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SVP-02-096

November 13, 2002

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Quad Cities Nuclear Power Station, Unit 1
Facility Operating License Nos. DPR-29
NRC Docket Nos. 50-254

Subject: Request for Approval of Pipe Flaw Evaluation

References:

(1) Letter from U.S. NRC to O. D. Kingsley (Exelon Generation Company, LLC), "Quad Cities, Unit 1 – Approval of Weld Overlay Repair Deferrals (TAC NO. MB0312)," dated November 7, 2000.

(2) Letter from T. J. Tulon (Exelon Generation Company, LLC) to U.S. NRC, "Quad Cities Nuclear Power Station Plans to Inspect and/or Weld Overlay Repair Welds 02BS-F4, 02AS-S4, and 02AD-F12," dated January 31, 2001.

(3) Letter from T. J. Tulon (Exelon Generation Company, LLC) to U.S. NRC, "Change of Commitment to Inspect and/or Weld Overlay Repair Welds 02BS-F4, 02AS-S4 and 02AD-F12," dated August 21, 2002.

(4) NRC Generic Letter 88-01, "NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping," dated January 25, 1988.

During the Fall 2001 Unit 1 refueling outage (i.e., Q1R16), Exelon Generation Company, LLC (EGC) planned to implement a full structural weld overlay repair of the 02BS-F4 weld in the Reactor Recirculation System piping at Quad Cities Nuclear Power Station, Unit 1. Due to high dose rates, only three weld layers were applied followed by surface conditioning (0.22 inch final thickness) and the plant was returned to service with a partial thickness overlay (approved in Reference 1). In Reference 2, EGC committed to complete the weld overlay repair of the 02BS-F4 weld, during the Unit 1 refueling outage scheduled for Fall 2002 (i.e., Q1R17). Subsequently, in Reference 3, EGC described a change of commitment due to anticipated high dose rates during Q1R17 and concerns with performing a chemical decontamination of the Reactor Recirculation System. Specifically, in lieu of completing the weld overlay of the 02BS-F4 weld during Q1R17, EGC committed to perform a Performance Demonstration Initiative (PDI) qualified Ultrasonic Test (UT) of the partial weld overlay repair to demonstrate the weld overlay and outer 50% of the original base metal is free from Intergranular Stress Corrosion Cracking (IGSCC) defects. EGC also committed to request NRC approval of a fracture mechanics evaluation to demonstrate continued

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structural integrity through at least the next cycle of operation, provided that the examination results are consistent to the previous examination.

On November 5, 2002, Q1R17 commenced, and on November 7, 2002, the PDI qualified UT of the partial weld overlay repair was performed. The results of the examination are consistent with the previous examination except the outer 50% of the pipe wall versus the outer 25% of the pipe wall including the weld overlay was examined with a PDI qualified manual technique. There was no change in the examination results (i.e., no additional crack growth was observed on weld 02BS-F4 since the previous inspection). This examination technique varies from past practice where only the outer 25% of the original pipe base metal was examined when a full structural weld overlay is in place. The examination results confirmed that the weld overlay and outer 50% of the base metal is free of IGSCC. Continued operation was evaluated using methods consistent with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) and NRC approved BWRVIP criteria conservatively assuming that there was a 360° full circumferential crack with a depth equal to 50% of the original pipe wall thickness.

Consistent with EGC's commitment made in Reference 3, EGC is requesting NRC approval of a pipe flaw evaluation that provides the technical basis for concluding that continued structural integrity will be maintained at least through the next cycle of Unit 1 operation (i.e., Cycle 18). The flaw does not meet the acceptance standards of ASME Code Section XI, 1989 Edition, for continued operation without evaluation. In accordance with GL 88-01 (Reference 4) identified cracks that do not meet these acceptance standards require NRC approval of the flaw evaluation before resumption of operation. The Attachment provides a copy of the pipe flaw evaluation.

The pipe flaw evaluation was performed using the methodology and acceptance criteria specified in ASME Code, Section XI, 1989 Edition, subarticle IWB-3640, the guidance of NUREG-0313, Revision 2, "Technical Report on Material Selection and Process Guidelines for BWR Coolant Pressure Boundary Piping" and NRC approved BWRVIP criteria. This evaluation considered the initial flaw size, expected growth rates, and plant chemistry parameters, and demonstrates that substantial structural margin exists for at least 2 two-year operating cycles since the acceptance criteria of subarticle IWB-3640 are met.

In addition to the structural margin, significant IGSCC mitigation strategies have been implemented at QCNPS. Hydrogen water chemistry has been implemented since 1990, and system average availability has been greater than 90% over the past three years, with electro-chemical potential (ECP) values consistently less than negative 230 millivolts – Standard Hydrogen Electrode (SHE). This indicates that IGSCC crack growth is expected to be negligible under these conditions. Based on the low ECP, it is reasonable to expect extremely low growth rates during the next cycle of operation. In addition, a noble metal chemical application was performed in April 1999.

QCNPS Unit 1 is currently scheduled to commence reactor startup on November 25, 2002. In order to avoid an unnecessary delay in plant startup, EGC requests NRC review and approval of the attached pipe flaw evaluation to support operation during Q1C18 by November 22, 2002.

If you have any questions or require additional information, please contact Mr. Wally Beck at (309) 227-2800.

Respectfully,

Timothy J. Tulon
Site Vice President
Quad Cities Nuclear Power Station

Attachment: General Electric Nuclear Energy Report No. GE-NE-0000-0009-4533-01, "Quad Cities Unit 1 Evaluation of the Indication in Weld 02BS-F4 in the 28 Inch Recirculation Piping," dated November 2002.

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station

Attachment

General Electric Nuclear Energy Report No. GE-NE-0000-0009-4533-01, "Quad Cities Unit 1 Evaluation of the Indication in Weld 02BS-F4 in the 28 Inch Recirculation Piping," dated November 2002

REACTOR SERVICES
GE Nuclear Energy
175 Curtner Avenue, San Jose, CA 95125

GE-NE-0000-0009-4533-01
DRF 0000-0009-4533
Class II
November 2002

Quad Cities Unit 1

Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping

November 2002

Prepared for

Exelon

Prepared by

GE Nuclear Energy

Quad Cities Unit 1

Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping

November 2002

Prepared by: ____________________
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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.Executive Summary

During the Fall 1998 outage at Quad Cities Unit 1, a flaw indication was identified in weld 02BS-F4 in the 28-inch recirculation piping. Earlier inspections in 1989 and 1996 had identified UT reflectors at the same location, but they were interpreted as root geometry. Since the weld had been subjected to stress improvement, it appears that the indication existed since 1989 and there was no appreciable growth since then. The evaluation of the indication in 1998 showed that operation for two cycles was justified, but Exelon Generating Company (EGC) decided to implement a full structural weld overlay repair in 2000. However, because of high dose rate, only three weld layers (0.22 in. thickness) were applied and it was decided that the plant was to return to service with a partial thickness overlay. The NRC approved deferral of the overlay completion to the next cycle. The weld was classified as a category F weld per Generic Letter 88-01 (cracked with inadequate repair) and shown to be acceptable for continued operation for at least one more cycle.

EGC decided to request a change in their commitment to complete the weld overlay in 2002 [7]. The change of commitment is due to (1) anticipated high dose rates during Q1R17, and (2) results of a review of BWRVIP-75 "BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules". In lieu of repair, EGC used a Performance Demonstration Initiative (PDI) qualified Ultrasonic Testing (UT) of the partial weld overlay repair to demonstrate the weld overlay and outer 50% of the original base metal is free from Intergranular Stress Corrosion Cracking (IGSCC) defects. This varies from the previous practice where only the outer 25% of the original pipe base metal is examined when a full structural weld overlay is in place. The examination results confirmed that there was no cracking in the weld overlay and the outer 50% of the original pipe. Continued operation was evaluated **assuming that** there was a 360° full circumferential crack with depth equal to 50% of the original pipe wall thickness. This report describes the results of the fracture mechanics evaluation. The analysis was performed using methods consistent with the ASME Code and NRC approved BWRVIP criteria. It is shown that continued operation can be justified for at least two more cycles (48 months) and the required ASME Code structural margins will be maintained. The fact that the weld has had multiple mitigations implemented – HWC operation with NobleChem™, stress improvement, and weld overlay – and the apparent absence of appreciable growth of the indication since 1989 adds further confidence on the justification for continued operation. As described in Ref. 7, the optimum time for completing the weld repair will be in the next scheduled outage in January 2005 (Q1R18) when the repair can be performed in a lower dose environment. This would be well within the acceptable period of continued operation as defined in this report.

2.Background

During the Fall 1998 outage at Quad Cities Unit 1, a flaw indication was identified in weld 02BS-F4 in the 28-inch recirculation piping. UT reflectors were found in the 1989 and 1996 inspections but were evaluated as root geometry. The 1998 inspection was performed by PDI qualified examiners using EPRI qualified procedures. The 1998 inspection determined that there was an Intergrannular Stress Corrosion Cracking (IGSCC) indication 0.25 in. deep and 27 inches long in the weld region.

As part of the mitigation program to reduce IGSCC susceptibility, the weld was subjected to induction heat stress improvement (IHSI) in 1984. The IHSI treatment was intended to eliminate the tensile weld residual stress pattern and produce a compressive residual stress pattern at the inside diameter surfaces of the girth welds. Fully effective IHSI produces compressive stresses up to the inner 50% of the pipe wall. Even if the IHSI were partially effective, the as-welded residual stresses would have been considerably reduced.

Hydrogen Water Chemistry (HWC) was implemented in 1990 and the plant has been operating with NobleChem™ since April 1999. Considering the fact that the weld has two mitigation measures in place, the likelihood of a service induced crack initiating during the last 10 years is low. This suggests that the weld had an existing indication since 1989 and the root geometry attributed by the 1989 and 1996 inspections was most likely the IGSCC indication identified in 1998. The indication was evaluated using ASME Code Section XI, IWB-3640 and Appendix C [1] procedures using crack growth rates for normal water chemistry based on NUREG-0313, Rev. 2 [2] and shown to be acceptable for continued operation for two 24 month operating cycles (until October 2002).

Nevertheless, it was decided that a weld overlay should be performed on weld 02BS-F4 during the October 2000 outage so that a permanent repair would be in place. The weld overlay was designed to be a full structural overlay that meets ASME Code Case 504-1 requirements. During the welding process the personnel exposure dose rate was found to be extremely high. If the overlay were to be completed as planned, the resulting personnel exposure would have been unacceptable. The weld overlay application was stopped after three layers (approximately 0.22 in.). A flaw evaluation was performed in 2000 which provided justification for continued operation until Fall of 2002.

EGC revised their commitment to the NRC regarding the schedule for completion of the full structural overlay on the subject weld [7]. Rather than completing the overlay during the upcoming outage (Q1R17), the weld was to remain classified as a category F weld (cracked with inadequate repair) [8], and would be re-examined with a manual PDI UT technique. The examination would interrogate the outer 50% of the original pipe thickness. EPRI/PDI reviewed the suggested PDI procedure and basis for its qualification and determined that the procedure could effectively examine the 02BS-F4 weld overlay material and the outer 50% of the original base metal [7].

During the Fall 2002 outage, the subject weld was re-examined using the PDI UT technique discussed in Reference 7. The examination results were consistent with the previous examination and showed that the outer 50% of the original base material and the weld overlay material were free of defects [9].

This report provides the justification for continued operation for two, two year cycles considering a fully circumferential flaw of depth equal to 50% of the nominal pipe thickness.

3.Water Chemistry

Quad Cities Unit 1has been operating with HWC since 1990 and NobleChem™ was implemented in April 1999. Figure 1 shows the conductivity data for the last cycle. It is seen that the overall conductivity ranges from 0.08 to 0.15 μS/cm over the last cycle. The ECP history during the last cycle is shown in Figure 2. The measured ECP is well below the –230 mV SHE threshold for crack arrest. IGSCC crack growth is expected to be negligible under these conditions.

The HWC availability was 97.9% for 2001 and 95.5% for 2002 to date. It is expected that HWC availability during the coming cycle will be comparable. Based on the low conductivity and ECP, it is reasonable to expect extremely low (near zero, $<10^{-7}$ in/hr) growth rates during the coming cycle.

4. IGSCC Indication Parameters

This flaw evaluation is performed using an assumed set of indication parameters. The indication previously identified in weld 02BS-F4 is assumed to be fully circumferential with a depth of 50% of the nominal pipe thickness, 0.62 inch. The indication initial size is repeated below:

Depth:	0.5*t	=	0.62	in
Length:	2πR	=	88	in

The subject weld was re-examined during the Q1R17 outage using an approved PDI UT technique. The examination results demonstrated that the previously identified indication in the subject weld is bounded by the assumed indication discussed above [9].

5. Structural Analysis and Crack Growth Prediction

This section describes both the analytical methods used to perform the structural analysis and the crack growth model used to predict the end of cycle crack depth.

5.1. Structural Analysis

The pipe weld with the indication can be evaluated using the procedures of ASME Code Section XI, Appendix C and the acceptance criteria of IWB-3640 [1]. The evaluation is based on the limit load failure mechanism. The limit load formulas are used to determine the allowable flaw size. The allowable number of hours of operation are calculated considering crack growth. A 90% HWC availability is assumed. The number of hours per cycle were determined using a 2 year operating cycle and a 100% capacity factor as shown below:

Hours per cycle = 2 years/cycle * 365.25 days/year * 24 hours/day * 1 = 17532 hours

5.1.1. Limit Load Analysis Methodology

The limit load method used in the analysis is consistent with the procedures outlined in Appendix C of Section XI of the ASME Code [1]. A brief description of the method is provided next.

Consider a fully circumferential crack of length, $l = 2\pi R$ and constant depth, d. In order to determine the flaw parameters at which limit load is achieved, it is necessary to apply the equations of equilibrium assuming that the cracked section behaves like a plastic hinge. For this condition, the assumed stress state at the cracked section is as shown in Figure 3, where the maximum stress is the flow stress of the material, σ_f. Equilibrium of longitudinal forces and moments about the original neutral axis gives the following equations:

$$\beta = \pi \cdot \frac{\left(1 - \frac{d}{t} - \frac{Pm}{2 \cdot \sigma f}\right)}{2 - \frac{d}{t}} \qquad (1)$$

$$Pb^{I} = \left(\frac{2 \cdot \sigma f}{\pi}\right) \cdot \left(2 - \frac{d}{t}\right) \cdot \sin(\beta) \qquad (2)$$

Where, t = pipe thickness in inches

d = the flaw depth in inches

β = angle that defines the location of the neutral axis in radians

P_m = Primary membrane stress in psi

P_b^I = Failure bending stress in psi

The safety factor, SF, is then incorporated as follows:

$$Pb^{I} \geq Z \cdot SF \cdot \left(Pm + Pb + \frac{Pe}{SF}\right) - Pm \qquad (3)$$

P_m and P_b are the primary membrane and bending stresses, respectively. P_e is the secondary stress and includes stresses from all displacement-controlled loadings such as thermal expansion and dynamic anchor motion. Pe is applicable for flux welds only. All three quantities are calculated from the analysis of applied loading. The safety factor is 2.77 for normal/upset conditions and 1.39 for emergency/faulted conditions. The Z factor is discussed next.

<u>Z Factor</u>

The test data considered by the ASME Code in developing the flaw evaluation procedure (Appendix C, Section XI) indicated that the welds produced by a process that did not use a flux had fracture toughness as good or better than the base metal. However, flux welds had lower toughness. To account for the reduced toughness of the flux welds (as compared to non-flux welds) the Section XI procedures prescribe a penalty factor, called a 'Z' factor. The examples of flux welds are submerged arc welds (SAW) and shielded metal arc welds (SMAW). Gas metal-arc welds (GMAW) and gas tungsten-arc welds (GTAW) are examples of non-flux welds. Figure IWB-3641-1 of Reference 1 may be used to define the weld-base metal interface. The expressions for the value of the Z factor in Appendix C of Section XI are given as follows:

$$Z = 1.15\,[1 + 0.013(OD-4)] \text{ for SMAW} \quad (4)$$
$$\;\; = 1.30\,[1 + 0.010(OD-4)] \text{ for SAW}$$

where OD is the nominal pipe size (NPS) in inches. Except for the root pass, the 02BS-F4 weld was completed using a SMAW process [3]. Therefore, the Z factor in the evaluation was calculated using the expression for SMAW.

5.1.2. Applied Piping Stresses

The applied piping stresses were extracted from the 2000 flaw evaluation report [3] and the internal pressure is obtained from the Extended Power Uprate (EPU) design specification [5]. For completeness, the discussion provided in Reference 3 regarding the applied piping stresses is repeated here.

The applied piping stresses were calculated from the reported axial and bending loads at the subject weld. Table 1 shows the calculated values of the stresses for various load cases. The three thermal load cases are the following:

1. System at 546°F, except between MO-1-0202-6A and -6B and from MO-1001-50 to penetration X-12 which is at 135°F

2. System at 546°F, except between MO-1-0202-6A and -6B and all of the line 1-1025-20"-A to penetration X-12 which is at 135°F

3. System at 340°F, except between MO-1-0202-6A and -6B which is at 135°F.

For the purposes of cross-section area and section modulus calculations, the pipe OD was 28 inches, and the pipe wall thickness was 1.24 inches. The stresses due to weight and seismic were treated as primary stresses (P_m and P_b) and those due to thermal load cases as secondary (P_e).

5.2. Crack Growth Evaluation

The crack growth rate approved by the BWRVIP-14 NRC SER [4] for effective HWC is used in this evaluation. Although the crack growth rates provided in BWRVIP-14 [6] are intended for shroud materials, they are consistent with the crack growth rates calculated using the NUREG-0313, Rev. 2 methodology [2]. Considering the agreement between the NUREG-0313 and BWRVIP-14 crack growth rates, it is acceptable to use the BWRVIP-14 value for this flaw evaluation.

Reference 4 approves the use of a factor of improvement (FOI) equal to 2 on the through wall crack growth rate in shroud materials of 2.2×10^{-5} in/hr for NWC if effective HWC can be demonstrated. Considering the FOI, the effective crack growth rate for 90% effective HWC is 1.1×10^{-5} in/hr.

6. Analytical Results

The allowable flaw size used to determine the allowable hours of operation is the limiting value between the ASME Code Section XI allowable depth (0.75t) [1], and the Appendix C flaw size predicted using the limit load formulas discussed above. Table 2 summarizes the two allowable flaw sizes. Table 3 summarizes the crack growth rate used and the allowable hours of operation.

7. Conclusions

This report presents the fracture mechanics evaluation results for an assumed indication of 360° length and 0.5t depth (0.62"). The PDI UT results of the subject weld obtained during the Fall 2002 outage demonstrated that the outer 50% of the original base material and the weld overlay material were free of defects [9]. These results are consistent with the assumed flaw parameters used in this evaluation. The ECP and Conductivity data contained in this report demonstrate that the water chemistry during the last cycle satisfied the requirements for effective HWC. It is expected that the water chemistry during the next cycles will remain consistent with the previous cycle; therefore, the crack growth rate used in this evaluation is acceptable. The fracture mechanics evaluation was conducted using the procedures of Appendix C and Paragraph IWB-3640, in ASME Section XI [1]. Considering the weld overlay thickness, at least two, two year fuel cycles of operation may be justified using the NRC approved [4] crack growth rate of $1.1x10^{-5}$ in/hr for effective HWC.

8. References

[1] ASME Boiler & Pressure Vessel Code, Section XI, 1995 Edition, through and including 1996 Addenda.

[2] "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," NUREG-0313, Revision 2, January 1998.

[3] Stark, Randy. "Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping", GE-NE. San Jose, CA. October 2000. GE-NE-B13-02064-00-18.

[4] Strosnider, Jack R. "Final Safety Evaluation of Proprietary Report TR 105873 "BWR Vessel and Internals Project, Evaluation of Crack Growth in BWR Stainless Steel Internals (BWRVIP-14)" (TAC NO. M94975)". USNRC. Washington D.C. December 3, 1999. 99-496.

[5] "Reactor Vessel – Power Uprate Certified Design Specification for Quad Cities 1 & 2", GE-NE, San Jose, CA. May 2000. (26A5588, Rev. 0).

[6] "Evaluation of Crack Growth in BWR Stainless Steel RPV Internals". BWRVIP-14. EPRI. Palo Alto, CA. EPRI TR-105873. March 1996.

[7] Tulon, Timothy J. "Change of Commitment to Inspect and/or Weld Overlay Repair Welds 02BS-F$, 02AS-S4 and 02AD-F12". SVP-02-072. August 21, 2002. Exelon.

[8] "Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules". BWRVIP-75. EPRI. Palo Alto, CA. EPRI TR-113932. October 1999.

[9] "GENE Examination Report", Q1R17-007. GE-NE. November 2002.

Table 1: Applied stresses at the 02BS-F4 Weld

Load	Weld 02BS-F4 Stresses (ksi)	
	Membrane	Bending
Weight	0.154	0.175
Thermal 1	0.036	3.065
Thermal 2	0.061	3.014
Thermal 3	0.001	1.905
Seismic OBE	0.032	0.193
Seismic DBE	0.063	0.387
Pressure	4.154	0

Table 2: Tabulation of ASME Section XI and Appendix C allowable flaw sizes.

	ASME Code Limit	Limit Load
Allowable Flaw Depth Ratio (d/t)	0.75	0.751
Allowable Flaw Depth, in (Considering WOL)	1.095	1.096

1. The nominal pipe thickness is 1.24 in
2. The partial weld overlay thickness is 0.22 in

Table 3: Summary of crack growth rates and allowable hours of operation.

Crack Growth Model	Crack Growth Rate, in/hr	Allowable Hours of Operation
BWRVIP-14 with HWC	1.1×10^{-5}	43182

1. One cycle of operation is 17,532 hours.

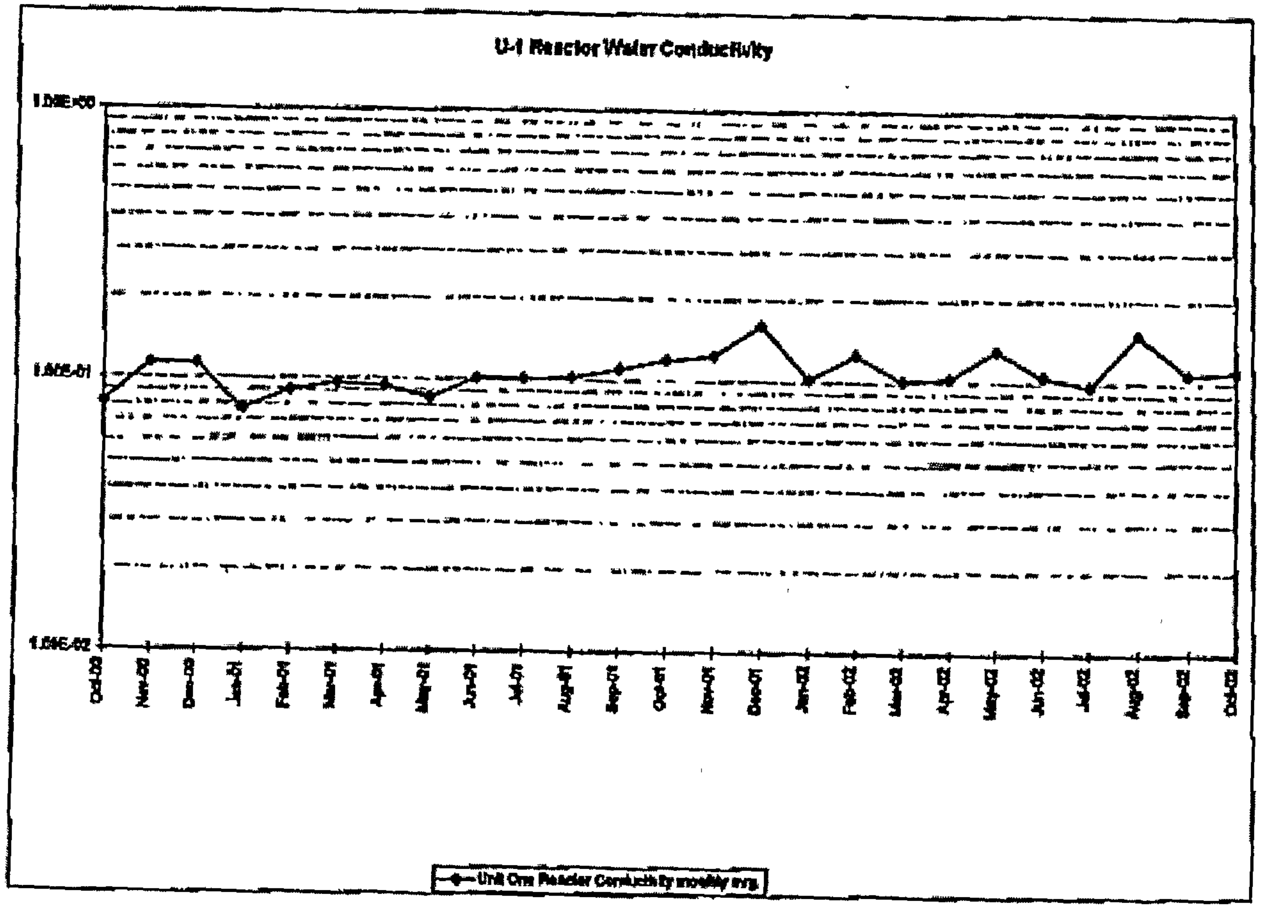

Figure 1: Average Monthly Conductivity During the Last Cycle

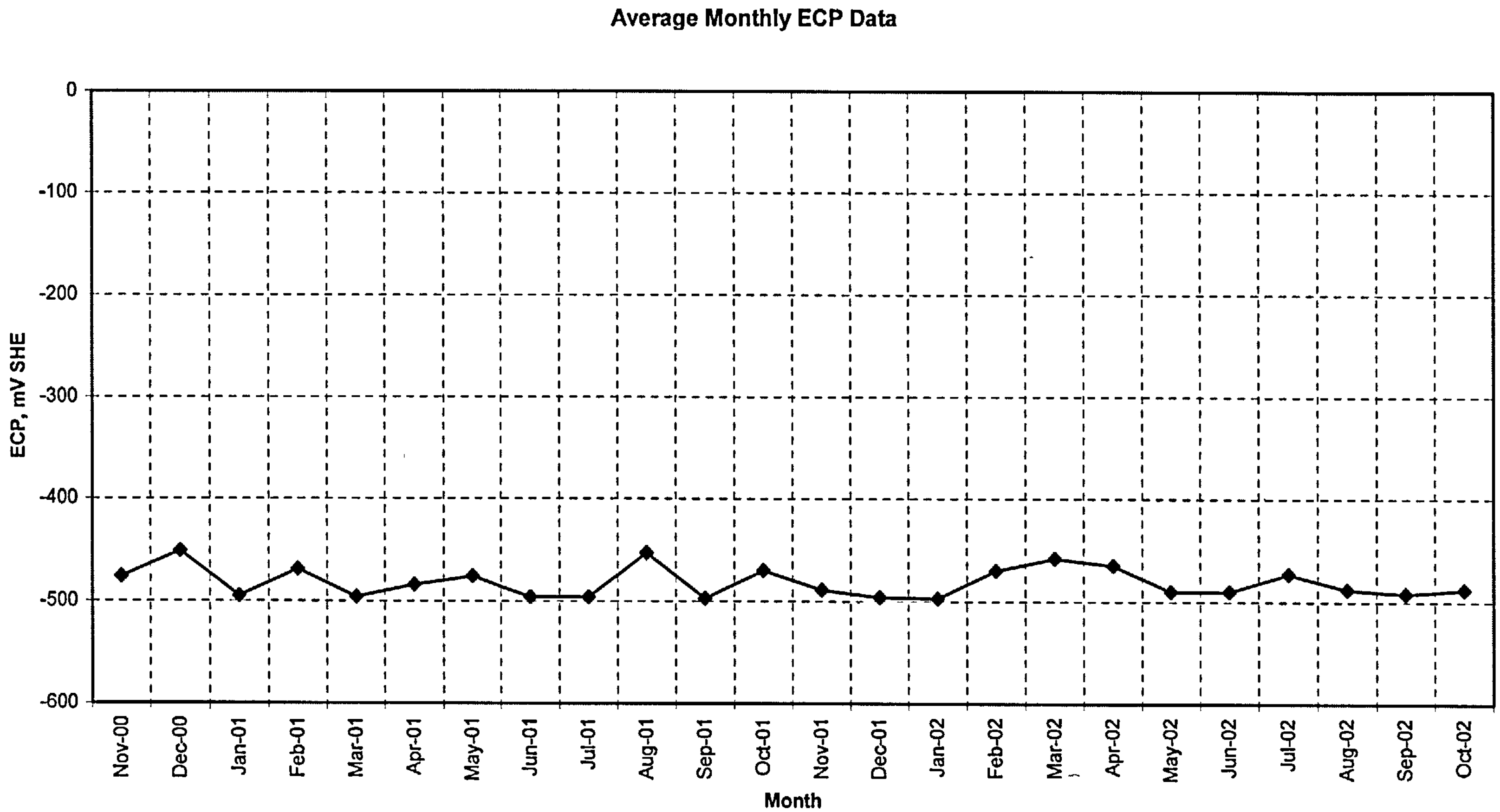

Figure 2: ECP History During the Last Cycle

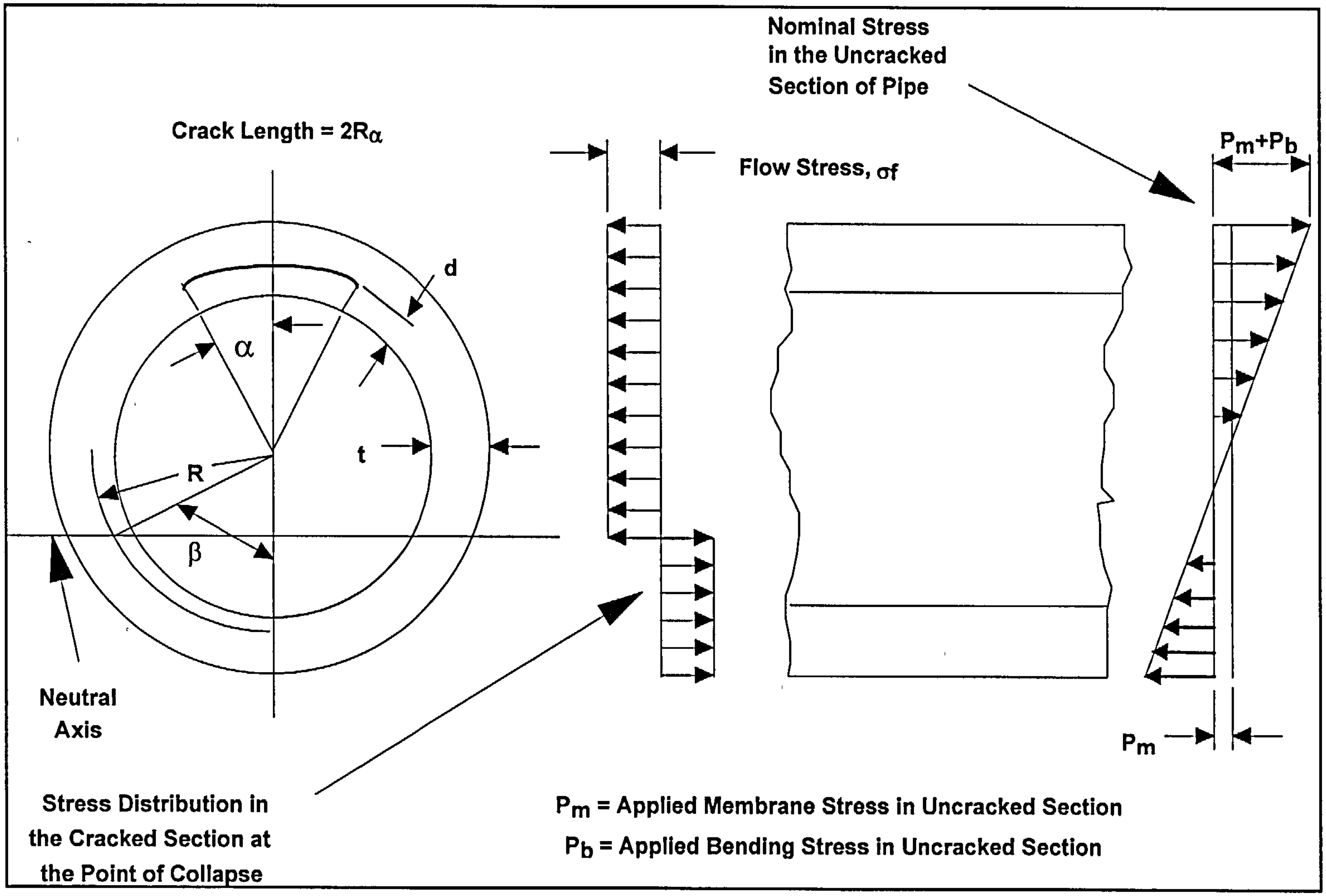

Figure 3: Stress Distribution in a Cracked Pipe at the Point of Collapse