

ENCLOSURE

**REPLACEMENT COPY OF ATTACHMENT (2) TO
NMPNS LETTER DATED MAY 10, 2007**

**FLAW EVALUATION OF THE NINE MILE POINT UNIT 1 (WELD
NO. 32-WD-164) NOZZLE-TO-SAFE END WELD INDICATION,
REVISION 2 DATED MAY 21, 2007**

**Performed for NMPNS
By
Structural Integrity Associates, Inc.**

**Nine Mile Point Nuclear Station, LLC
May 25, 2007**



Structural Integrity Associates, Inc.

File No.: NMP-29Q-301

CALCULATION PACKAGE

Project No.: NMP-29Q

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Nine Mile Point Unit 1 Recirculation Inlet Nozzle Flaw Evaluation, Weld 32-WD-164

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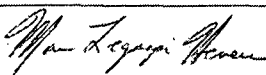
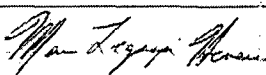
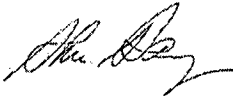
Constellation Energy

PLANT:

Nine Mile Point Unit 1

CALCULATION TITLE:

Flaw Evaluation of Nine Mile Point Unit 1 Recirculation Inlet Nozzle-to-Safe End Weld (32-WD-164)
Indication and Allowable Flaw Size Calculation

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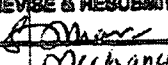
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1.0 INTRODUCTION

During in-service inspections at NMP1, a flaw was identified in the recirculation inlet nozzle (N2) to safe end weld. Reference 1 provides the details of the weld examination. In Reference 1, it is stated that the flaw was found on the safe end side of the weld in the area of a known weld repair. The repair was performed to remedy the incomplete fusion condition of the original weld. The weld examination summary does state that the UT indication characteristics are more indicative of a lack of fusion reflector than a service induced flaw. The weld examination summary report states that the indication was evaluated as a flaw. For purposes of this evaluation, the flaw will be assumed to be an active intergranular stress corrosion crack (IGSCC) since the weld metals (Alloy 82/182) present at this location are known to be susceptible to this mechanism.

Figures 1 and 2 present the observed flaw information. Figure 1 shows that the indication is associated with the safe end side of the butt weld and not with the weld butter that is located on the nozzle side of the weld. Figure 2 reports the flaw as 0.27 inches deep and with a circumferential length of 1.59 inches (based on the ID). For purposes of this evaluation, the flaw depth will be assumed to be 0.3 inches.

The objective of this evaluation is to determine the flaw depth and length at the end of the next 24 month operating cycle and compare these against the allowable flaw size. Both IGSCC and fatigue crack growth are considered.

2.0 TECHNICAL APPROACH

The methodology consists of the following steps:

1. Determination of allowable flaw size using the provisions in ASME Code Section XI, IWB-3600 [5].
2. Crack growth evaluation considering IGSCC of Alloy 82/182 materials as documented in BWRVIP-59 [2]. To perform the crack growth evaluation, representative weld residual stress has to be assumed. In this evaluation, it is assumed that the welds were subjected to repairs during the fabrication process and hence, the weld residual stress associated with a weld repair will be used in the crack growth evaluation.
3. An initial flaw size of 0.3 inches is assumed and using the crack growth evaluation, the flaw size at the end of the next 24-month operating cycle will be established. Results for both normal water chemistry (NWC) and hydrogen water chemistry (HWC) are presented.
4. Fatigue crack growth evaluation assuming the ASME Section XI crack growth law for air environment and adjusting for water environment.



3.0 ASSUMPTIONS / DESIGN INPUTS

The following assumptions were made in the evaluation:

- The dimensions of the flaw used in the evaluation are shown in Figures 1 and 2, which were taken from the UT Weld Examination Summary Report [1].
- The evaluation assumes that significant weld repairs were performed during fabrication of these welds.

Note that with the consideration of a weld repair, the residual stresses are tensile on the inside portion of the pipe which is different than the conventional profile used for butt weld at a dissimilar metal joint of a nozzle-to-safe end weld without weld repair as shown in Figures 3 through 5 [3, 4]. Several studies performed recently have demonstrated that weld repairs have a significant impact on the weld residual stress state. In fact, weld repairs result in significant tensile residual stress in the vicinity of the weld. Figure 6 [4] confirms that with an ID weld repair, the inner portion of the pipe is expected to be highly tensile.

When the operating stresses (pressure, thermal, etc.) are added to the weld residual stress, the resulting stress distribution is significantly tensile through the inner half of the pipe wall. This observation has significant impact on the selection of the crack growth rates and is discussed later in the cracked growth section.

The loads at the nozzle-to-safe end location are shown in Table 1 and are from References 7 and 11. The pipe diameter and thickness as well as section properties are given in Table 2. A design pressure of 1250 psi is used in the evaluation. The S_m for the Alloy 82/182 is taken as that for Alloy 600 and is 23.3 ksi at 550°F.

4.0 CALCULATIONS

4.1 Allowable and Critical Flaw Sizes

The allowable flaw size can be determined using Tables IWB-3641-1 and IWB-3641-2 of ASME Code Section XI [5] or using the source equations in Appendix C of the ASME Code Section XI. Note that the ASME Code limits any flaw to a maximum of depth equivalent to 75% of the pipe wall. If the source equations were to be used, it is possible that a given flaw with depth greater than 75% of wall could still meet the required safety factors of ASME Code Section XI. In fact, it is possible for through-wall flaws to meet the required safety factors given that they remain below a certain length that depends on the applied stresses. However, for this flaw evaluation, and consistent with ASME Code, the allowable flaw depth will be limited to 75% of wall.

The allowable flaw depth will be determined using Tables IWB-3641-1 (for normal and upset conditions, Figure 7) and IWB-3641-2 (for emergency and faulted conditions, Figure 8). These tables provide the allowable depth for a given flaw length. As can be seen in Tables IWB-3641-1 and IWB-

3641-2 (Figures 7 and 8), for many cases, the flaw depth arbitrarily is limited to 75% of wall thickness except for cases of high stress or long circumferential flaws.

4.2 Crack Growth Evaluation

4.2.1 IGSCC

Since the weld material is Alloy/82/182, the BWRVIP-59 [2] crack growth correlation is used. The BWRVIP-59 crack growth disposition curves are of the form:

$$\frac{da}{dt} = C_0 K^n \text{ in/hr for } K \leq 25 \text{ ksi } \sqrt{\text{in}} \quad (1)$$

$$\frac{da}{dt} = C_1 \text{ in / hr for } K > 25 \text{ ksi } \sqrt{\text{in}} \quad (2)$$

where

K = stress intensity factor (ksi $\sqrt{\text{in}}$)

C_0 = 1.6×10^{-8} , $C_1 = 5.0 \times 10^{-5}$ and $n = 2.5$ for normal water chemistry

C_0 = 3.2×10^{-10} , $C_1 = 5.0 \times 10^{-6}$ and $n = 3.0$ for hydrogen water chemistry

It should be noted that this crack growth correlation has a K dependent regime for K less than or equal to 25 ksi $\sqrt{\text{in}}$ as well as a K independent regime for K above 25 ksi $\sqrt{\text{in}}$. As discussed earlier, because it is known that this location was weld repaired, significant weld residual stress will be present at this location and at the crack tip. Therefore, for purposes of this crack growth calculation, the crack growth corresponding to $K > 25$ ksi $\sqrt{\text{in}}$ will be conservatively used.

NMP1 is currently on HWC and has been Noble Metal (NMCA) treated. Thus, it is expected that there is some level of benefit in terms of reducing the ECP at this location. However, for purposes of this evaluation, the crack growth will be determined using the crack growth rate for NWC. The crack growth will also be calculated using the hydrogen water chemistry crack growth rate (for $K > 25$ ksi $\sqrt{\text{in}}$) for information. Since the plateau values corresponding to $K > 25$ ksi $\sqrt{\text{in}}$ are being used, it is not required to determine the stress intensity factor.

Therefore, for NWC, a constant crack growth rate of 5×10^{-5} in/hr is used and for HWC, a constant crack growth rate of 5×10^{-6} in/hr is used.

4.2.2 Fatigue Crack Growth

Typically, fatigue loading at this location is relatively small and fatigue usage factors at this location are minimal [6]. In addition, it should be noted that the crack growth being considered here is for one operating cycle, therefore the number of cyclic loadings during the next operating cycle at this location is very small. The fatigue crack growth is a function of the number of cyclic loadings, the



range of stress intensity factor (ΔK) for each of these cycles and the crack growth rate behavior for the material. A simplified evaluation can be used to demonstrate that fatigue crack growth is small by assuming a conservative number of cycles and loading conditions.

Another consideration when performing fatigue crack growth is the number and type of transients/events that occur during a cycle. The design report provides significant numbers of events, many of which do not contribute to fatigue usage or fatigue crack growth. In addition, the actual plant history can differ significantly from that assumed in the design report. The approach used here will determine the number of significant transients that can be tolerated before the 75% of wall limitation is met. At this location, it is usually the startup-shutdown cycles that are the major contributors to the fatigue loadings. Field experience has demonstrated that fatigue (initiation and growth) at this location and similar locations is not significant.

5.0 RESULTS OF ANALYSIS

5.1 Allowable Flaw Size

The allowable flaw depth is a function of the stress level at the location of interest and the length of the flaw. The stresses are calculated using the stress information provided in Reference 7 and a design pressure of 1250 psi [8].

The axial pressure stress is:

$$\sigma = PR/2T = 5.36 \text{ ksi}$$

where P = design pressure = 1250 psi [8]

R = Outside radius = $29.04/2 = 14.52$ inches [9]

T = thickness = 1.69 inches [1]

The applied forces and moments are shown in Table 1 and were determined using References 7 and 11. For purposes of this calculation, the thermal stresses are conservatively included as primary stresses. The forces and moments are combined using square root of the sum of the squares as shown in Table 1.

The length of the flaw due to IGSCC at the end of the next operating cycle is

$$l = 1.59 \text{ in} + (5 \times 10^{-5} \text{ in/hour})(2 \text{ years})(365 \text{ days/year})(24 \text{ hrs/day})(2 \text{ crack tips}) = 3.34 \text{ in}$$

The ratio of crack length to inside diameter length is:

$$a/l = (3.34 / (2\pi(29.04/2 - 1.69))) = 0.041$$

The stresses being considered here are those for normal and upset conditions, which will be the bounding case since the increase in stresses for emergency and faulted will not exceed the increase in



the safety factor for emergency and faulted conditions. Therefore only Table IWB-3641-1 is required for this evaluation.

Table 3 gives the stress calculation which results in a total stress ($P_m + P_b$) of 8.73 ksi using the Section properties in Table 2. Note that this conservatively assumes that the thermal stress is a primary stress. The stress ratio needed for Table IWB-3641-1 is $8.73\text{ksi}/23.3\text{ksi} = 0.38$, where 23.3 ksi is the S_m for Alloy 600, which is the corresponding base material for Alloy 82/182.

From Table IWB-3641-1 for a stress ratio of 0.38 and a/l of 0.041, the allowable flaw depth/wall thickness is 0.75, or 75% of wall.

5.2 Crack Growth

5.2.1 Stress Corrosion Crack Growth

The flaw depth due to IGSCC at the end of the next cycle using NWC is:

$$a = 0.3 \text{ in} + (5 \times 10^{-5} \text{ in/hr})(24)(2)(365) = 1.176 \text{ inch or } 69.6\% \text{ of wall}$$

The flaw depth at the end of the next cycle using HWC is:

$$a = 0.3 \text{ in} + (5 \times 10^{-6} \text{ in/hr})(24)(2)(365) = 0.388 \text{ inch or } 23\% \text{ of wall}$$

Note that if the actual measured thickness, 1.75 inches [1] is used, the percentage of wall reduces to 67.2% and 22.2% for the NWC and HWC cases, respectively.

5.2.2 Fatigue Crack Growth

As mentioned earlier, the number of cycles that can be tolerated such that the flaw, using NWC growth rate, grows to 75% of wall will be used as a measure of the importance of fatigue crack growth.

The margin between the 75% limit and the flaw depth considering IGSCC (NWC) only at the end of the next operating cycle (75%-69.6%) is,

$$M = (0.75 - 0.696)(1.69) = 0.09 \text{ inches}$$

The fatigue crack growth rate (FCGR) from the ASME Code (Figure C-3210-1, [5]) is used. Using the multiplier of 10 on the air crack growth rate curve [10] at 550°F in Figure C-3210-1, provides the crack growth rate as a function of ΔK in the BWR environment. For purposes of this evaluation, a ΔK of 50 ksi $\sqrt{\text{in}}$ will be used to determine the crack growth rate. A ΔK of 50 ksi is representative of the case of an ID flawed pipe subjected to 30 ksi membrane stress using the ASME Code Section XI crack model with an aspect ratio similar to the actual flaw. This also assumes that all cyclic loads occur after the flaw has grown by SCC. Since there will be significant residual stress present, an R



ratio (K_{min}/K_{max}) of 0.79 will be used (center curve in Figure C-3210-1). For a ΔK of 50 ksi \sqrt{in} , the crack growth rate is approximately 2×10^{-4} in/cycle.

The number of allowable cycles can then be calculated as:

$$N = M/FCGR = 0.09/2 \times 10^{-4} = 450 \text{ cycles}$$

During one two-year operating cycle, the number of startup-shutdown cycles is very limited and is well below this value. Even if other transients were included (which would likely be less in magnitude compared to a startup-shutdown stress cycle), the number of cycles would very likely be bounded by the 450 cycles.

This calculation demonstrates that the impact of fatigue is not significant on the flaw.

6.0 CONCLUSIONS AND DISCUSSIONS

From the results of this evaluation, the following conclusions can be made.

- The allowable through-wall flaw depth is 75% of pipe wall.
- The N2 flaw meets the ASME Code Section XI IWB-3640 requirements (75% of wall for the as-found lengths) at the end of the next two-year operating cycle using NWC conditions. The flaw depth at the end of the next cycle is 69.6% of wall. Even though NMP1 is operating on HWC and NMCA, no credit is taken for the benefit on water chemistry and crack growth rate.
- Fatigue crack growth for actual expected transients over the next operating cycle is not significant.
- Under HWC conditions, the flaw depth at the end of the next cycle is only 23% of wall. Based on the fact that NMP1 is on HWC, and assuming that the flaw is an active flaw, flaw growth would be substantially closer to the HWC value (23%) than the NWC value (69.6%).

7.0 REFERENCES

1. WesDyne Weld Examination Summary Report # W-1-1105-07-007, March 30, 2007.
2. BWR Vessels and Internals Project: Evaluation of Crack Growth in BWR Nickel Base Austenitic Alloys in RPV internals (BWRVIP-59), EPRI, Palo Alto, CA, 1998.
3. EPRI Report NP-7085-D, "Inconel Weld-Overlay Repair for Low-Alloy Steel Nozzle to safe End Joint," January 1991.
4. *Materials Reliability Program: Welding Residual and Operating Stresses in PWR Plant Alloy 182 Butt Welds (MPR-106)*, EPRI, Palo Alto, CA, 2004, 1009378 (Proprietary).
5. ASME Boiler and Pressure Vessel Code, Section XI, 1995 Edition with Addenda up to and including 1997.



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6. SI Calculation Package NMP-09Q-301, Rev. 1, "Cycle-Based Fatigue Development for RPV and Torus-Attached Piping Penetration Locations for NMP-1," December 2005.
 7. NMP Calculation S12.9-32P003, Rev. 0, Attachment A.
 8. NMP-1 Calculation No. S0VESSELM026, Revision 01, Disposition 01A (Combustion Engineering, Inc. Analytical Report No. CENC-1142), "Analytical Report for Niagara Mohawk Reactor Vessel," SI File No. NMP-09Q-246.
 9. Newport News Industrial Corporation, Number CWI-1399K-4-14, Rev. B Sept. 1982.
 10. Journal of Pressure Vessel Technology, Transactions of the ASSME, "Evaluation of Flaws in Austenite Steel Primary" Section XI Task Group for Piping Flaw Evaluation, ASME Code, Vol. 108, August 1988.
 11. NMP Calculation S12.9-32P003, Rev. 0, Attachment B.

Table 1: Applied Loads at N2 [7, 11]

Load	Fx (lbs)	Fy (lbs)	Fz (lbs)	Mx (in-lbs)	My (in-lbs)	Mz (in-lbs)
Weight	70	3270	190	-106710	58090	-61859
Thermal (+)	0	22260	10360	0	1497010	352070
Thermal (-)	-3520	-5680	0	-602960	0	-1915560
OBE Seismic	6583	5123	1302	232416	312302	323629
Max Seismic	6583	5123	1302	232416	312302	323629
OBE E.E.	4725	4065	1437	210045	292348	259513
Max E.E. DY	4725	4065	1437	210045	292348	259513
Total (+)	11379	34719	13290	442462	2159750	873352
Total (-)	-14759	-11599	-2740	-1152132	-604650	-2560562
SRSS (+)	38878			2.371×10^6		
SRSS (-)	18970			2.872×10^6		

Note: Thermal loads were taken from Ref. 7 and combined conservatively including shear load (Fy, Fz) and torsional (Mx) moments in calculating the membrane and bending stress. This results in higher stress compared to using the Ref. 11 thermal loads considering only the membrane and bending contributing components (Fx, My, Mz).

Table 2: Section Properties

Property	
OD (in) [9]	29.04
Thickness (in) [1]	1.69
Area	145.21
Moment of Inertia (in ⁴)	13629.3
Section Modulus Z (in ³)	938.66

Table 3: Stress Calculations

Source of Stress	Stress (ksi)
Pressure	$PR/2t = 5.36$
Force	$38878/145.21 = 0.27$
Moment	$2.872 \times 10^6 / 938.66 = 3.1$
Total	$5.36 + 0.27 + 3.1 = 8.73$

WESDYNE <small>INTERACTIVE</small>		SKETCH Sheet		Report # <u>W-1-1105-07-007</u>	
Site: <u>Nine Mile</u>	Unit: <u>1</u>	Outage #: <u>N1R19</u>	Procedure # <u>WDI-SSP-1105</u>	Revision: <u>0</u>	FCN: <u>N/A</u>
System: <u>Recirc.</u>		Weld #: <u>32-WD-164</u>			

INDICATION #1

SKETCH CONSTRUCTED USING DRAWING # 00788-3667

C. SHAW <i>[Signature]</i>	II	3-28-07			
Drawn By	Level	Date			
Review by	Level	Date	Utility Review by <i>[Signature]</i>	3-30-07	
			Date	ANII Review by	Date

Figure 1: Flaw Examination Indication Data [1]

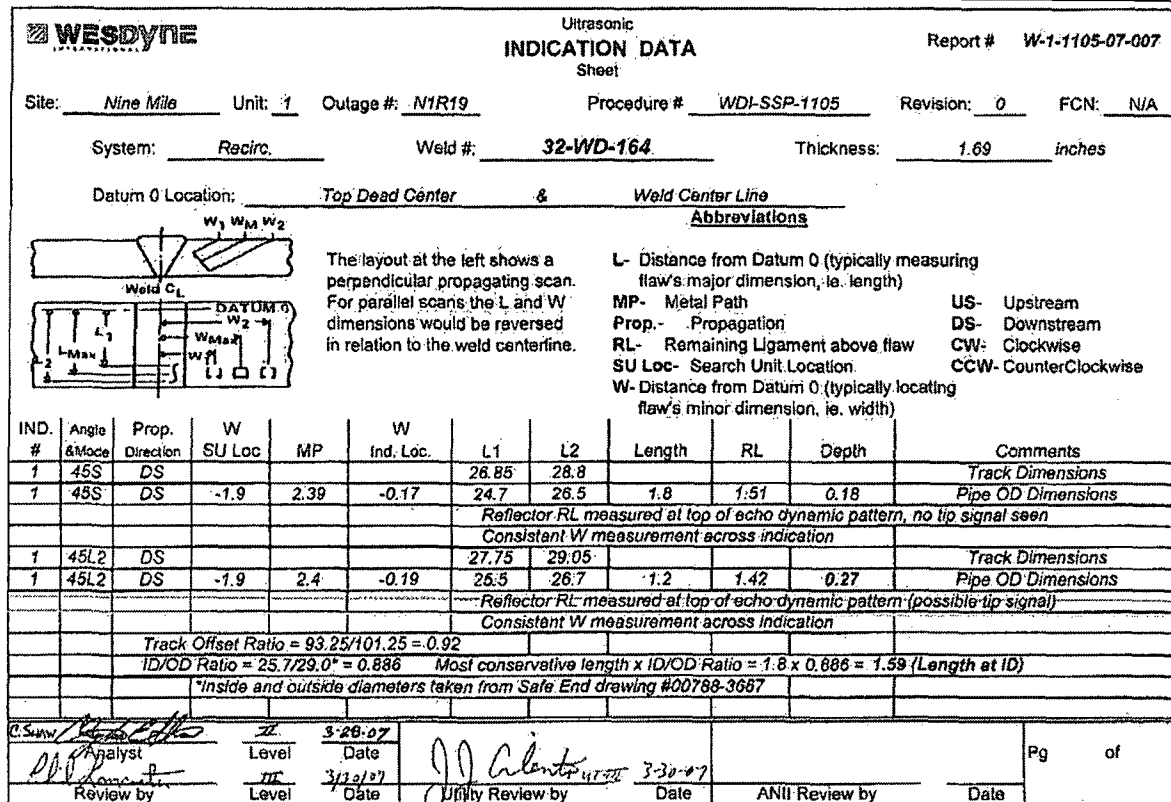


Figure 2: Flaw Examination Indication Data [1]

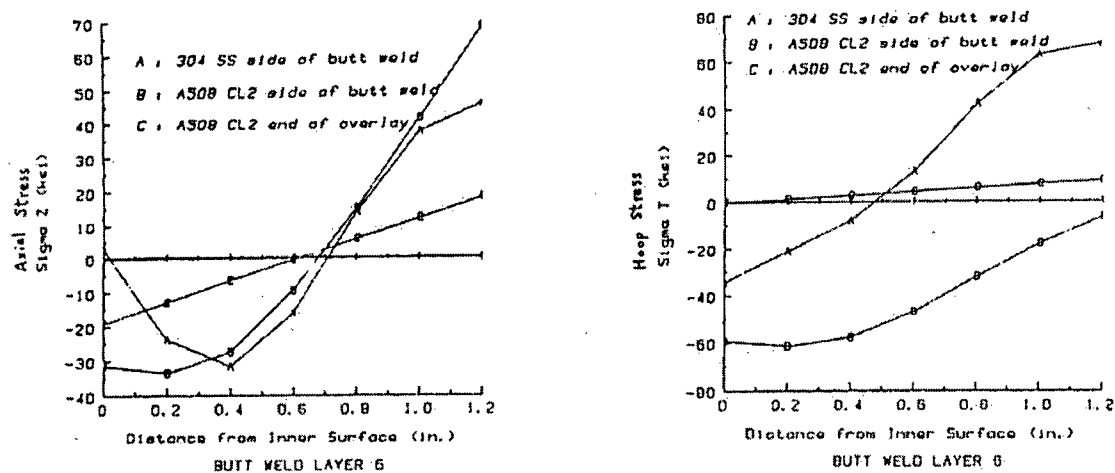
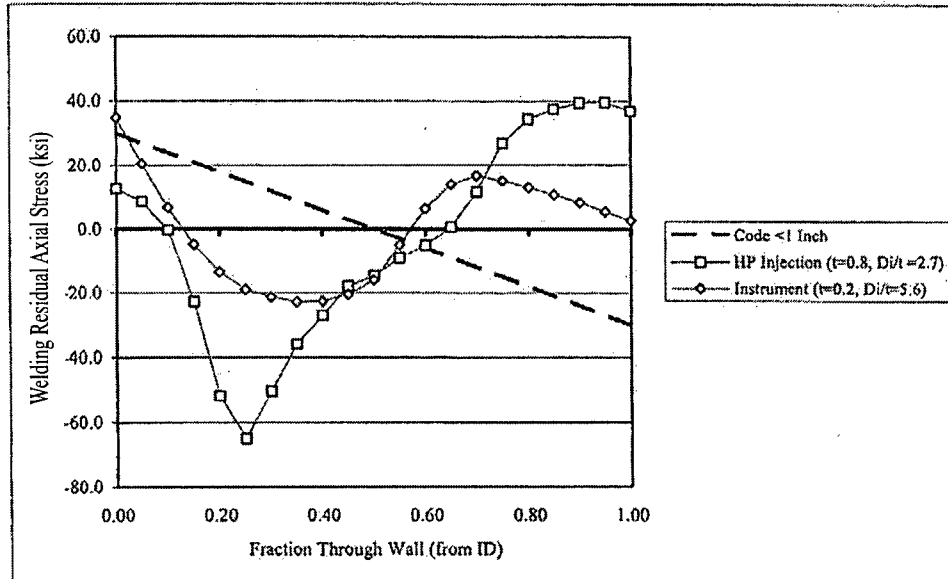


Figure 3: Through-Wall Residual Stress [3]

For Pipes < 1" Thickness



For Pipes > 1" Thickness

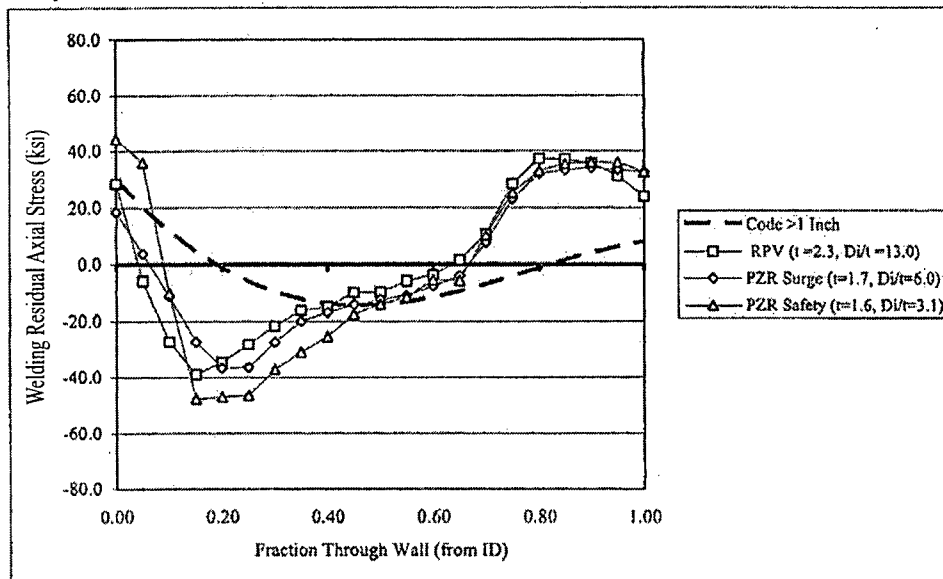
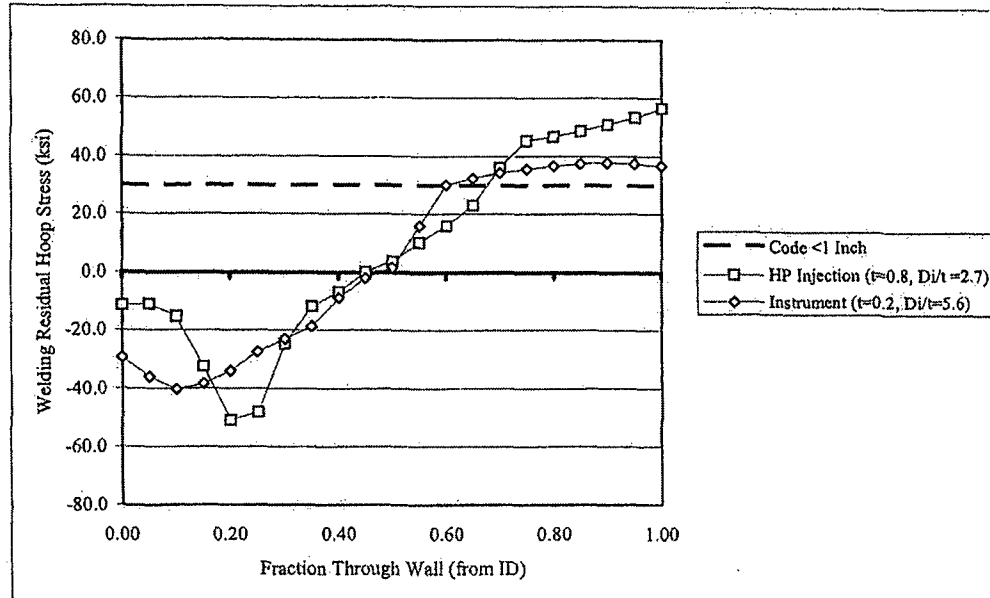


Figure 4: Through-Wall Axial Residual Stresses without Weld Repair [4]



For Pipes < 1" Thickness



For Pipes > 1" Thickness

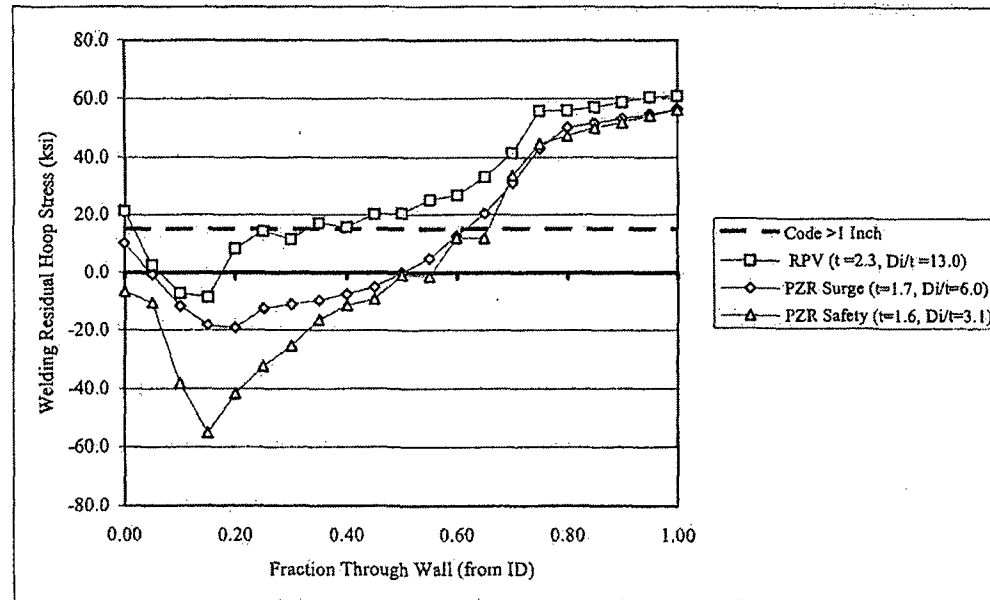


Figure 5: Through-Wall Hoop Residual Stresses without Weld Repair [4]

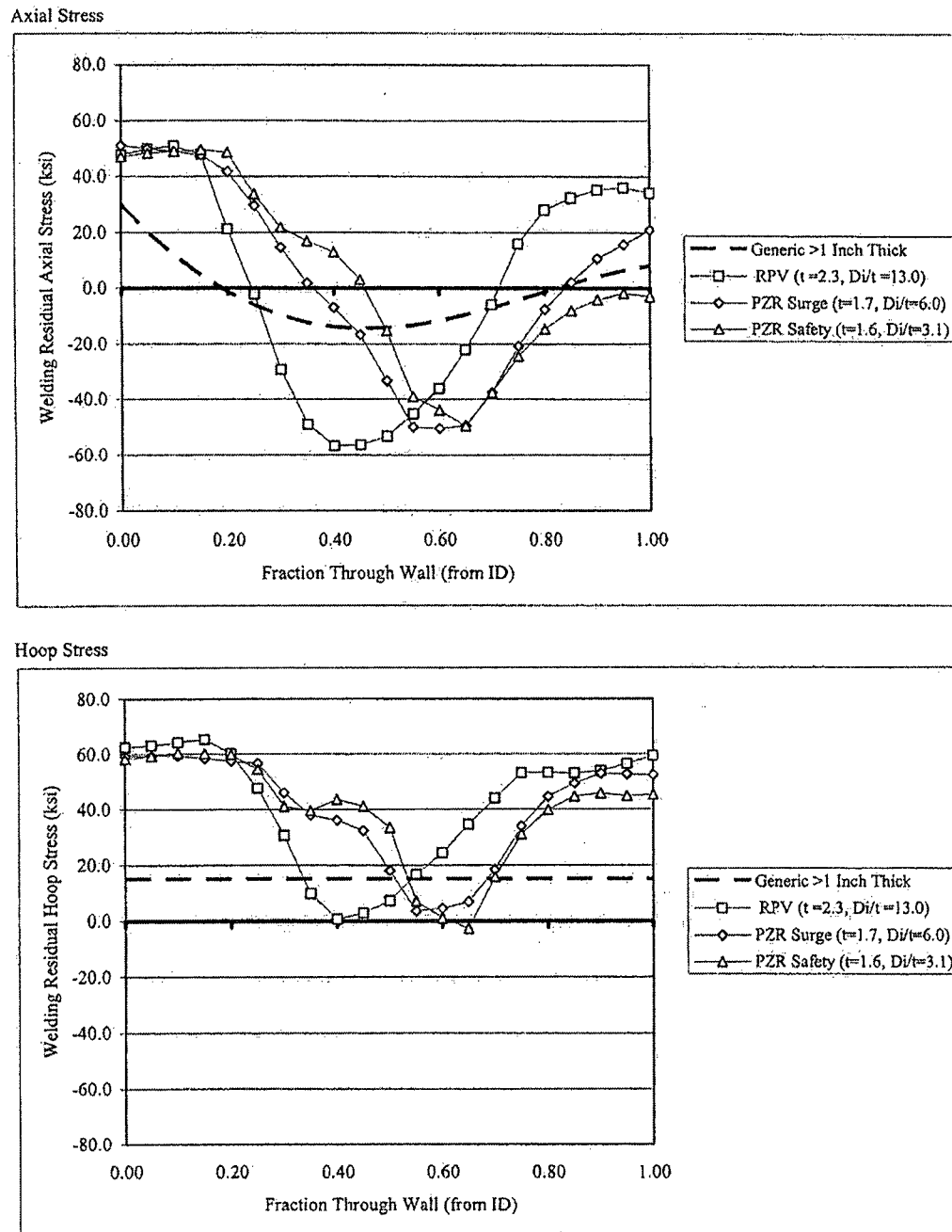


Figure 6: Through-Wall Residual Stress with 360° Inside Surface Weld Repair [4]

TABLE IWB-3641-1
ALLOWABLE END-OF-EVALUATION PERIOD FLAW
DEPTH¹ TO THICKNESS RATIO
FOR CIRCUMFERENTIAL FLAWS — NORMAL OPERATING (INCLUDING UPSET AND TEST) CONDITIONS

$\frac{P_m + P_b}{S_m}$ [Note (2)]	Ratio of Flaw Length, ℓ , to Pipe Circumference [Note (3)]					
	0.0	0.1	0.2	0.3	0.4	0.5 or Greater
1.5	(4)	(4)	(4)	(4)	(4)	(4)
1.4	0.75	0.40	0.21	0.15	(4)	(4)
1.3	0.75	0.75	0.39	0.27	0.22	0.19
1.2	0.75	0.75	0.56	0.40	0.32	0.27
1.1	0.75	0.75	0.73	0.51	0.42	0.34
1.0	0.75	0.75	0.75	0.63	0.51	0.41
0.9	0.75	0.75	0.75	0.73	0.59	0.47
0.8	0.75	0.75	0.75	0.75	0.68	0.53
0.7	0.75	0.75	0.75	0.75	0.75	0.58
≤ 0.6	0.75	0.75	0.75	0.75	0.75	0.63

NOTES:

- (1) Flaw depth = a_s for a surface flaw
 $2a_s$ for a subsurface flaw
 t = nominal thickness
 Linear interpolation is permissible.
- (2) P_m = primary longitudinal membrane stress ($P_m \leq 0.5 S_m$)
 P_b = primary bending stress
 S_m = allowable design stress intensity (in accordance with Section III)
- (3) Circumference based on nominal pipe diameter.
- (4) IWB-3514.3 shall be used.

Figure 7: Table IWB-3641-1 [5]

TABLE IWB-3641-2
ALLOWABLE END-OF-EVALUATION PERIOD FLAW
DEPTH¹ TO THICKNESS RATIO
FOR CIRCUMFERENTIAL FLAWS —
EMERGENCY AND FAULTED CONDITIONS

$P_m + P_b$	Ratio of Flaw Length, ℓ , to Pipe Circumference [Note (3)]							
S_m [Note (2)]	0.0	0.1	0.2	0.3	0.4	0.5	0.75	1.0
3.0	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
2.8	0.75	0.46	0.24	0.17	0.13	(4)	(4)	(4)
2.6	0.75	0.75	0.39	0.27	0.22	0.19	0.17	0.17
2.4	0.75	0.75	0.54	0.38	0.30	0.26	0.24	0.24
2.2	0.75	0.75	0.68	0.48	0.38	0.33	0.30	0.29
2.0	0.75	0.75	0.75	0.58	0.46	0.40	0.35	0.35
1.8	0.75	0.75	0.75	0.67	0.54	0.47	0.41	0.40
1.6	0.75	0.75	0.75	0.75	0.62	0.53	0.46	0.46
1.4	0.75	0.75	0.75	0.75	0.69	0.60	0.51	0.51
≤ 1.2	0.75	0.75	0.75	0.75	0.75	0.66	0.56	0.55

NOTES:

- (1) Flaw depth = a_s for a surface flaw
 $2a_s$ for a subsurface flaw
 t = nominal thickness
 Linear interpolation is permissible.
- (2) P_m = primary longitudinal membrane stress ($P_m \leq 1.0 S_m$)
 P_b = primary bending stress. The sum ($P_m + P_b$) shall not exceed $2S_y$, where S_y is the Section III specified minimum yield stress.
 S_m = allowable design stress intensity (in accordance with Section III)
- (3) Circumference based on nominal pipe diameter.
- (4) IWB-3514.3 shall be used.

Figure 8: Table IWB-3641-2 [5]