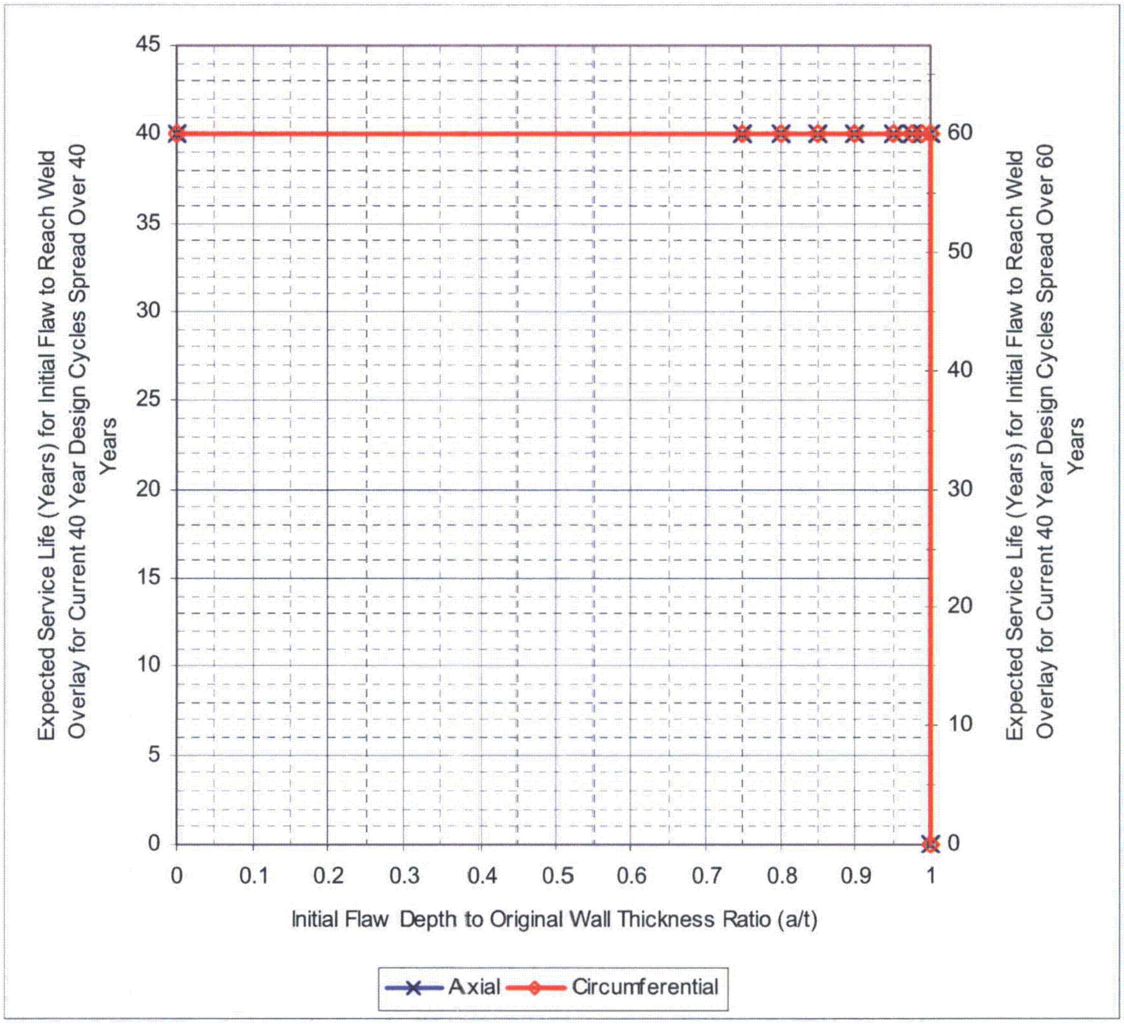

Figure 6-11: Expected Time for the Initial Flaw Depth to Reach the Weld Metal Interface for Safety/Relief Nozzles Stainless Steel Weld

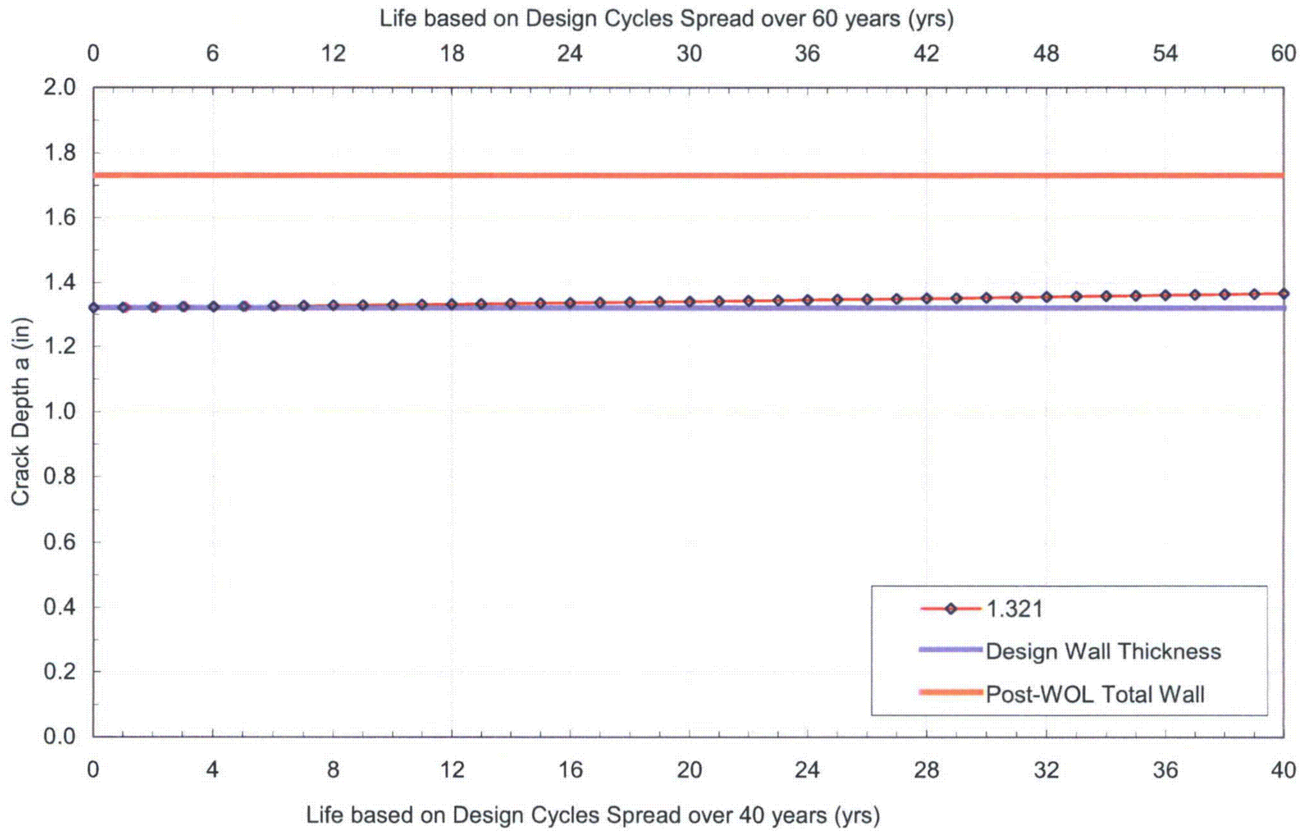

Figure 6-12: Flaw Growth versus Service Period in Alloy 52/52M at the Alloy Weld

6.6 IMPACT ON DESIGN QUALIFICATION OF NOZZLE AND PIPE

The impact of the weld overlay is evaluated to demonstrate that the presence of the weld overlay repair does not have any adverse impact on the existing stress qualification of the pressurizer safety/relief nozzle with respect to the ASME Section III Code of Construction. The applicable Codes of Construction are [28] for the pressurizer safety/relief nozzles for Unit 3.

The evaluation of the effect of the weld overlay on the nozzle has concluded that there is no adverse impact on the Section III qualification of the nozzle. Therefore, the allowable piping reaction nozzle loads are also not impacted.

Effects of Structural Weld Overlay on the Existing Section III Analysis

Since the intention of the structural weld overlay is to mitigate/repair the potentially cracked dissimilar-metal butt-weld at the pressurizer safety/relief nozzle safe-end, the crack growth analyses discussed in Section 7.5 using the ASME Code Section XI methodology are acceptable bases to address the fatigue qualification of the weld overlay region for the safety/relief nozzle.

The effects of the overlay on the existing stress results and fatigue qualification of the safety and relief nozzles are evaluated by a comparative evaluation using finite element analysis. Although the evaluation was performed for a spray nozzle, the evaluation conclusions are also considered applicable to the safety and relief nozzles, based on similarities in design and materials.

The study compares mechanical and thermal transient stresses using finite element models of the spray nozzle with and without the weld overlay. Stresses in the original butt-welds without the weld overlay are compared to the stresses after the weld overlay is installed. Details of this analysis are presented below.

The weld overlay was evaluated to determine its impact on stresses resulting from design and service condition loadings. This is required per ASME Code Case N-740-2(b)1.

> *The axial length and end slope of the weld overlay shall cover the weld and heat-affected zones on each side of the weld and provide for load redistribution from the item into the weld overlay and back into the item without violating applicable stress limits of NB-3200 or the construction code.*

This has been demonstrated for the pressurizer spray nozzles by a comparative evaluation using finite element analysis of the nozzle with the overlay and without the overlay.

The overlay, based on inspection requirements, covers the pressure boundary material associated with the A82/182 dissimilar-metal (DM) weld as well as the stainless steel safe-end- to-pipe component weld. Of these components, the stainless steel weld is limiting from a Section III standpoint because of the following:

- Smaller cross-section area and section modulus, therefore higher stresses for equivalent nozzle loads

- Lower allowable stress intensity (S_m)
- Higher stress indices (as-welded butt weld versus machined flush weld)
- For the spray nozzle, the stainless weld is not covered by the thermal sleeve and therefore is subject to higher thermal transient stresses
- Based on this limiting condition, the Section III design basis results currently documented for the stainless steel weld are considered controlling for the nozzle, as compared to the DM weld.

Based on this limiting condition, the Section III design basis results currently documented for the stainless steel weld are controlling for the nozzle, as compared to the dissimilar-metal weld.

The effects of the weld overlay on the existing stress results and fatigue for the spray nozzle were evaluated by finite element analysis. The analysis was used to evaluate the model for mechanical and thermal transient stresses with and without the weld overlay. Figures 6-13 and 6-14 shows the stress cuts applied to the with-overlay model and the without-overlay model. The evaluation compares the stresses in the original butt-welds without weld overlay to the stresses after the weld overlay is installed at the pipe-to-overlay transition region. The ratios of stress intensities are listed in Table 6-10 below. They are a comparison of the with-overlay to without-overlay stress intensities at the critical locations. Numbers less than 1.0 represent a reduction in comparative stress due to the weld overlay application. It is shown that the thermal transient stress intensity results are less severe with the weld overlay than without the weld overlay at all locations. The with-overlay stresses resulting from mechanical loads are less than or approximately equal to the without-overlay configuration except for the total stress due to the torsion load. However, these stresses are much less controlling than the thermal stresses, which were shown to improve as a result of the weld overlay.

Since the thermal transient loading for the safety and relief nozzles is much less severe than that of the spray nozzle, and the fatigue usage factors reported in the pressurizer stress reports [7] are small (less than 0.1), fatigue is not the controlling criterion. It can therefore be concluded that the existing ASME Section III analysis remains applicable for the safety and relief nozzles under the post-weld-overlay condition.

Table 6-10: Ratio of Calculated Stress Intensities with Weld Overlay to without Weld Overlay

Case	Inside		Outside	
	Membrane plus Bending	Total	Membrane plus Bending	Total
Pressure	0.96	0.96	0.82	0.94
Bending	0.93	0.76	0.76	1.01
Torsion	0.94	0.83	0.94	1.08
Thermal	0.79	0.84	0.78	0.69

Additionally, a study was performed on a representative nozzle to address the impact on these results if the SWOL was doubled from the target or minimum thickness. The results of this comparison show that similar stress results are produced in the minimum and doubled overlay thickness.

Also, in support of the Section III Evaluation previously discussed for the nozzle to pipe interface, stress and fatigue analyses were performed in accordance with the ASME Section III guidelines for ASN 2 and

3, as shown in Figure 6-15. The results are considered representative of the nozzle to pipe interface. The results are used to demonstrate that the stresses and cumulative fatigue at the discontinuity meet ASME Section III limits.

Primary Stress

Primary stress limits are generally addressed based on the NB-3600 equations. Addition of the SWOL does not affect the B indices or the loads from the piping, but increases the section modulus in the overlay region. The applicable primary loads (pressure and mechanical loads) are not changed by the SWOL. Therefore, the primary stresses in the structures with SWOL are, by definition, less than or equal to those without SWOL, and the previous qualifications, performed for the surge line weld to nozzle safe end, apply.

Primary plus Secondary Stress

A simplified elastic plastic analysis was performed for ASN 2 and 3. The results of the simplified elastic plastic analysis were used to include the applicable Ke penalty in the fatigue usage factor estimation, and the remaining criteria of NB-3228.5 were checked and shown to be acceptable.

Expansion Stress

A simple approach to address the thermal expansion stress is to use the maximum thermal moment range with the minimum pipe section property and applicable piping C2 stress index from NB-3683. The results (20.23 ksi) are shown to be within the 3Sm limit for the weakest material in the nozzle SWOL region. The results shown in Table 6-1 of [6] demonstrate that (C2*M)/Z is less than 3Sm; therefore, the expansion stress requirement is satisfied.

Total/Peak Stress

The total/peak stress requirement is met by showing fatigue usage less than 1.0. Conservative analyses for the surge nozzle with SWOL were performed using applicable loads and transients. The results show that a maximum fatigue usage of 0.0042 was achieved at ASN 2, and is considered appropriate for the Code reconciliation. Therefore, the stresses in the structure with SWOL repair can be concluded to be within the Code limits on total/peak stress.

Thermal Stress Ratchet

Thermal stress ratchet requirements were also shown to be met for ASN 2 and ASN 3 using transient loads applicable to the surge nozzle with SWOL. Based on the nature of the geometry and transient loadings, the maximum ratio of thermal membrane plus bending stress at ASN 2 is 0.35, and the allowable value is within the limit of 1.0. Therefore, the stresses in the structure with SWOL repair can be concluded to be within the Code limits for thermal stress ratchet.

Therefore, it is concluded that the existing ASME Section III analysis of the referenced safety and relief is not adversely affected by the addition of the weld overlay.

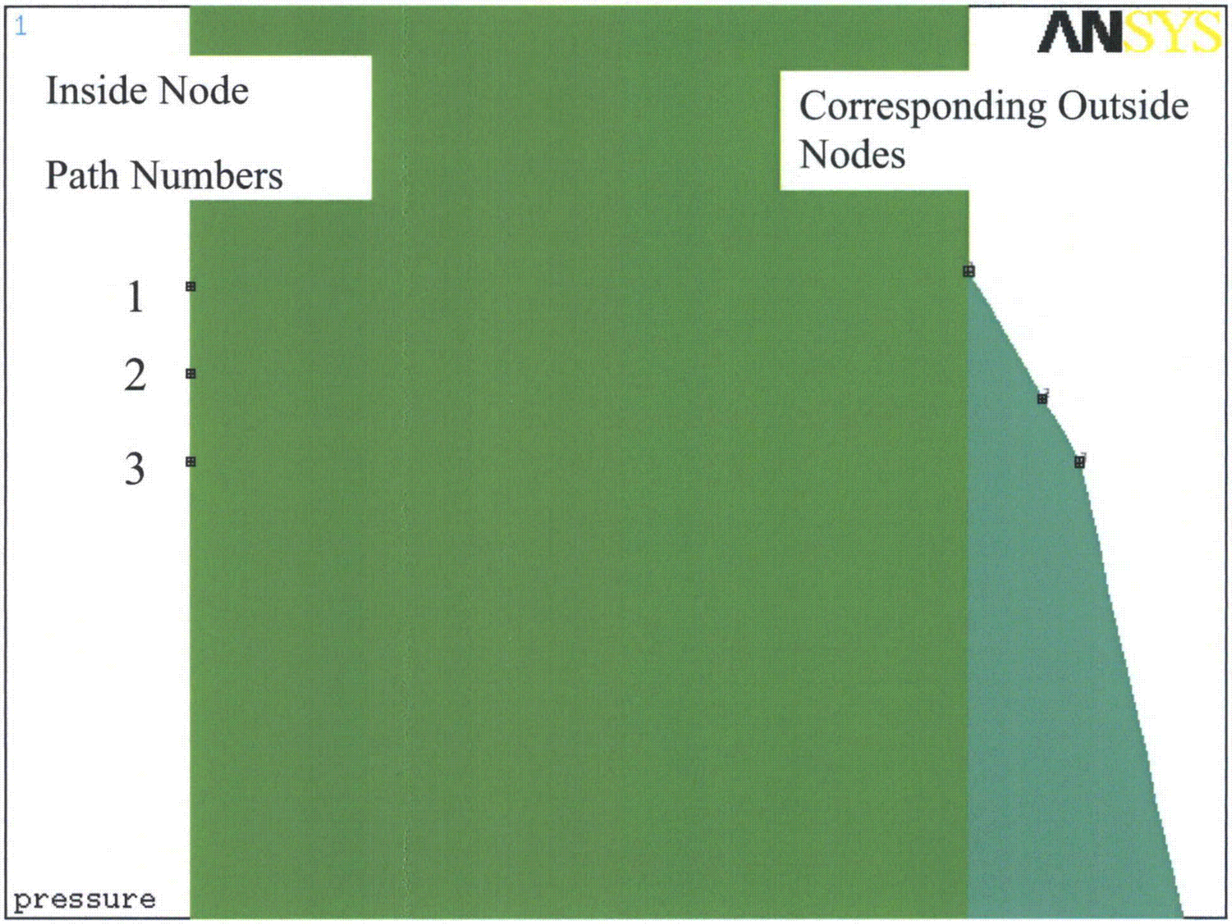

Figure 6-13: Linearization Paths with Weld Overlay

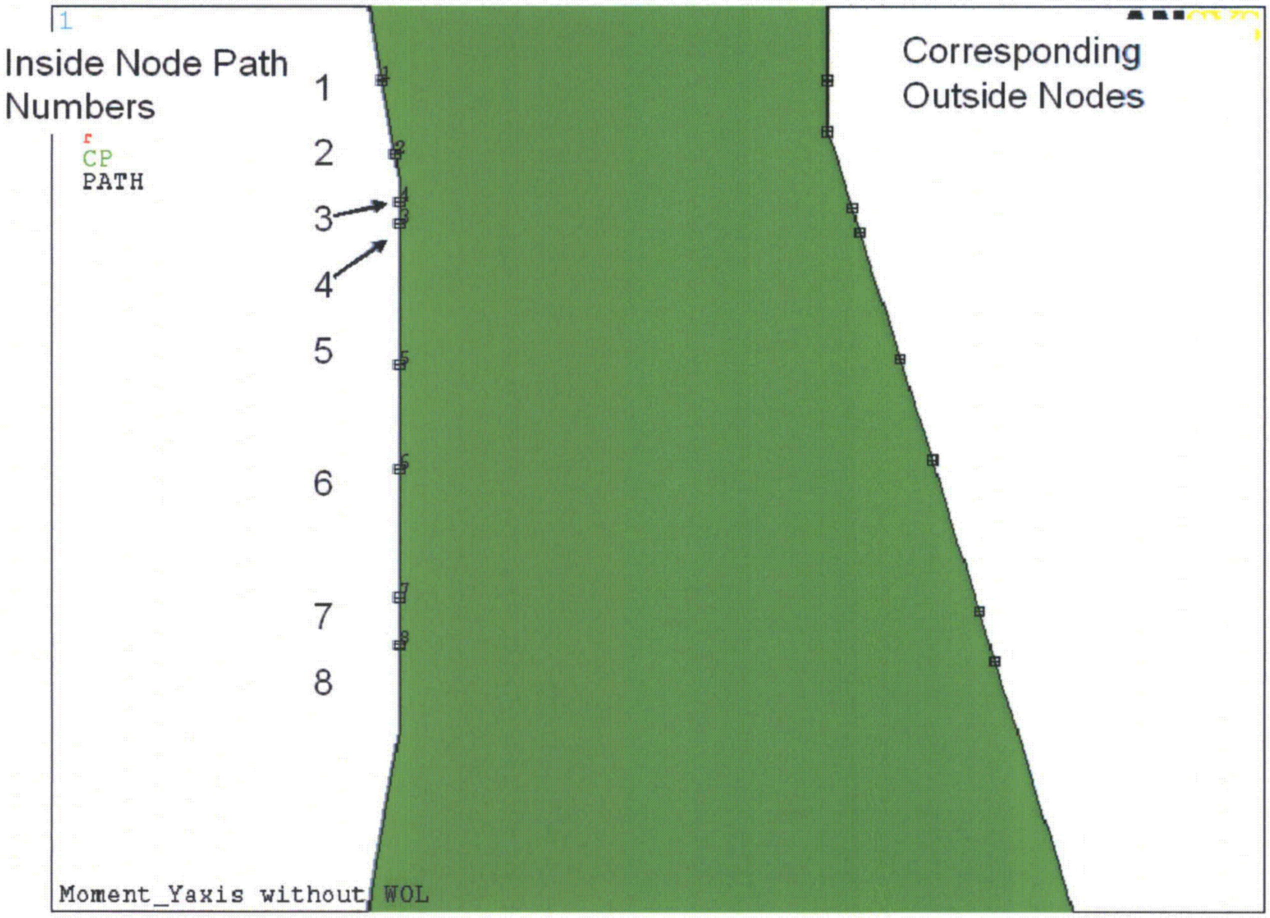

Figure 6-14: Linearization Paths without Weld Overlay

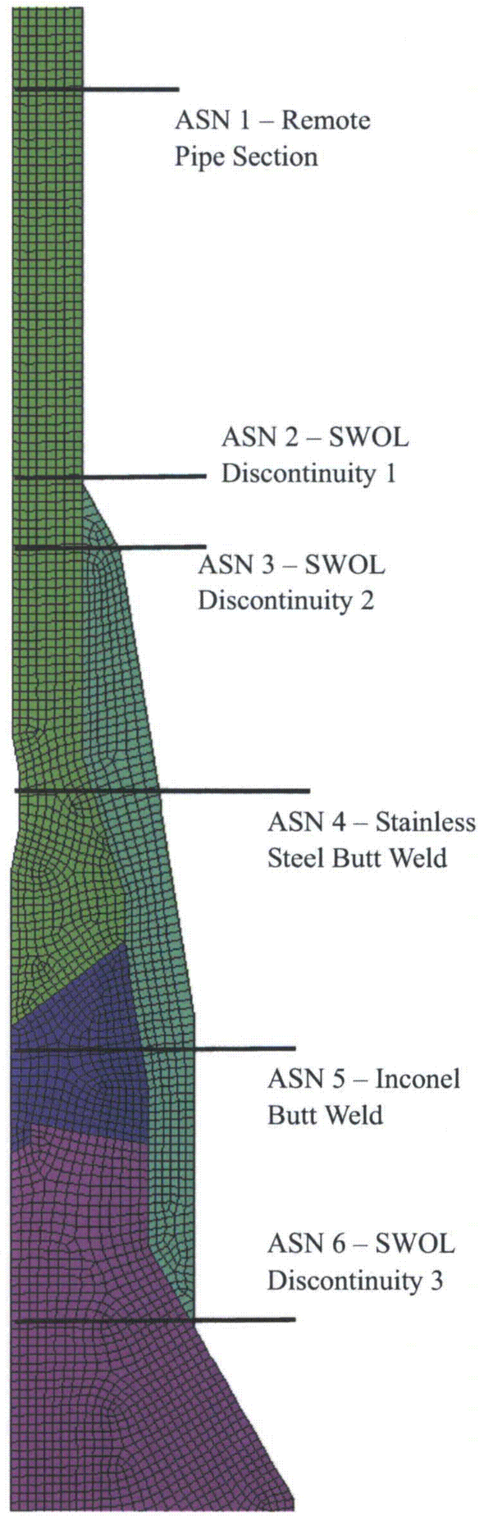

Figure 6-15: Safety and Relief Nozzle ASN Definitions

Effects of Additional Mass and Weld Shrinkage on Piping/Support System

The effects of SWOL on the piping/support system, including mass and shrinkage effects, shall be documented in a separate report addressing piping stress reconciliation.

7 WELD OVERLAY DESIGN QUALIFICATION ANALYSIS: SURGE NOZZLE

7.1 INTRODUCTION

This section provides the structural weld overlay design qualification analysis to demonstrate the adequacy of the SWOL design for the pressurizer surge nozzle. The effectiveness of a weld overlay with Alloy 52/52M weld material is demonstrated using crack growth analysis per IWB-3640 of [6], to ensure that the SWOL does not deteriorate during service. Using the residual weld stresses developed by the finite element model of the weld overlay process, future crack growth was evaluated at the surge nozzle safe-end weld locations using the operational design transients affecting the weld overlay region. The advantage of the Alloy 52/52M material is its high resistance to PWSCC, which minimizes the possibility for future PWSCC crack growth. Since the purpose of the SWOL is to mitigate/repair a potentially cracked dissimilar-metal butt-weld, performing crack growth analyses using the ASME Code Section XI methodology is the accepted method used to address the fatigue qualification of the weld overlay region for the pressurizer surge nozzle.

The effect of the SWOL on the existing fatigue qualification of the pressurizer surge nozzle outside the weld overlay region is addressed in accordance with the ASME Section III requirements, considering the effect of the applicable thermal transient stresses, structural discontinuities, and bimetallic effects resulting from the SWOL. The impacts of weld shrinkage from the overlay are also addressed.

7.2 LOADS

Under certain operating conditions, sudden changes in RCS mass inventory may cause fluid to enter the pressurizer (insurge) or exit the pressurizer (outsurge) through the pressurizer surge nozzle in the lower head. When there is a steam bubble in the pressurizer, the fluid in the pressurizer is typically at the saturation temperature corresponding to system pressure. The temperature of the fluid in the reactor coolant loop (RCL) hot leg is lower than that in the pressurizer. The temperature differences typically vary between 30°F and 320°F, depending on the plant mode of operation. The largest temperature differences occur during heatup and cooldown transients. When a significant insurge occurs, the cooler fluid entering the pressurizer may produce a temperature transient, cooling the surge nozzle. In some cases, a subsequent outsurge may also produce a transient that heats the nozzle back to the initial pressurizer fluid temperature. The pressurizer surge nozzle SWOL qualification considered postulated insurges and outsurges during heatup and cooldown operations and also various other plant operating transients including the effects of thermal stratification [34]. The insurge/outsurge transients documented in WCAP-14950 [31] will be applied in order to account for the insurge/outsurge issue documented in [31]. In particular, the transient set listed in Table 5-7 of [31], "Modified Steam Bubble Method and Nitrogen Bubble Method Heatup and Cooldown...Cooldowns" will be used for heatup and cooldown. The other transients as they relate to insurge/outsurge will be considered consistent with the methods outlined in [31].

The thermal transients and the number of occurrences of these transients over the design life of the surge nozzle are needed to perform fatigue crack growth analyses and ASME Section III fatigue reconciliation. The thermal transients that were used for the analysis of the reference pressurizer surge nozzle are summarized in Table 7-1. These transients were determined to be bounding for the Millstone transients, which are specified in [7], [30] and [33].

The piping reaction loads used for the design of the SWOL are shown in Table 7-2. These loads are listed in [2] and specified in [32]. The load combinations considered in the weld overlay design are listed in Table 7-3. The thermal piping reaction loads used for fatigue reconciliation are shown in Table 7-4. These nozzle loads are bounding for the actual Millstone nozzle loads.

Table 7-1: Summary of Design Transients for Reference Surge Nozzle		
Transient ID	**Transient Title**	**Total Events**
1	HU330	8
2	HU320	8
3	HU290	3
4	HU280	2
5	HU270	5
6	HU250	2
7	CD360	2
8	CD340	2
9	CD320	6
10	CD310	2
11	CD290	2
12	CD270	5
13	CD250	7
14	CD240	2
15	MOPHU320	34
16	MOPHU290	43
17	MOPHU280	52
18	MOPHU270	43
19	MOPHU250	0
20	MOPCD320	26
21	MOPCD310	52
22	MOPCD290	43
23	MOPCD270	34
24	MOPCD250	17
25	MOPCD240	0
26	Unit Loading EPU	18,300
27	Unit Unloading EPU	18,300
28	Small Step-Load Decrease EPU	2,000
29	Large Step-Load Decrease	200

Table 7-1: Summary of Design Transients for Reference Surge Nozzle (cont.)		
Transient ID	**Transient Title**	**Total Events**
30	Feedwater Cycling EPU	4,000
31	Normal Loop Shutdown	150
32	Loss of Load EPU	80
33	Loss of Power EPU	40
34	Partial Loss of Flow EPU	80
35	Inadv. RCS Depressurization	30
36	Pressure Group A EPU	2,000
37	Pressure Group B EPU	90
38	Pressure Group C EPU	480
39	Pressure Group D	50
40	Primary Hydro Group	410
41	OBE 20 Cycles	20(1)

Note:
1. 20 occurrences, each with 20 stress cycles

Table 7-2: Enveloping(1) Surge Nozzle Loads used for SWOL Design				
Load Type	**Axial(2) F_x (kips)**	**Torsion(2) M_x (in-kips)**	**Bending(2) M_y (in-kips)**	**M_z (in-kips)**
DW	2.52	0.23	19.61	25.39
TH	28.10	608	2544	1553
LOCA	2	120	180	120
OBE	0.41	72.72	102.42	54.62
SSE	0.49	80.40	102.92	64.81

Notes:
1. The loads used in the surge nozzle fatigue crack growth calculations bound the Millstone specific design loads [32] for Unit 3, which remain unchanged as a result of the application of the weld overlay.
2. F_x = axial force; M_x = torsion moment; M_y, M_z = bending moments

Table 7-3: Load Combinations

Load	Pressurizer[1]	Surge Piping[2]
Design	P + DW + OBE	P + DW
Normal	P_A + TH + DW	P_A + TH + DW
Upset	P_B + TH + DW + OBE	P_B + TH + DW + OBE
Faulted	P_D + DW + RSS[3] (LOCA, SSE)	P_D + DW + TH + SSE + LOCA
Test	P + DW	P + DW

Notes:
1. Based on pressurizer stress report [7]
2. Based on pipe end loads [32]
3. RSS indicates that the root-sum-of-the-squares method is to be used

P = Internal Pressure (subscripts A, B, C, and D indicate service levels)
DW = Deadweight
TH = Thermal (including thermal stratification)
OBE = Operating Basis Earthquake
LOCA = Loss of Coolant Accident
SSE = Safe Shutdown Earthquake

Table 7-4: Enveloping[1] Surge Nozzle Thermal Load Cases for Fatigue Crack Growth

Case	T_{pzr}[2] (°F)	T_{rc}[2] (°F)	DT_{pipe}[2] (°F)	Torsion[3] M_x (in-kips)	Bending[3] M_y (in-kips)	M_z (in-kips)
1	455	135	272	94.7	1680.6	710.4
2	455	135	0	252.0	-171.9	485.5
3	653	450	203	356.6	1231.4	885.5
4	653	617	36	513.3	63.7	679.5

Notes:
1. The loads used in the surge nozzle fatigue crack growth calculations are bounding for the Millstone specific design loads [32], which remain unchanged as a result of the application of the weld overlay.
2. T_{pzr} = pressurizer temperature; T_{rc} = reactor coolant temperature; DT_{pipe} = temperature difference in pipe
3. M_x, = torsion moment; M_y, M_z = bending moments

7.3 WELD OVERLAY DESIGN SIZING

The minimum weld overlay thickness was determined based on a through-wall flaw in the original pipe. The methodology used to determine the weld overlay design thickness and length is discussed in Section 3. Using the methodology described in Section 3, radii from the design geometry, as shown in Table 7-5, are used to design the minimum SWOL parameters. As-designed inside and outside radii at the thickest portion of the Alloy 82/182 and stainless steel welds are presented here. The thickest portion results from considering the smallest inner radius ($R_{i\text{-}min}$) and the largest outer radius ($R_{o\text{-}max}$). Using the thickest section in sizing the overlay results in a conservative design thickness and length. The weld overlay length was based conservatively on the recommended length, per Code Case N-740, of:

$$L_{WOL} = 0.75\sqrt{Rt}$$

Where,

R = $R_{o\text{-}max}$ = outside radius

t = $R_{o\text{-}max} - R_{i\text{-}min}$ = wall thickness at the location of indication

It should be noted that the weld overlay length (L_{WOL}) will extend from the weld/base metal interface on either side of the Alloy 82/182 and stainless steel welds as shown in Figure 7-1. The weld overlay thickness (t_{WOL}) was determined by the following equation:

$$t_{WOL} = t/0.75 - t$$

The minimum design weld overlay dimensions are shown in Table 7-6.

In accordance with ASME Section XI IWB-3640, the criterion from Section XI, Appendix C is used to evaluate the maximum resulting post-weld-overlay stresses from the actual applied loadings. To determine the applied post-weld-overlay stresses, the minimum post-weld-overlay thicknesses are considered. This results in a conservative method of determining stresses for comparison to the allowable stress criterion. The thinnest portion of the Alloy 82/182 and stainless steel welds results from considering the largest inner radius ($R_{i\text{-}max}$) and the smallest outer radius post-weld-overlay ($R_{o\text{-}min\text{-}WOL}$). These parameters and also the resulting geometric section properties are presented in Table 7-7.

The applied bending stresses were calculated by:

$$\sigma_b = \frac{\sqrt{M_x^2 + M_y^2 + M_z^2}}{Z}$$

where,

M_x, M_y, and M_z are per Table 7-2

Z is per Table 7-7

$$Z = \frac{\pi(R_{o-\min-wol}^4 - R_{i-\max}^4)}{4(R_{o-\min-wol})}$$

Where,

$R_{i\text{-}max}$ and $R_{o\text{-}min\text{-}wol}$ are per Table 7-7

The applied membrane stresses were calculated by:

$$\sigma_m = \sigma_p + \frac{F_x}{A_x}$$

Where,

$$\sigma_p = \frac{\pi R_{i-\max}^{2}}{\pi\left(R_{o-\min-wol}^{2} - R_{i-\max}^{2}\right)} P$$

F_x is per Table 7-2

A_x is per 7-7

$A_x = \pi\ (R_{o\text{-min-wol}}^2 - R_{i\text{-max}}^2)$.

Where,

$R_{i\text{-max}}$ and $R_{o\text{-min-wol}}$ are per Table 7-7

P = 2,485 psig, see Table 7-3.

The allowable stress intensity S_m (at 650°F) used in the sizing of the Alloy 52/52M (N06690) overlay is 23.3 ksi [9]. This allowable is based on the annealed condition of SB-167. The normal operating pressure and design pressure are 2,235 psig and 2,485, respectively. The applicable service condition pressure is required; however, the design pressure is conservatively used to determine all applied loads.

The resulting bending stresses, determined by using the equation shown above and the loads and load combinations from Tables 8-2 and 8-3, respectively, are listed and compared to the Code allowables in Table 7-8.

Table 7-5: Surge Nozzle Geometry for SWOL Design Calculations [2]

Alloy 82/182 Weld			Stainless Steel Weld		
Inside Radius $R_{i\text{-}min}$ (in)	Outside Radius $R_{o\text{-}max}$ (in)	Wall Thickness t_{design} (in)	Inside Radius $R_{i\text{-}min}$ (in)	Outside Radius $R_{o\text{-}max}$ (in)	Wall Thickness t_{design} (in)
5.907	7.515	1.609	5.744	7.410	1.666

Table 7-6: Surge Nozzle Minimum Structural Weld Overlay Design Dimensions [2]

Alloy 82/182 Weld		Stainless Steel Weld	
t_{WOL} (in)	L_{WOL} (in)	t_{WOL} (in)	L_{WOL} (in)
0.69	2.61	0.71	2.64

Table 7-7: Surge Nozzle Geometry for Stress Check in Post-Weld-Overlay Condition [2]

Alloy 82/182 Weld				Stainless Steel Weld			
Inside Radius $R_{i\text{-}max}$ (in)	Outside Radius $R_{o\text{-}min\text{-}WOL}$ (in)	Cross-Sect. Area A_x (in^2)	Section Modulus Z (in^3)	Inside Radius $R_{i\text{-}max}$ (in)	Outside Radius $R_{o\text{-}min\text{-}WOL}$ (in)	Cross-Sect. Area A_x (in^2)	Section Modulus Z (in^3)
6.000	8.025	89.223	279.067	5.754	7.530	74.118	220.998

Table 7-8: Applied and Allowable Post-WOL Bending Stress Comparison for Surge Nozzle [2]

Location	Applied Stress σ_b (ksi)	Allowable Stress(1) P_b (ksi)
Alloy Weld	3.183	7.897
SS Weld	3.527	7.471

Note:
1. The allowable stress is a function of the applied piping membrane stress per ASME Section XI, Appendix C, 3320.

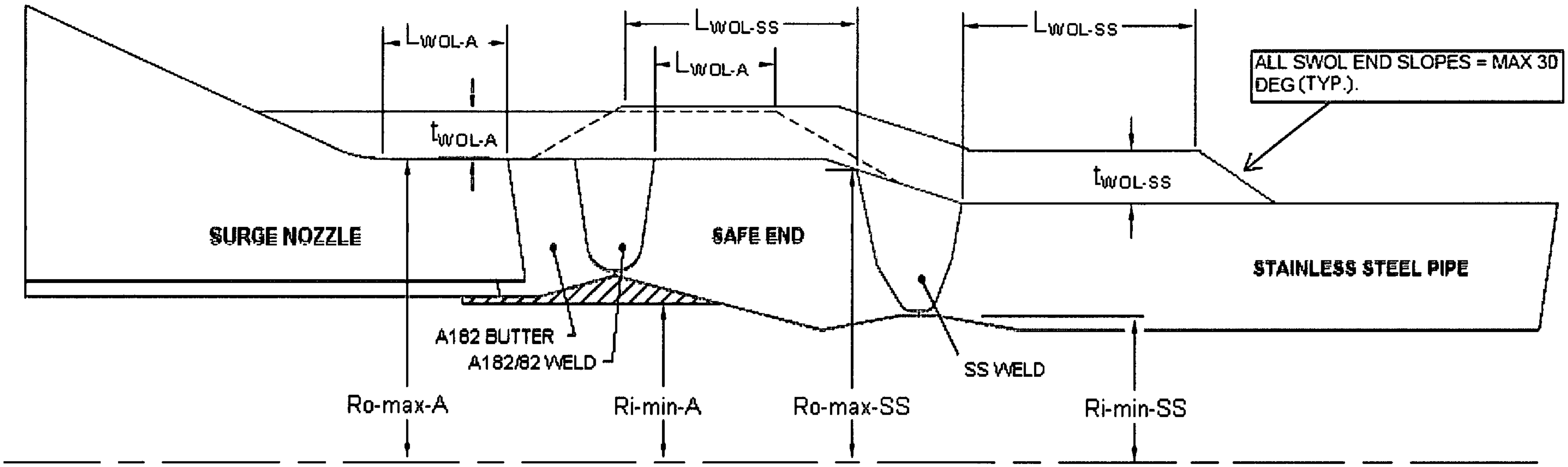

Figure 7-1: Sketch Showing Structural Weld Overlay Design Parameters for the Surge Nozzle
(Not to scale)

7.4 WELD OVERLAY RESIDUAL WELD STRESS RESULTS

The finite element model was developed to capture the parts of the structure in the vicinity of the surge nozzle safe-end with the SWOL repair/mitigation. This includes a portion of the surge nozzle attached to the nozzle safe-end and a length of stainless steel pipe attached to the safe-end. An ID weld repair was considered in the finite element model as discussed in Section 5.3. The overall finite element model is shown in Figure 7-2. The nozzle is fixed in the axial direction to simulate the rest of the nozzle. The stainless steel piping is coupled in the axial direction to simulate the remaining portion of the stainless steel piping not included in the model. The model assumes that a 50 % through-wall weld repair was performed from the inside surface of the surge nozzle to safe-end Alloy 82/182 butt-weld.

The final residual weld stresses, including normal operating pressure and temperature conditions, are shown in Figures 7-4 through 7-7 for selected stress cuts in the Alloy 82/182 and stainless steel welds. The locations of the stress cuts are shown in Figure 7-3. The axial and hoop stress contours in the pressurizer surge nozzle after the weld overlay application are provided in Figures 7-8 and 7-9, respectively.

From Figures 7-4 and 7-5, both the axial and hoop residual weld stresses at normal operating condition resulting from the SWOL are compressive up to about 80 % of the original pipe wall thickness. This stress distribution minimizes the potential for crack growth in the dissimilar-metal weld region. For the stainless steel weld, both the axial and hoop residual weld stresses shown in Figures 7-6 and 7-7, respectively, remain compressive at normal operating conditions for the entire original pipe wall thickness. Therefore, the potential for FCG is minimized.

Acceptable post-weld-overlay residual stresses (i.e., stresses that satisfy the requirements for mitigating PWSCC) are those that are sufficiently compressive over the entire length and circumference of the inside surface of the Alloy 82/182 weld (at operating temperature, but prior to applying operating pressure and loads) that the resulting total stress, after application of operating pressure and loads, remains less than 10 ksi tensile [27]. This target level has been selected as a conservatively safe value, below which PWSCC initiation, or growth of small initiated cracks, is very unlikely. Additionally, the residual plus operating stresses must remain compressive through some portion of the weld thickness away from the inside surface. The residual stresses in the Alloy 82/182 weld of the surge nozzle, resulting from the weld overlay, are well below this stress level through at least 80 % of the original weld thickness. Furthermore, the maximum bending moment in the surge nozzle under normal operating conditions is approximately 3,013 in-kips and the resulting maximum bending stress in the 82/182 weld is about 10.8 ksi. Therefore, the combination of normal operating and residual weld stresses in the axial direction is compressive through at least 80 % of the original weld thickness and the flaws in this region are not susceptible to PWSCC. Thermal transient stresses need not be considered since only steady-state conditions are applicable for determining PWSCC susceptibility.

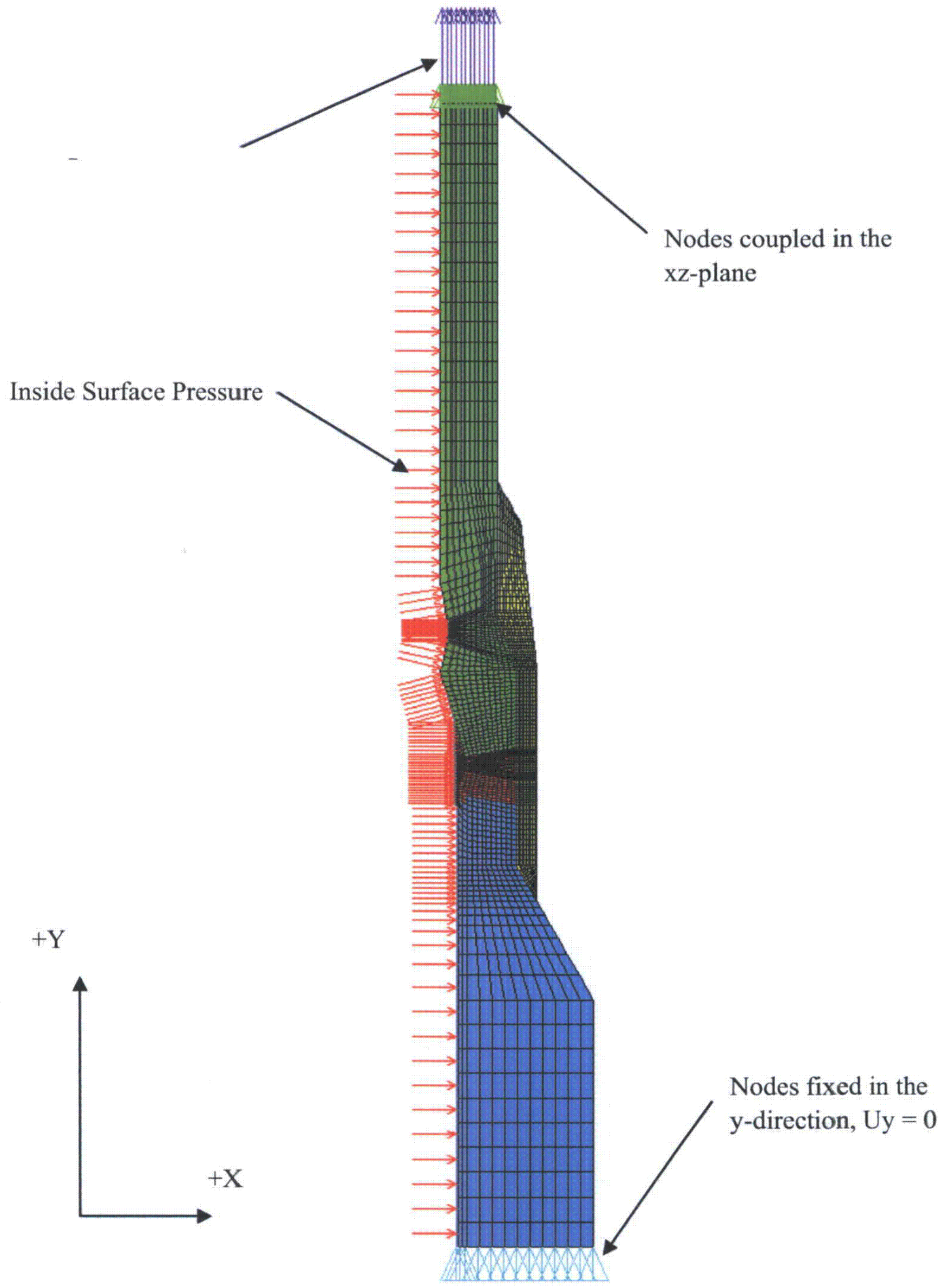

Figure 7-2: Axisymmetric Finite Element Model Used for Surge Nozzle Weld Overlay Analysis

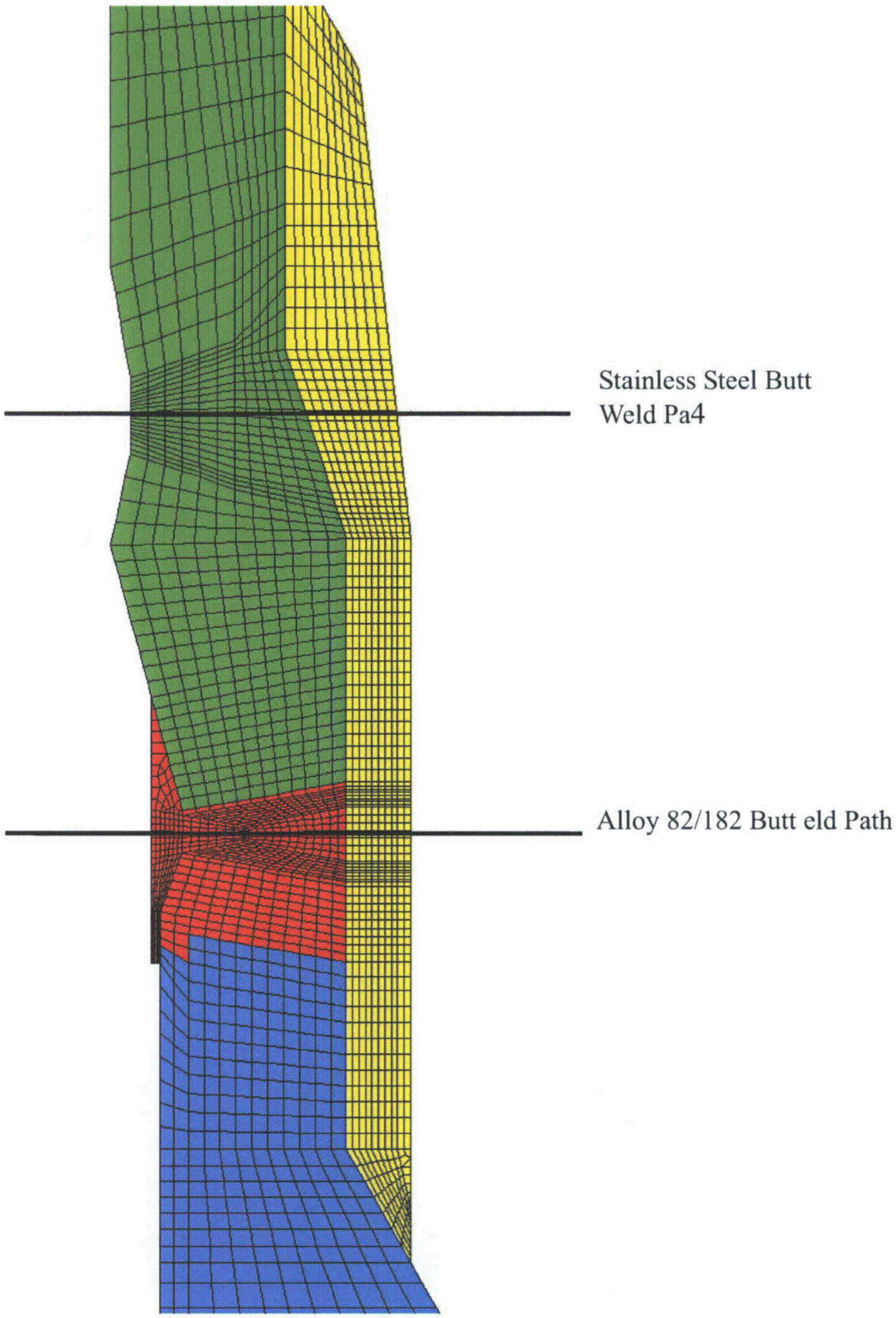

Figure 7-3: Surge Nozzle Structural Weld Overlay Stress Cut Locations

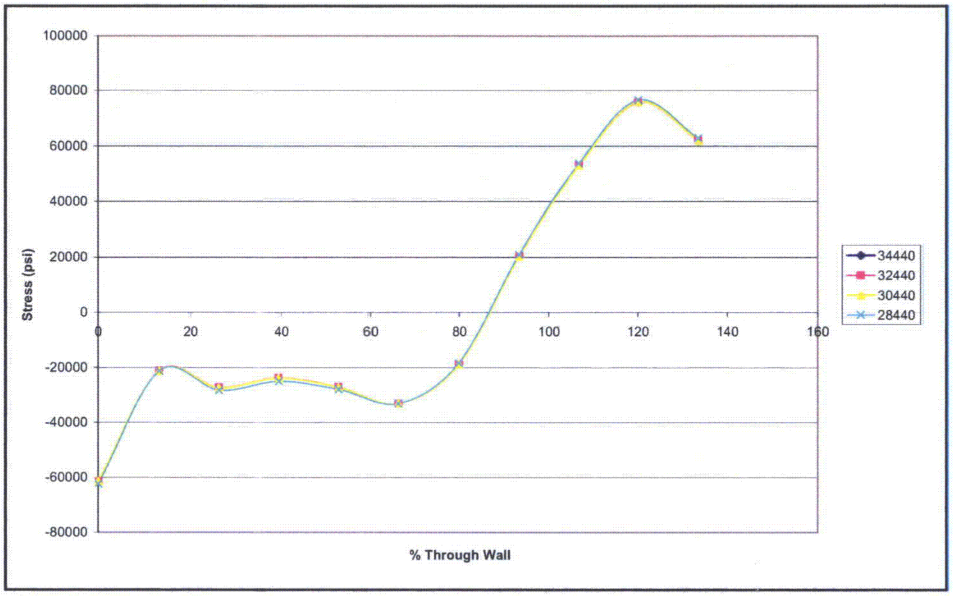

Figure 7-4:Axial Residual Stress Distribution for Alloy 82/182 Weld at Normal Operating Conditions*

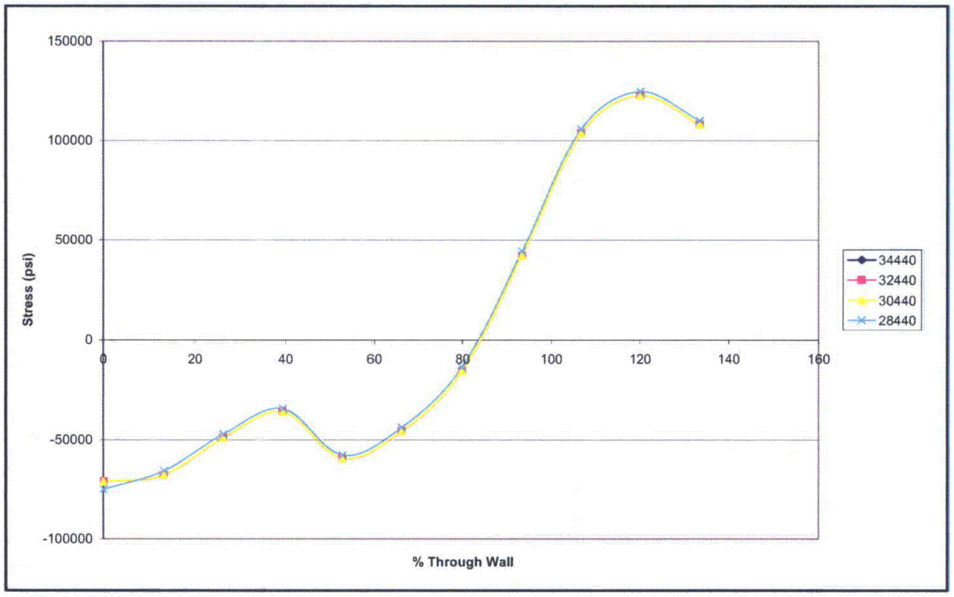

Figure 7-5:Hoop Residual Stress Distribution for Alloy 82/182 Weld at Normal Operating Conditions*

*Note: The percent through-wall indicated on the horizontal axis is expressed in terms of the original pipe wall thickness. The weld overlay region is the region beyond 100 % wall thickness.

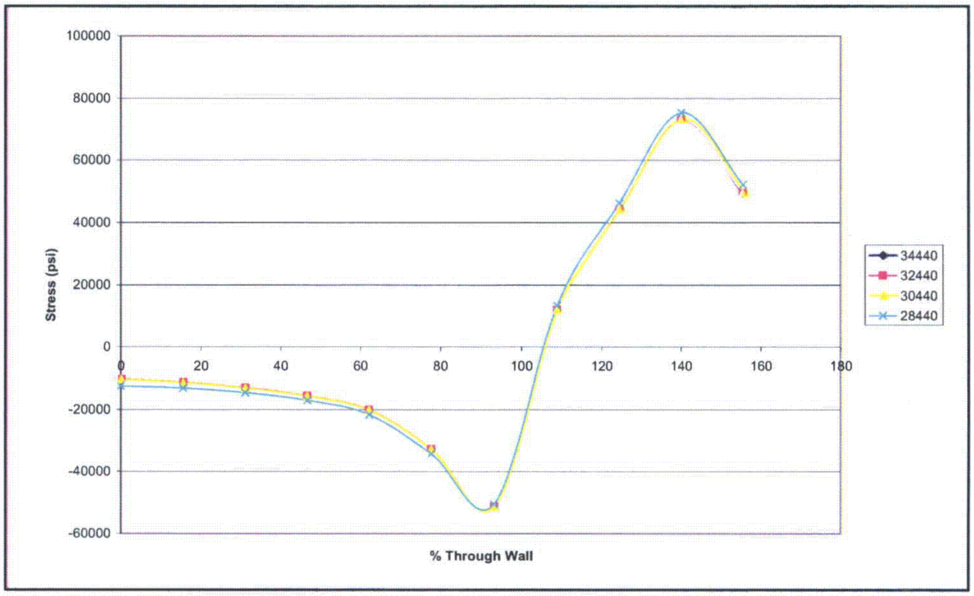

Figure 7-6:Axial Residual Stress Distribution for Stainless Steel Weld at Normal Operating Conditions*

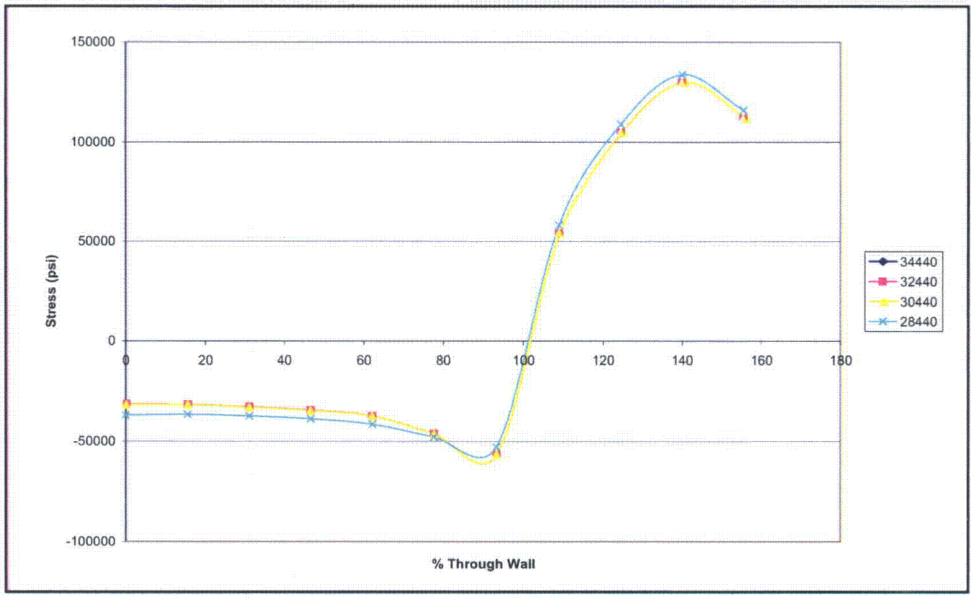

Figure 7-7:Hoop Residual Stress Distribution for Stainless Steel Weld at Normal Operating Conditions*

*Note: The percent through-wall indicated on the horizontal axis is expressed in terms of the original pipe wall thickness. The weld overlay region is the region beyond 100 % wall thickness.

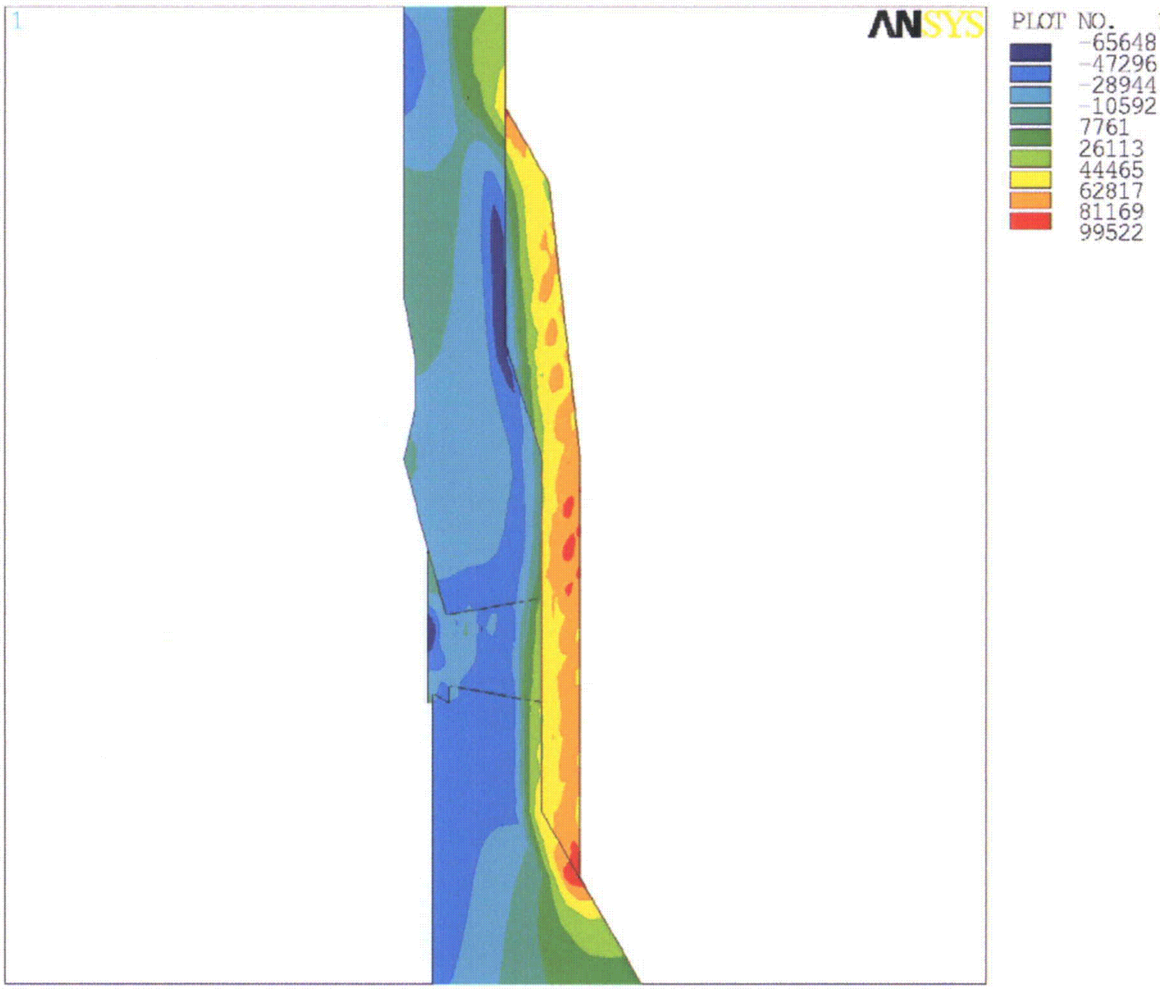

Figure 7-8: Axial Stress (psi) Contour Plot at Normal Operating Conditions

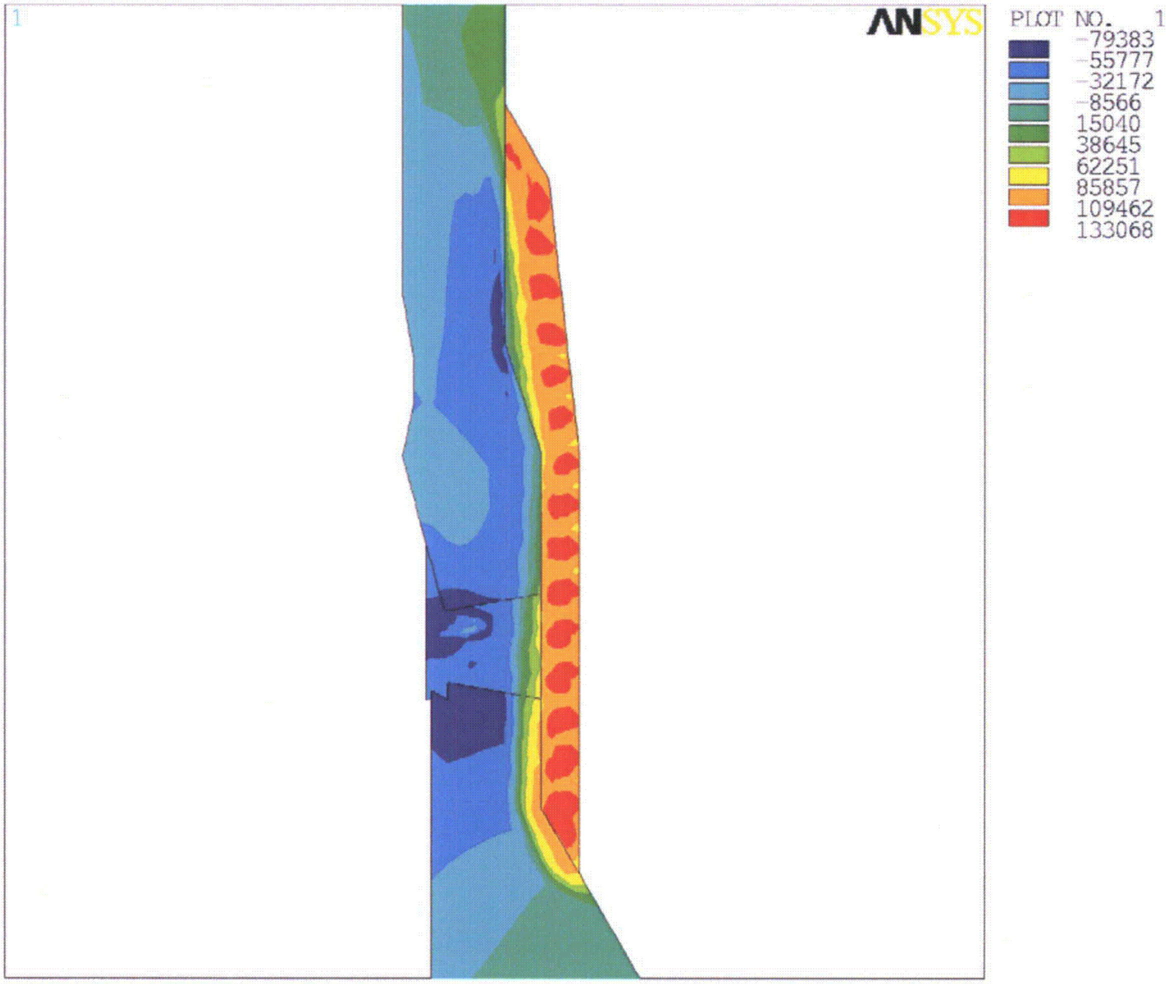

Figure 7-9: Hoop Stress (psi) Contour Plot at Normal Operating Conditions

7.5 FATIGUE CRACK GROWTH RESULTS AND ESTIMATE OF WELD OVERLAY DESIGN LIFE: SURGE NOZZLE REGION

The methodology used to determine fatigue crack growth is described in Section 4.4. Fatigue crack growth analyses were performed for the surge nozzle using the through-wall stress distribution including residual stresses generated from the weld overlay mitigation/repair process and the thermal transient stresses.

The weld overlay service life is a function of the flaw depth found in the region being overlaid, and the projected growth of that flaw. The limitation on the maximum flaw depth is 75 % of the piping wall thickness (including the weld overlay thickness), per Section XI, IWB 3640 [6].

A range of possible flaw sizes, ranging from small depths on the inside surface to a maximum depth of 100% of the original design wall thickness, were postulated in the fatigue crack growth evaluations. The results of these evaluations for the flaw depths less than the original design wall thickness have been plotted, in Figures 7-10 and 7-11, in the form of expected time for these flaws to reach the interface between the original wall and the newly laid weld overlay material. Figure 7-10 shows results for the Alloy 82/182 weld, and Figure 7-11 shows results for the stainless steel weld. For the maximum possible flaw depths of 100% of the original design wall thickness propagating in to the Alloy 52/52M weld overlay material, results are shown in Figure 7-12. This case includes the extra weld overlay material 0.15-inch thickness, provided in the repair design beyond the minimum required to account for the flaw growth in to the Alloy 52/52M material. Figure 7-12 shows the estimated flaw depth with time for the design cycles spread over either the original design life or the extended life of the plant.

Figures 7-10 and 7-11 provide expected time in years for the initial flaw depth to reach the weld metal interface, based on 100% of the original design transient cycles for 40 years of plant operation. In Figure 7-10, the vertical axis is the estimated time in years, and the horizontal axis is the initial flaw depth to the original wall thickness. The initial flaw depth is determined based on examination. The curves show the estimated time for the flaw to reach the weld metal interface for a specified initial flaw depth. Results are provided for both axial and circumferential flaws. For example, if a circumferential flaw with a depth of 65% of the original wall thickness was found, the estimated time for it to reach the weld metal interface would be 100% of the original design cycles. Conversely, if a circumferential flaw with a depth of 75% of the original wall thickness was found, the estimated time to reach the weld overlay metal interface would be approximately 15 years, based on the original design cycles assumed to be spread over 40 years, as shown on the left axis, or 22 years, if the same cycles are spread over the 60 years, as shown on the right axis. Once the flaw reaches the weld metal interface, the crack growth will be entirely in the Alloy 52/52M metal, with significantly less growth rates, as shown in Figure 7-12. Estimated service life of the repair is then at least another 10 years, or one 10-year inspection.

For the case of an initial flaw depth of 100% of the original wall thickness, which is essentially a through-wall flaw, Figure 7-11 shows that the total flaw growth into the newly laid Alloy 52/52M welds material in one 10-year inspection interval, based on the original design cycles to be spread over the 60 years period, is less than 100 mils. The final flaw depth after the 10-year period with the fatigue crack growth considered is still within 75% of the total post-WOL wall thickness, as required by SWOL criteria.

Two examination scenarios exist: a pre-overlay examination and a post-overlay examination. If an examination found no flaws, the largest flaw that might have been missed by the examination would govern the overlay service life. For an examination performed prior to the weld overlay installation, a conservative approach would be to assume that the flaw depth is 10% of the original wall thickness. Alternatively, this would be 75% of the original wall for an examination performed after the weld overlay installation. This is because the area required to be inspected after the overlay is only the outer 25% of the original pipe thickness (plus the overlay itself). The PDI qualification blocks do not contain any flaws in the inner 75% of the pipe wall, so it would be conservative to assume such a flaw for the qualification. From Figure 7-10, a circumferential flaw as deep as 75% would result in a remaining service life of approximately 22 years, based on the design cycles spread over the 60-year period. If the design cycles are assumed to be spread over 40 years of plant operation, the remaining life of the SWOL would be 15 years, assuming a 75% flaw. This is beyond the required 10-year in-service inspection (ISI) interval. If, after the next ISI, no flaws are detected in the outer 25% of the original welds, the SWOL life is at least 15 years from the time of the latest inspection.

In the unlikely event that the post-overlay inspection detected a flaw that is as large as the full depth of the original design wall thickness, expected service life of the weld overlay is at least one 10-year inspection interval period. Alloy 52/52M weld overlay repair material has significantly lower fatigue crack growth rate, and is not susceptible for the PWSCC. This indicates that the expected service life of the repair would be well beyond the one 10-year inspection interval.

The stainless steel weld is not susceptible to PWSCC; therefore, Figure 7-11 can be used for flaws even greater than 80% of the original weld. As seen in Figure 7-11, the service life of the SWOL begins to drop off for circumferential flaws greater than 75%. The design loads and transients applicable to the surge nozzle are more severe than those for the top nozzles, resulting in more rapid crack growth rates for larger circumferential flaws. However, even for circumferential flaws as large as 90% through the original weld, 30% of the total design cycles remain. This would provide adequate justification for operation up to the next ISI interval.

The actual time required to use the remaining cycles depends on plant operating practice.

Table 7-9: Surge Nozzle Alloy 52/52M FCG Data – Circumferential Flaw

Nozzle Thickness (in)	Initial Flaw Depth (in)	Final Flaw Depth in 10 years (in)	Total Flaw Growth in 10 years (in)
2.270	1.580	1.657	0.077

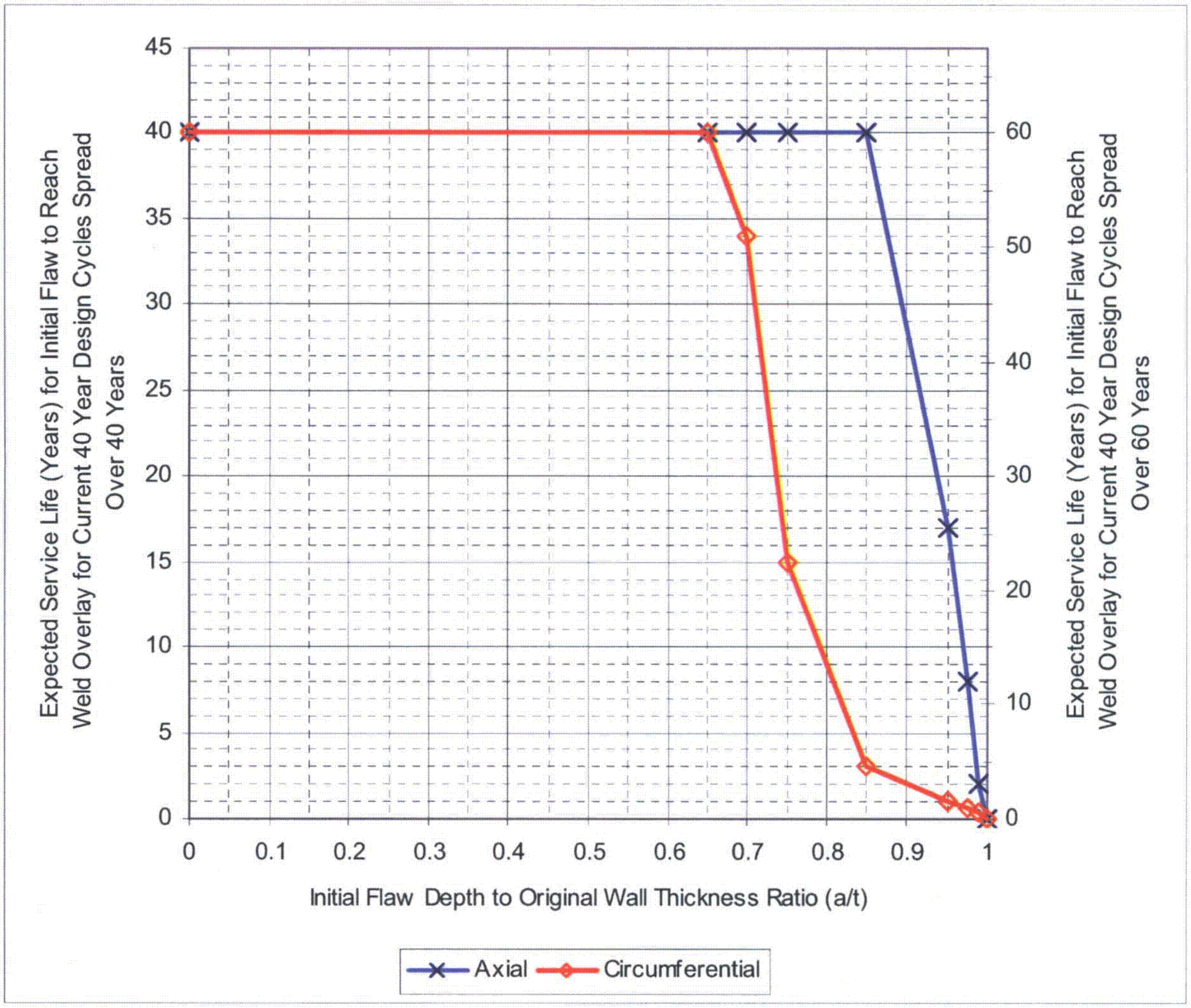

Figure 7-10:Expected Time for the Initial Flaw Depth to Reach the Weld Metal Interface for the Surge Nozzle Safe-End Alloy 82/182 Weld

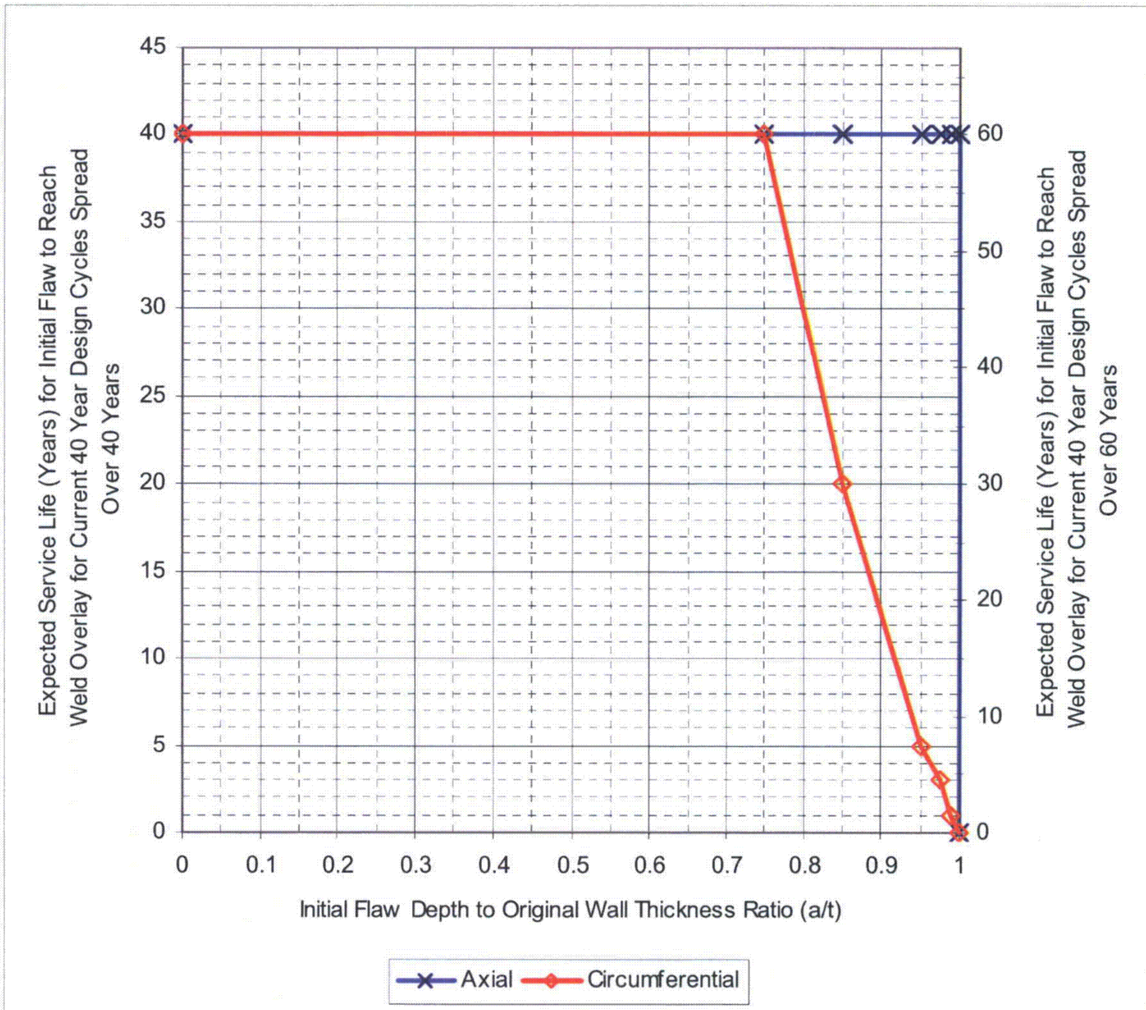

Figure 7-11:Expected Time for the Initial Flaw Depth to Reach the Weld Metal Interface for the Surge Nozzle Safe-End Stainless Steel Weld

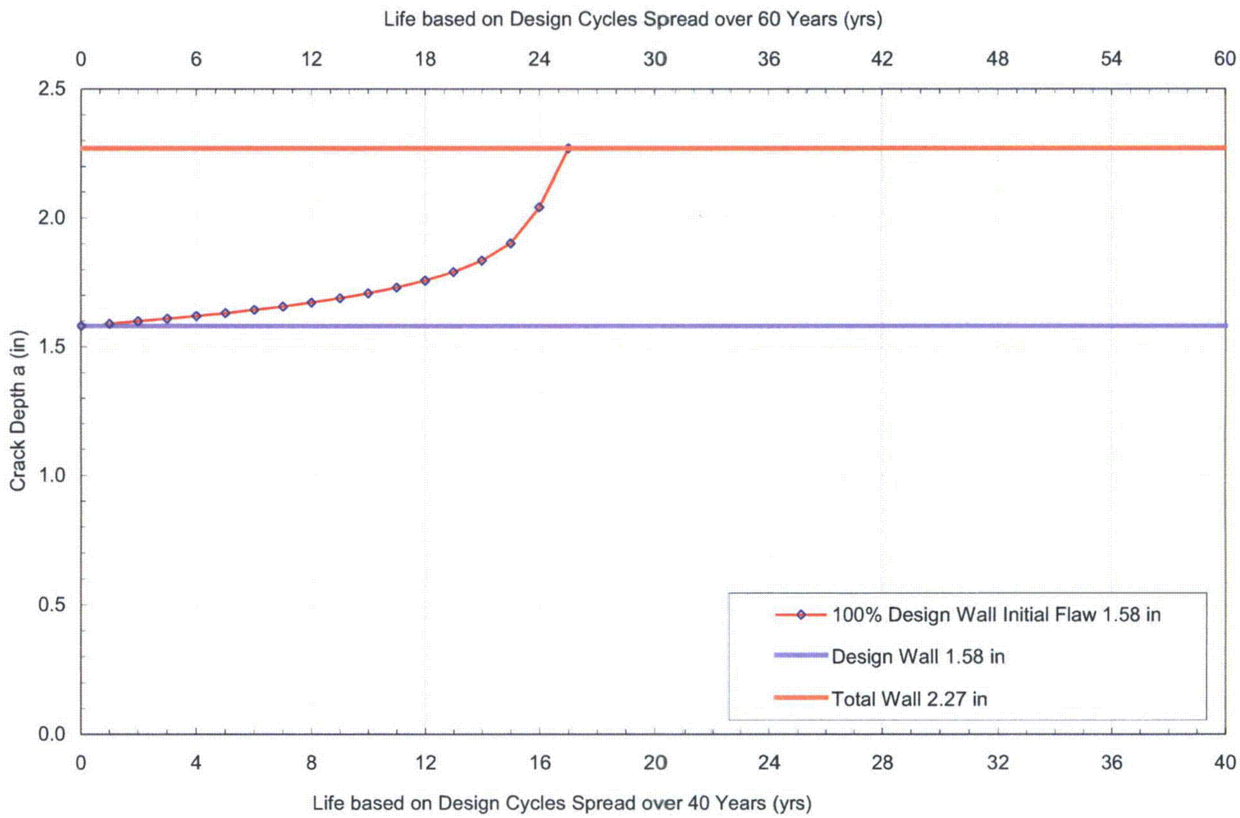

Figure 7-12: Flaw Growth versus Service Period in Alloy 52/52M at the Alloy Weld

7.6 IMPACT ON DESIGN QUALIFICATION OF NOZZLE AND PIPE

The impact of the structural weld overlay was evaluated to demonstrate that the presence of the structural weld overlay repair does not have any adverse impact on the existing stress qualification of the pressurizer surge nozzle with respect to the ASME Section III Code of Construction. The applicable Codes of Construction are [28] for the pressurizer surge nozzles of Unit 3

The evaluation of the effect of the weld overlay on the nozzle has concluded that there is no adverse impact on the Section III qualification of the nozzle. Therefore, the allowable piping reaction nozzle loads are also not impacted.

Effects of Structural Weld Overlay on Section III Stresses and Fatigue

Since the intention of the SWOL is to mitigate/repair the potentially cracked dissimilar-metal butt-weld at the pressurizer surge nozzle safe-end, the crack growth analyses discussed in Section 7.5 using the ASME Code Section XI methodology are acceptable bases to address the fatigue qualification of the weld overlay region for the surge nozzle.

The weld overlay was evaluated to determine its impact on stresses resulting from design and service condition loadings. This is required per ASME Code Case N-740 2(b)(1):

> *The axial length and end slope of the weld overlay shall cover the weld and heat-affected zones on each side of the weld and provide for load redistribution from the item into the weld overlay and back into the item without violating applicable stress limits of NB-3200 or the construction code.*

This has been demonstrated for the pressurizer surge nozzle by a comparative evaluation using finite element analysis of the configurations with and without the weld overlay.

The weld overlay, based on examination requirements, covers the pressure boundary material associated with the Alloy 82/182 dissimilar-metal (DM) weld as well as the stainless steel safe-end-to-pipe component weld. Of these components, the stainless steel weld is limiting from a Section III standpoint because of the following:

- Smaller cross-section area and section modulus, therefore higher stresses for equivalent nozzle loads.
- Lower allowable stress intensity (S_m) [9].
- Higher stress indices (as-welded butt-weld versus machined flush-weld).
- Stainless steel weld is not covered by the thermal sleeve and therefore is subject to higher thermal transient stresses.

Based on this limiting condition, the Section III design basis results that are currently documented for the stainless steel weld are considered controlling for the nozzle, as compared to the DM weld.

The effects of the weld overlay on the existing stress results and fatigue for the surge nozzle were evaluated by finite element analyses. The analyses evaluated the model for mechanical and thermal transient stresses with and without the weld overlay. Figures 7-13 and 7-14 show the stress cuts applied to the with-overlay model and the without-overlay model, respectively. The evaluation compares the stresses at the pipe/overlay interfaces after the weld overlay is installed to the stresses in the original butt-welds (Figure 7-14) without the weld overlay. The ratios of stress intensities are listed in Table 7-10. The ratios are a comparison of the maximum with-overlay stress intensity at any of the cut locations shown in Figure 7-13 to the maximum without-overlay stress intensity at any of the cut locations shown in Figure 7-14. Table 7-10 shows that the ratios are essentially 1.0 or less, which means the stress intensities are no more severe with the weld overlay than without the weld overlay for all load cases. Therefore, the existing ASME Section III analyses for the Millstone surge nozzle remain valid.

Table 7-10: Ratio of Calculated Stress Intensities with Weld Overlay to without Weld Overlay

Case	Inside		Outside	
	Membrane plus Bending	**Total**	**Membrane plus Bending**	**Total**
Pressure	0.99	0.99	0.96	0.95
Bending	0.74	0.78	1.02	0.92
Torsion	0.93	0.83	0.93	0.93
Thermal	0.97	0.85	0.96	0.79

Additionally, a study was performed on a representative nozzle to address the impact on these results if the SWOL was doubled from the target or minimum thickness. The results of this comparison show that similar stress results are produced in the minimum and doubled overlay thickness.

Also, in support of the Section III Evaluation previously discussed for the nozzle to pipe interface, stress and fatigue analyses were performed in accordance with the ASME Section III guidelines for ASN 2 and 3, as shown in Figure 7-15. The results are considered representative of the nozzle to pipe interface. They are used to demonstrate that the stresses and cumulative fatigue at the discontinuity meet ASME Section III limits.

Primary Stress

Primary stress limits are generally addressed based on the NB-3600 equations. Addition of the SWOL does not affect the B indices or the loads from the piping, but increases the section modulus in the overlay region. The applicable primary loads (pressure and mechanical loads) are not changed by the SWOL. Therefore, the primary stresses in the structures with SWOL are, by definition, less than or equal to those without SWOL, and the previous qualifications, performed for the surge line weld to nozzle safe end, apply.

Primary plus Secondary Stress

A simplified elastic plastic analysis was performed for ASN 2 and 3. The results of the simplified elastic plastic analysis were used to include the applicable Ke penalty in the fatigue usage factor estimation, and the remaining criteria of NB-3228.5 were checked and shown to be acceptable except for expansion stress.

Expansion Stress

A simple approach to address the thermal expansion stress is to use the maximum thermal moment range with the minimum pipe section property and applicable piping C2 stress index from NB-3683. The results (32.37 ksi) are shown to be within the 3Sm limit for the weakest material in the nozzle SWOL region. The results shown in Table 6-1 of [6] demonstrate that (C2*M)/Z is less than 3Sm; therefore, the expansion stress requirement is satisfied.

Total/Peak Stress

The total/peak stress requirement is met by showing that the fatigue usage is less than 1.0. Conservative analyses for the surge nozzle with SWOL were performed using applicable loads and transients. The results show a maximum fatigue usage of 0.3377 was achieved at ASN 2, and is considered appropriate for the Code Reconciliation. Therefore, the stresses in the structure with SWOL repair can be concluded to be within the Code limits on total/peak stress.

Thermal Stress Ratchet

Thermal stress ratchet requirements were also shown to be met for ASN 2 and ASN 3 using transient loads applicable to the surge nozzle with SWOL. Based on the nature of the geometry and transient loadings, the maximum ratio of thermal membrane plus bending stress at ASN 2 is 0.59, and the allowable value is within the limit of 1.0. Therefore, the stresses in the structure with SWOL repair can be concluded to be within the Code limits for thermal stress ratchet.

Therefore, it is concluded that the existing ASME Section III analysis of the referenced surge nozzle is not adversely affected by the addition of the weld overlay.

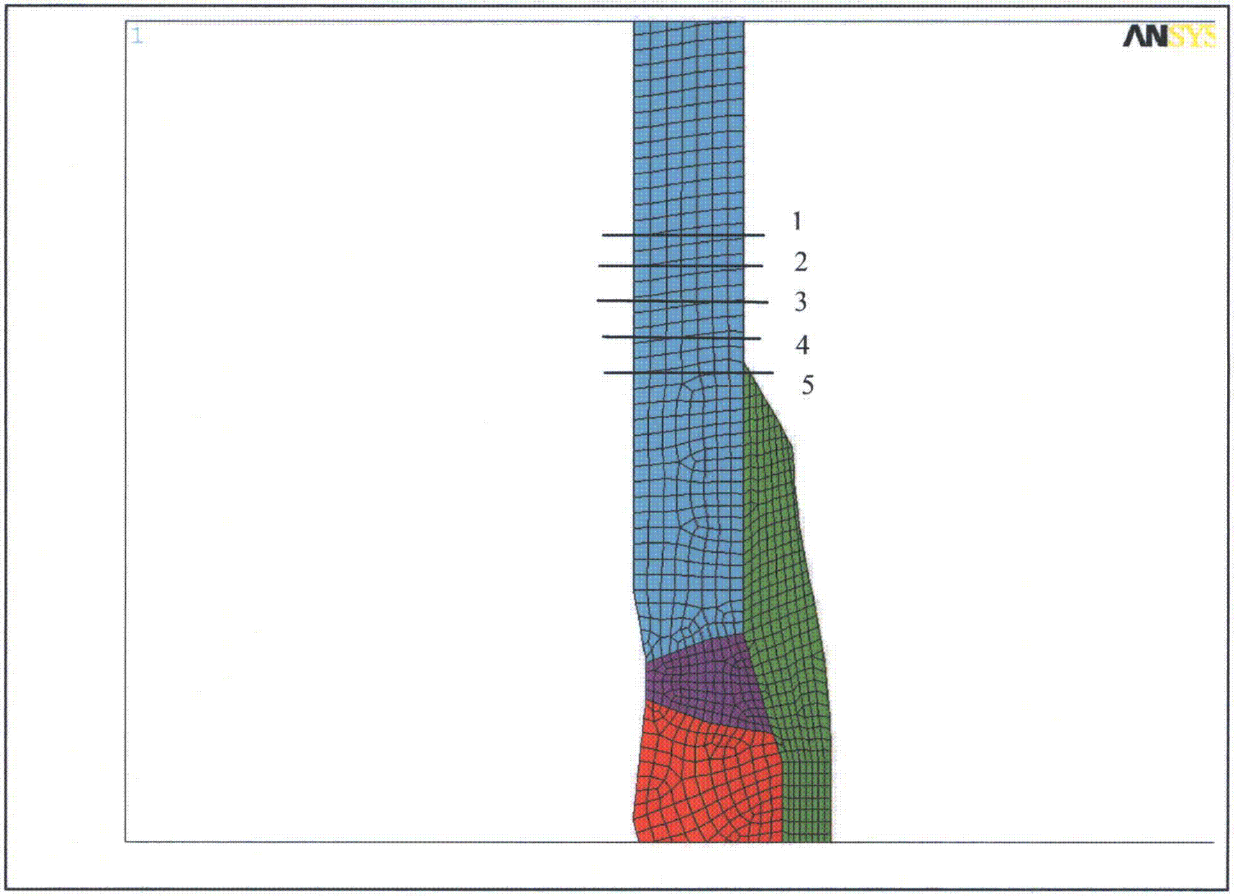

Figure 7-13: Linearization Paths with Weld Overlay

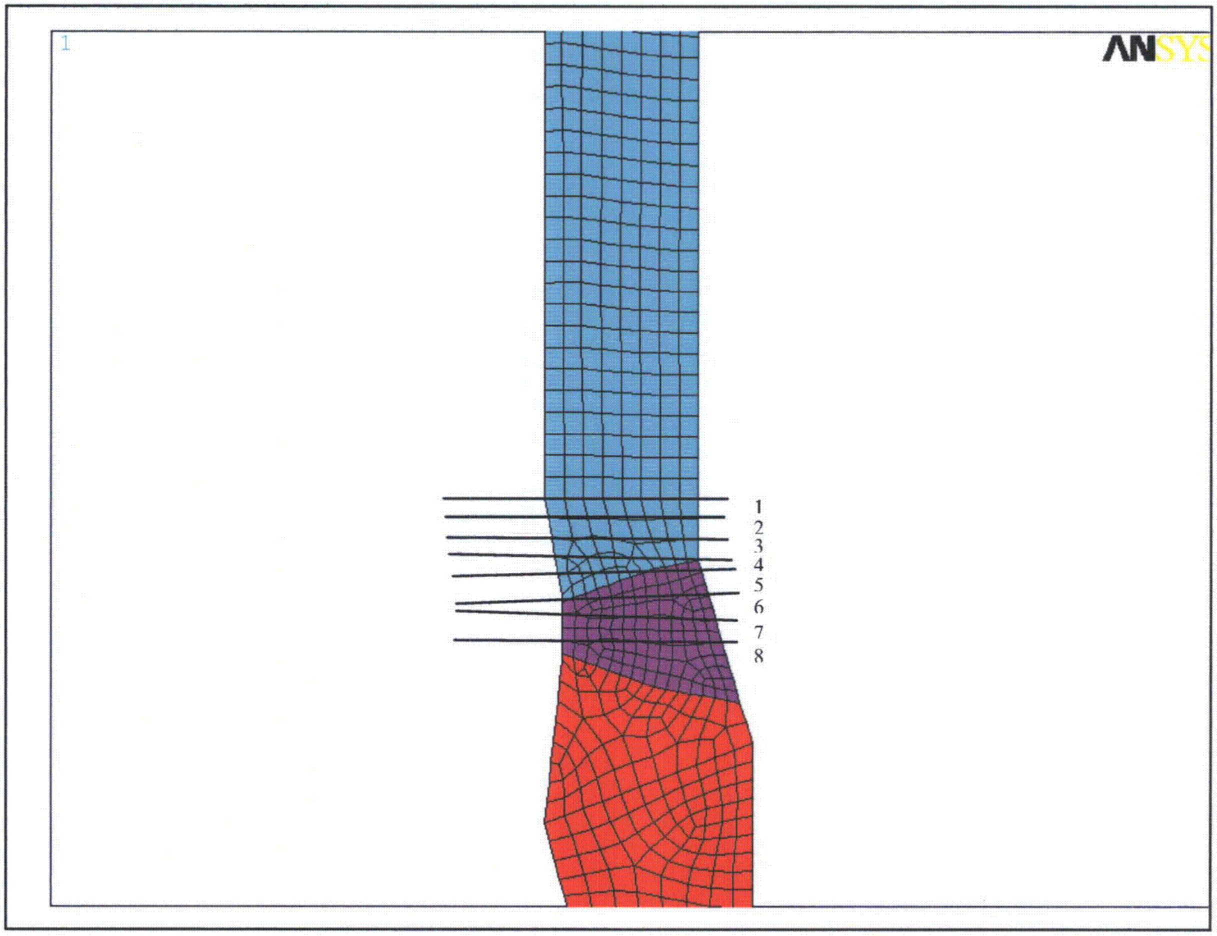

Figure 7-14: Linearization Paths without Weld Overlay

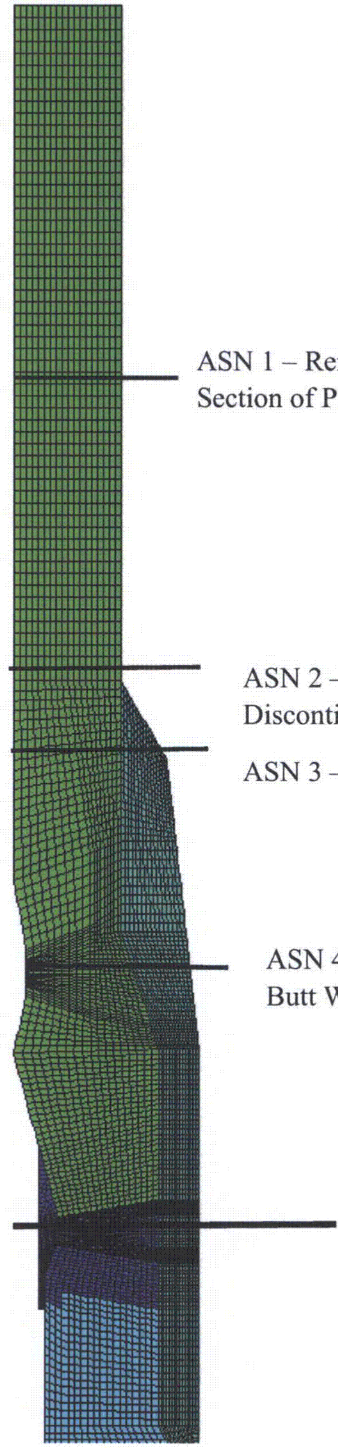

Figure 7-15: Surge Nozzle ASN Definitions

Effects of Structural Weld Overlay on the Thermal Sleeve

The effect of the SWOL on the surge nozzle thermal sleeves is judged to be insignificant. The nozzles have a thermal sleeve welded on the inside diameter of the nozzle that shields the nozzle body and the dissimilar-metal weld. The thermal sleeve is not a pressure-retaining component; nor is it a load path for the piping forces and moments imposed on the nozzle safe-end.

From a structural standpoint, the weld between the thermal sleeve and the nozzle safe-end is affected by pressure load in the nozzle and thermal transients, and may displace relative to the safe-end, which may result in stresses that are expected to maximize near the attachment weld. The SWOL on the outside of the nozzle would not be expected to have a significant detrimental effect on the stresses at the thermal sleeve attachment weld for the following reasons:

- For pressure loading, the relative displacement between the sleeve and the safe-end would be less with a SWOL, because of increased stiffness.

- The response to a thermal transient is expected to be dominated by the differential temperature gradient through the sleeve thickness, and its corresponding relative displacement to the internal nozzle surface responding to the same transient. Thermal stress in the sleeve thickness due to shock effects of the transient would not be expected to change, since the sleeve thickness does not change. Thermal stress in the sleeve due to differential expansion of the sleeve and the nozzle inside surface is not expected to be significant, due to the large difference in the stiffness of the sleeve and the nozzle. Therefore, thermal stresses in the sleeve attachment are not expected to be affected by the SWOL.

These points are supported by an analysis of a spray nozzle, with and without SWOL, which examined the stresses at the controlling location in the thermal sleeve due to identical pressure loads and thermal transient loads. Selected results from the evaluation are shown in Table 7-11 and Figures 7-16 and 7-17. Note that the stress intensity results in Table 7-10 are not linearized and are reported for comparison of stress intensity at a selected node. Therefore, the stresses are not intended for comparison to ASME Code stress intensity limits.

As expected, the maximum stress intensity in the thermal sleeve occurs in the same location in both models. The stress in the sleeve with SWOL due to the 1,000 psi pressure load was less than that in the sleeve without SWOL, as expected. The stress in the sleeve with SWOL due to a typical bidirectional thermal transient load was essentially the same (less than 2 % lower) as that in the sleeve without SWOL, as expected. This example demonstrates the validity of the previously discussed points. Therefore, the SWOL repairs have a negligible impact on the integrity of thermal sleeves in spray nozzles.

In addition to the pressure load and thermal transients, the nozzle will also undergo some radial shrinkage from the SWOL process. However, the impact of radial shrinkage on the thermal sleeve is not a concern for the following reasons:

- The thermal sleeve is attached at a relatively stiff location on the nozzle, so the magnitude of shrinkage at the sleeve attachment point is expected to be insignificant. No radial shrinkage could occur at any other contact points. The shrinkage would cause compressive and shear stresses at the weld, as well as a small amount of bending in the sleeve.

- The attachment weld can accommodate the shrinkage as it is similar to the effect of a heatup shock (e.g., after spray is complete and steam refills the nozzle). The sleeve, having less thermal inertia, expands faster than the nozzle. More importantly, the weld shrinkage is only one cycle of a compressive strain/stress on the weld location; therefore it would not be a fatigue concern.

If clearances/tolerances were such that the sleeve became tight at the attachment location, this tightness would not have any adverse functional effect on the sleeve. The conclusions drawn are based on an analysis of a spray nozzle thermal sleeve, which is also considered applicable for the surge nozzle based on similarities in the thermal sleeve designs.

Therefore, it may be concluded that the SWOL repairs to the surge nozzle have no significant impact on the integrity of the thermal sleeve or the nozzle.

Effects of Additional Mass and Weld Shrinkage on Piping/Support System

The effects of SWOL on the piping/support system, including mass and shrinkage effects, shall be documented in a separate report addressing pipe stress reconciliation.

Table 7-11: Comparison of Maximum Stress Intensity for Pressure and Thermal Transient Loading at the Thermal Sleeve Weld		
	Stress Intensity (ksi)	
	Pressure Case	Thermal Transient Case
With WOL	3.0	93.7
Without WOL	3.7	95.3

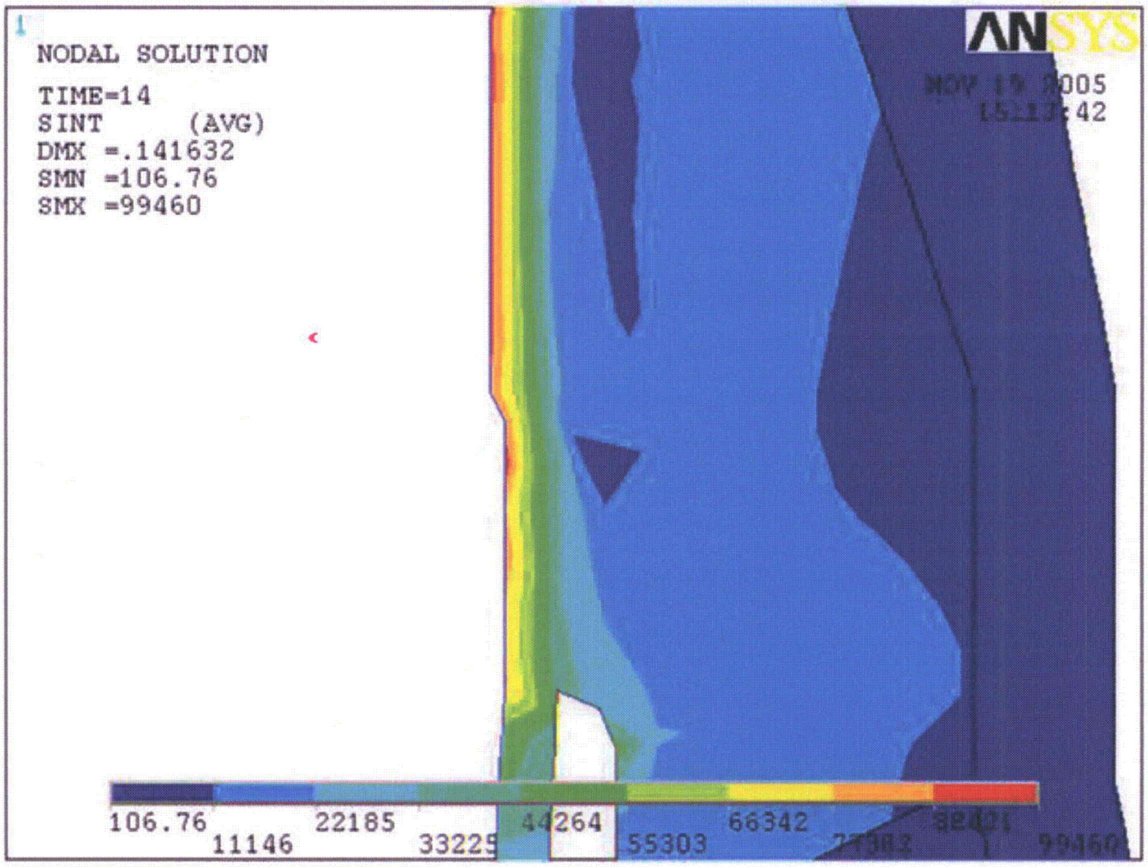

Figure 7-16: Stress Intensity (psi) Contour Plot with WOL for Thermal Transient Loading

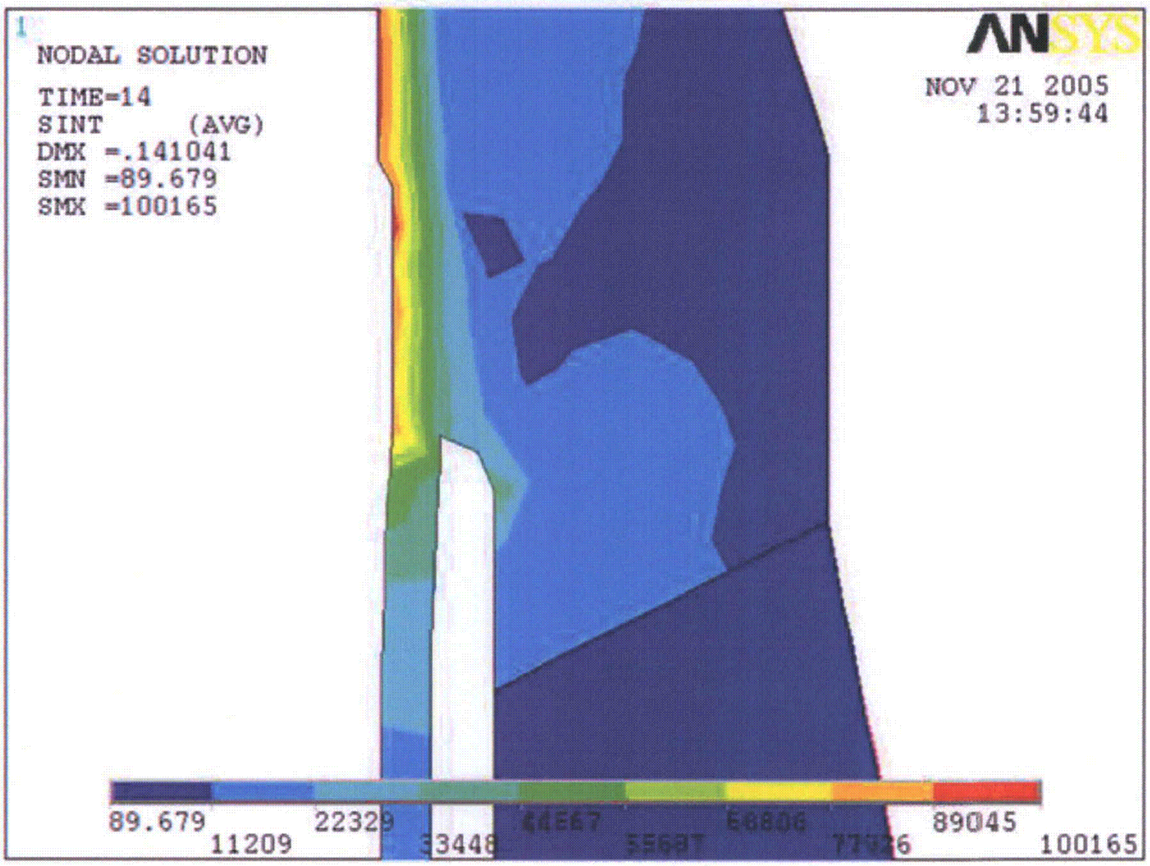

Figure 7-17: Stress Intensity (psi) Contour Plot with No WOL for Thermal Transient Loading

8 SUMMARY AND CONCLUSIONS

The pressurizer nozzle weld overlay designs have been demonstrated to meet the intent of the requirements in ASME Code Case N-740 and Section XI IWB-3640 through finite element analysis and fracture mechanics evaluations. In accordance with ASME Code Case N-740, the minimum SWOL thicknesses and lengths for the dissimilar-metal butt-welds and the stainless steel welds are listed in Table 8-1.

The minimum thickness does not include any dilution or sacrificial layers [29]. Additional weld passes or a larger weld overlay thickness will not invalidate the results of the analysis and qualification. The weld overlay design values given in this report are considered the minimum acceptable values. The resulting weld overlay designs shown in Figures 3-1, and 3-2 have also considered the issues of weldability and future UT inspectability, such that the weld overlay for the stainless steel weld is also a SWOL. Therefore, the length of the weld overlay exceeds the minimum length required for a full SWOL in accordance with ASME Code Case N-740.

Alloy 52/52M or equivalent weld material is widely accepted in the industry for its stress corrosion resistance, along with the GTAW process that will further reinforce the effectiveness of a SWOL repair. The finite element analysis results for the SWOL design of the Millstone pressurizer nozzles, as discussed in Sections 6 and 7, show that the weld overlay repair will create a favorable compressive stress field to mitigate PWSCC on the inner portion of the pipe, thereby minimizing the potential for any future PWSCC crack initiation and/or future crack propagation.

Fatigue crack growth analyses using the ASME Code Section XI methodology were performed to address the fatigue qualification at the weld overlay regions. Once the post-weld-overlay examination has been completed, the remaining service life of the weld overlay can be determined from Figures 6-10 and 6-11 for the safety/relief nozzles, and Figures 7-10 and 7-11 for the surge nozzle.

An evaluation of the impact of the SWOL on the stress qualification of the pressurizer nozzles was performed in accordance with the existing Code of Construction. The impact of the addition of weld overlay material on the existing primary stress qualification, which considers deadweight and dynamic loadings (such as those due to earthquake), as well as the effects of weld shrinkage, shall be evaluated in a separate document. Reconciliation of the existing fatigue evaluation was performed for the limiting locations outside the SWOL and it was demonstrated that the pressurizer nozzles with the SWOL would still meet the applicable ASME Code Section III requirements.

Since the intent of the requirements of ASME Code Case N-740, Section XI IWB-3640, and ASME Section III is met, the structural integrity of the nozzle dissimilar-metal weld region is maintained with the SWOL repair. It should be noted that the weld overlay design is developed based on the assumptions that a 360-degree through-wall flaw exists and the crack growth mechanism is PWSCC. The use of Alloy 52/52M PWSCC-resistant weld material for the weld overlay will prevent any future PWSCC crack growth into the weld overlay even if any indications grew through the existing pipe wall thickness. Consequently, the SWOL repair implemented for the Millstone pressurizer nozzles will mitigate future PWSCC crack initiation and/or propagation and therefore maintaining structural integrity of the dissimilar-metal weld region.

Table 8-1: Minimum Structural Weld Overlay Thicknesses and Lengths [2]

Nozzle	Alloy 82/182 Structural Weld Overlay		Stainless Steel Structural Weld Overlay	
	Thickness (in)	**Length (in)**	**Thickness (in)**	**Length (in)**
Safety and Relief	0.48	1.81	0.33	1.43
Surge	0.69	2.61	0.71	2.64

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33. Westinghouse Design Specification 952371, Rev. 4, "Addendum to Design Specification 955285, Rev. 0, Northeast Utilities Service Company Millstone Nuclear Power Station Unit No. 3", Westinghouse NES, July 5, 1988. (Westinghouse Proprietary Class 2 Document)

34. Westinghouse Letter, NEU-07-18, Rev. 0, "Dominion Nuclear Connecticut Millstone Power Station - Millstone Unit 3 MP3 SPUP Licensing Report Input – Technical Evaluation for Surge Line Stratification" February 5, 2007. (Westinghouse Proprietary Class 2 Document)

35. Westinghouse Letter, PCWG-06-9, Rev. 0, "Millstone Unit 3 (NEU): Approval of Category III (for Contract) PCWG Parameters to Support a 7% Stretch Power Uprate (SPU) Program", April 25, 2006. (Westinghouse Proprietary Class 2 Document)

36. Westinghouse Letter, LTR-SCS-06-70, Rev. 0, "Millstone 3 Stretch Power Uprate – Revised NSSS Design Transients", June 12, 2006. (Westinghouse Proprietary Class 2 Document)

37. Westinghouse Letter, LTR-SCS-06-102, Rev. 1, "Millstone 3 Stretch Power Uprate – NSSS Design Transients – Revised Loss of Power and Loss of Load Transient Parameters", October 19, 2006. (Westinghouse Proprietary Class 2 Document)

Serial No. 06-731A
Docket No. 50-423

PROPRIETARY INFORMATION
Withhold from Public Disclosure
in accordance with 10 CFR 2.390

ENCLOSURE 2

WESTINGHOUSE LETTER CAW-07-2262, WITH AFFIDAVIT

WESTINGHOUSE REPORT

WCAP-16734-P, REV. 0

MILLSTONE UNIT 3 PRESSURIZER SAFETY, RELIEF, AND SURGE NOZZLES STRUCTURAL WELD OVERLAY QUALIFICATION

(Proprietary)

(99 pages)

PROPRIETARY INFORMATION
Withhold from Public Disclosure
in accordance with 10 CFR 2.390

MILLSTONE POWER STATION UNIT 3
DOMINION NUCLEAR CONNECTICUT, INC.

Westinghouse Electric Company
Nuclear Services
P.O. Box 355
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USA

U.S. Nuclear Regulatory Commission
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Our ref: CAW-07-2262

March 29, 2007

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: WCAP-16734-P, "Millstone Unit 3 Pressurizer Safety, Relief, and Surge Nozzles Structural Weld Overlay Qualification," dated March 29, 2007 (Proprietary)

The proprietary information for which withholding is being requested in the above-referenced report is further identified in Affidavit CAW-07-2262 signed by the owner of the proprietary information, Westinghouse Electric Company LLC. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying affidavit by Dominion Nuclear Connecticut, Inc. (DNC).

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-07-2262, and should be addressed to B.F. Maurer, Acting Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

for B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: Jon Thompson (NRC O-7E1A)

AFFIDAVIT

STATE OF CONNECTICUT:

ss Windsor

COUNTY OF HARTFORD:

Before me, the undersigned authority, personally appeared Ian C. Rickard, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

I. C. Rickard,
Licensing Project Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed before me
this 29th day of March, 2007

Laurie J. White
Notary Public

My commission expires 8/31/09.

(1) I, Ian C. Rickard, dispose and say that I am a Licensing Project Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of

Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in WCAP-16734-P, "Millstone Unit 3 Pressurizer Safety, Relief, and Surge Nozzles Structural Weld Overlay Qualification," dated March 29, 2007 (Proprietary), for submittal to the Commission, being transmitted by Dominion Nuclear Connecticut, Inc., Application for Withholding Proprietary Information from Public Disclosure to the Document Control Desk. The proprietary information as submitted for use by Westinghouse for Millstone Unit 3 contains design information relevant to the qualification of the Westinghouse weld overlay process that enables Westinghouse to support other utilities with NSSS plants in preparing nozzle repairs. This information includes analytical crack growth methods and results that support the application of weld overlay to pressurizer nozzles.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for the purposes of meeting NRC requirements for licensing documentation.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar calculation, evaluation and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).