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Volume 1
Design Report for Recirculation and Reactor Water Cleanup System Evaluations and Repairs Performed During the 1988 Refueling Outage at the Quad Cities Nuclear Power Plant, Unit 2

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REVISION CONTROL SHEET

SECTION	PARAGRAPH	DATE	REVISION	COMMENTS
All	All	5-24-88	1	Miscellaneous editorial changes
Rev. Control Page	ii	5-24-88	1	Add (page ii)
3.0	3-7, para. 1	5-24-88	1	Add that first weld overlay layer on RWCU will contain 7.5 FN minimum.
	Table 3-2, page 3-9	5-24-88	1	Change last weld no. to 12S-F26AR
	Table 3-4 page 11	5-24-88	1	Change last weld no. to 12S-F26AR
	Table 3-6 page 13	5-24-88	1	Change weld no. for last overlay to 12S-F26AR and 12S-S26R.

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1.0 INTRODUCTION

As part of the 1988 refueling outage, Commonwealth Edison Company's Quad Cities Unit 2 Nuclear Power Plant performed ultrasonic (UT) examinations of IGSCC susceptible piping welds. A total of 157 weldments were ultrasonically examined during the current Quad Cities Unit 2 refueling outage. These included:

- 66 welds and 14 weld overlay repairs applied in previous outages which were the initial examination scope, and

- 77 additional welds which were part of the expanded sample or post-MSIP UT examinations.

A total of 47 welds in the core spray, residual heat removal (LPCI), and recirculation systems were stress improved using the mechanical stress improvement process (MSIP). Furthermore, all new weld overlays in the recirculation system will be surface conditioned and UT examined this outage in accordance with the EPRI developed techniques.

This report (Volume 1) documents the disposition and repair of flaw indications found by the above examinations [1]. In particular, the evaluation of flaw indications and the design of weld overlay repairs are described in detail. All flaw evaluations and weld overlay repair designs were performed by Structural Integrity Associates, Inc. in accordance with NUREG-0313, Revision 2 [2].

A total of six welds in the 28 inch recirculation system piping were evaluated as being acceptable with flaw indications without repair for at least one additional fuel cycle. As-welded residual stress distributions [2] were conservatively employed for these flaw growth analyses.

Standard design [2], full structural, weld overlay repairs were designed for each of the eleven 12 inch recirculation riser weldments with flaw indications, and for two locations in the 6 inch RWCU system piping. Commonwealth Edison Company elected to repair all flaw indications in the 12 inch and 6 inch piping, with the above standard design weld overlay repairs.

In addition to the flaw evaluations and weld overlay repair designs, Structural Integrity Associates investigated the flaw indications found in previously IHSI treated welds. This discussion is also included in Volume 1 of this report.

Volume 2 of this report will be issued after all weld overlay repairs have been completed. It will include as-built weld overlay dimensions and the disposition of any flaw indications in weld overlays. The results of a system shrinkage stress piping analysis for the recirculation and RWCU piping, from weld overlay shrinkages, will also be documented in Volume 2. The results of this shrinkage stress analysis will be compared to the bounding shrinkage stress of 1 ksi assumed in Volume 1 for flaw evaluations in 28 inch recirculation system piping.

2.0 DESIGN CRITERIA

The requirements for flaw evaluations and the design of weld overlay repairs are defined in NUREG-0313, Revision 2 [2]. Flaw indications are evaluated, and the analytical bases for repairs are in accordance with the requirements of ASME Section XI, IWB-3641 [3] as specified in NUREG-0313.

2.1 Flaw Evaluation

Flawed pipe analyses were performed by Structural Integrity Associates on 28 inch pipe weldments with flaw indications. These evaluations, for disposition of the flaw indications, were done in accordance with NUREG-0313, Revision 2 [2]. Crack growth in the length and depth directions was treated by the methods of [2]. For the purpose of predicting crack growth in the depth direction, a 360° circumferential crack was assumed, along with as-welded residual stresses and a bounding weld overlay shrinkage-induced stress of 1 ksi. The time required to grow the flaw from the maximum reported 1988 depth to the allowable size in accordance with IWB-3641 for shielded metal arc welds (SMAW) was calculated, and compared to the duration of a fuel cycle (18 months).

Sustained stresses for the crack growth analyses included pressure, deadweight, thermal, overlay-induced shrinkage and as-welded residual stresses, to be discussed later in this report. Applied primary and secondary stresses for the evaluation of allowable flaw sizes, in accordance with IWB-3641 [3] for SMAWs, included pressure, deadweight, OBE, thermal and overlay-induced shrinkage stresses.

2.2 Weld Overlay Repair

Weld overlay repairs are considered to be acceptable long term repairs to IGSCC flawed locations if they meet a conservative set of design assumptions to qualify as standard weld overlays as defined in NUREG-0313 [2]. The two principal design requirements to qualify a weld overlay as a standard weld overlay, and therefore IGSCC Category E, are:

1. The design basis flaw for the repair is a circumferentially oriented flaw which extends 360° around the component, and is through the original component wall. This conservative assumption eliminates any potential concern about the reliability of the ultrasonic examination to size flaws. In addition, concerns about the toughness of the original butt weld material are not applicable, since no credit is taken in the design process for the load carrying capability of the remaining component wall ligament.

2. Following the repair, the surface finish of the repair must be sufficiently smooth to allow ultrasonic examination through the overlay material and into a portion of the original wall. The purpose of this examination is, in part, to demonstrate that the repair thickness does not degrade with time due to continued flaw propagation.

In addition to the requirements of Reference 2 , the requirements of the Structural Integrity Associates Technical Specification SIS-88-001, Revision 0 [4] apply to the application of weld overlay repairs at Quad Cities Unit 2. This document defines the technical requirements for the application of weld overlay repairs, and also specifies inspection requirements for the in-process and completed repairs.

As required by ASME Section XI, IWB-3640 [3], pressure, deadweight, and seismic (OBE) components were considered in the evaluation of the weld overlay repairs. Thermal and other secondary stress components were not required to be addressed, since the toughness of the original butt weld material is not a concern for a standard weld overlay, and since no credit is taken for remaining ligament in the original component wall.

3.0 ANALYSIS

Flaw characterization (by UT), stresses, flaw evaluation and weld overlay repair design results are presented in this section of the report, for flaw indications found in piping welds during the 1988 outage.

3.1 Flaw Characterization

During the 1988 augmented stainless steel examination program at Quad Cities Unit 2, flaw indications requiring evaluation (disposition) and repair were identified in the recirculation system 12 inch and 28 inch piping, and in the RWCU 6 inch piping. These UT examination results are summarized in Tables 3-1 (for 28 inch welds to be evaluated for acceptance without repair) and 3-2 (for 12 inch and 6 inch welds to be repaired by weld overlay). Details [1] and the results of previous UT examinations are given in Appendix A.

The reported flaw indication lengths and depths shown in Table 3-1 were employed as starting crack sizes to be grown to allowable flaw sizes in accordance with NUREG-0313 [2]. The crack depth was assumed as the maximum reported depth for the entire length. Although the cracks were grown in depth by assuming a 360° circumferential crack, the cracks were also grown in length (in accordance with [2]), from the initial length in Table 3-1, for comparison against IWB-3641 allowable flaw lengths and depths.

The reported flaw indications in Table 3-2 for 12 inch and 6 inch pipes are not relevant to the weld overlay repairs for these pipe welds, since 360° through-wall cracks are conservatively assumed for the original unrepaired pipe in the standard design basis [2] overlay.

3.2 Stresses

Applied stresses for the pipe welds shown in Tables 3-1 and 3-2, were computed from the pressure, forces and moments from the system stress reports [5], conservatively using the minimum wall thicknesses shown in Tables 3-1 and 3-2. The stresses employed in the 28 inch pipe flaw evaluations and the 12 inch and 6 inch pipe weld overlay designs are summarized in Tables 3-3 and 3-4, respectively.

The general equation used to compute deadweight, thermal and seismic (OBE) stresses is:

$$\sigma = \frac{F_x}{A} + \frac{(M_y^2 + M_z^2)^{1/2}}{Z}$$

where:

F_x = Axial force, local coordinates
M_y, M_z = Bending moments, local coordinates
A = Pipe cross sectional area
Z = Pipe section modulus

Using the above equation, OBE stresses were computed for the x, y and z global coordinate directions, and the maximum stress in either the x or z direction was added to the stress in the y direction absolutely, to obtain the OBE stress in the same manner as in the stress report [5]. The effects of stress concentrations (e.g., stress indices or stress intensification factors) are not included in these stresses [2], since the weld locations are considered to be removed from stress concentrations (such as elbow crotches) and are under the influence of nominal pipe stresses.

Several conservative assumptions, aside from using the pipe minimum wall thickness for calculating stresses, were employed in arriving at the stresses for flaw evaluation and weld overlay repair design. Axial pressure stresses were computed using the conservative thin-wall pipe formula:

$$\sigma = \frac{pR}{2t}$$

where:

p = Design pressure, 1250 psig for recirculation discharge and RWCU, and 1150 psig for recirculation suction.

R = Pipe outer radius

t = Pipe minimum wall thickness.

Use of a more exact pressure stress equation gives axial stresses significantly lower than above. Furthermore, in advance of the completion of weld overlay application and the corresponding shrinkage stress analysis, shrinkage stresses of 1 ksi were conservatively assumed for flaw evaluations in 28 inch recirculation piping. Shrinkage stresses in this piping are likely to be significantly less than this enveloping value, based on the analysis performed after the last outage [6], which gave a maximum repair shrinkage stress of 0.424 ksi in 28 inch pipe.

3.3 Flaw Evaluations

A summary of the flaw evaluations performed for 28 inch recirculation system piping welds is given in Table 3-5. All fracture mechanics evaluations were done using Structural Integrity's pc-CRACK computer program [7], and following the procedures of NUREG-0313, Revision 2 [2]. All flaw indications in the six welds evaluated are acceptable without repair for at least another 18-month fuel cycle (13,140 hrs.). The minimum calculated life, to reach the flaw acceptance limit, is approximately 14,000 hrs. for weld 02BD-F8. Details of the flaw evaluations follow, and are given in Appendix B, for the six welds of interest.

The circumferential flaws in Table 3-5 were conservatively grown [7] as 360° cracks with an initial depth corresponding to the maximum shown in Appendix A (summarized in Table 3-1). Crack growth was in accordance with the following law [2]:

$$da/dt = 3.590 \times 10^{-8} K^{2.161}$$

where:

da/dt = crack growth rate, in/hr.

K = stress intensity factor [2,7]

Weld residual stresses were conservatively assumed as "as-welded" and were in accordance with the fourth order polynomial given in [2], but were curve-fit to a third order polynomial for use in pc-CRACK [7]. Excellent agreement for this curve-fit is demonstrated by the example in Figure 3-1. Third order polynomial coefficients for both suction (1.203 inch thick) and discharge (1.359 inch thick) 28 inch pipe welds are given with the pc-CRACK runs in Appendix B. As mentioned, bounding repair shrinkage stresses of 1 ksi were assumed for crack growth (and flaw acceptance limits). Pressure, deadweight and thermal stresses from Table 3-3 were added to the above repair shrinkage and weld residual stresses to compute K for the crack growth predictions. Crack length was grown in accordance with NUREG-0313, Revision 2 [2], including multiple crack effects for weld 02BD-F8.

The times predicted for the 360° cracks to grow in depth from the initial size to the final allowable size are summarized in Table 3-5. The allowable sizes are computed by pc-CRACK [7] and are based upon the ASME Section XI IWB-3641 table for SMAW welds. These allowable flaw size calculation results are also given in Appendix B of this report. It can be seen in Appendix B that the allowable flaw depth depends on the flaw length, as a fraction of the pipe circumference. Growth of the flaw in the length direction was performed in accordance with [2]. For example, the multiple flaw indications in weld 02BD-F8 are grown in length so that the flaw aspect ratio increases as a multiple of the increase in predicted flaw depth. This growth in length has the effect of approximately quadrupling the crack length for each of the three 3 inch to 3.5 inch flaw indication segments. The total flaw length, as grown, is greater than 30% of the pipe circumference; thus, a 360° flaw length is required [2] to compute the final allowable flaw depth.

For the computation of final allowable flaw sizes in Appendix B, the tabular solutions [7] from IWB-3641 [3] are employed, and are slightly more conservative than the source equation solutions permitted by IWB-3642 [3]. Stresses are taken from Table 3-3, with the primary membrane stress equal to the pressure stress, the primary bending stress equal to the deadweight plus OBE stresses, and the thermal expansion stresses equal to the thermal plus repair shrinkage (1 ksi) stresses.

3.4 Weld Overlay Repairs

Volume 1 of this report documents the weld overlay repair designs for the 12 inch recirculation riser and 6 inch RWCU welds, as summarized in Table 3-6. Details of these designs are given in Appendix C. Volume 2 of this report will include "as-built" overlay dimensions, as well as a repair shrinkage analysis to evaluate the influence of these overlay repairs on piping stresses. These repair shrinkage stresses are of particular use in evaluating the flaw indications in 28 inch recirculation pipe welds, which were accepted for another fuel cycle without repair.

As discussed in Section 2.0 of this report, standard design basis [2] weld overlay repairs were designed for flaw indications in eleven 12 inch recirculation risers and for two 6 inch RWCU pipe locations. As shown in the repair drawings for the 6 inch RWCU piping in Appendix C, in one case a single weld overlay was employed to cover two adjacent butt welds and a plugged location where a sockolet was removed. The stresses from Table 3-4 were used to design these full structural overlays, with the primary membrane stress equal to the pressure stress, and the primary bending stress equal to the deadweight plus OBE stresses. Again, these designs are in accordance with the methods of NUREG-0313, Revision 2 [2] and Section XI, IWB-3641 tables [3] using pc-CRACK [7]. The minimum design width of the 360° overlays exceeds the dimension 1.5 $\sqrt{Rt}$, where R is the original pipe outer radius and t is the original pipe wall thickness, except where piping component geometries justify less width. Details are given in Appendix C.

In accordance with the Structural Integrity technical specification [4], the surface of the 12 inch recirculation riser welds to be weld overlay repaired will be liquid penetrant (PT) examined and any indications repaired prior to weld overlay application. The first weld overlay layer will contain a minimum delta ferrite content of 7.5 FN. Each of these weld overlays will be surface conditioned to allow for UT examination using the EPRI developed weld overlay examination techniques.

IGSCC-like flaws were evaluated in two 6 inch RWCU system weldments outside of the drywell (see Table 3-2). Several repair options were evaluated and, based on a successful hydrostatic testing of the inaccessible welds, a standard design basis weld overlay in accordance with NUREG-0313, Revision 2 [2] was chosen. Two differences in these weld overlay repairs have been presented to the NRC staff and found acceptable; these being: application of a "dry first layer" and the final weld overlay surface finish.

Due to the through-wall axial and other flaws, a first weld overlay layer, not considered in the design thickness, will be applied to the RWCU weldments with the system drained. This layer is intended to provide an additional "barrier" against welding problems. This completed layer will contain 7.5 FN minimum, be PT examined and any repairs made prior to refilling the system. The weld overlay will then be applied in the normal manner in accordance with the Structural Integrity technical specification [4].

The weld overlay repairs applied to the RWCU system will not be surface conditioned for ultrasonic examination at this time for ALARA and other reasons. If the service life of these repairs is intended to be longer than two fuel cycles of operation, the weld overlays will be surface conditioned and UT examined using the EPRI developed weld overlay UT examination techniques.

TABLE 3-1

Flaw Characterization in 28 inch Pipe Locations

- 1988 Outage -

WELD NUMBER	PIPE O.D. (INCHES)	PIPE THICKNESS (INCHES)	FLAW INDICATION ORIENTATION (AXIAL OR CIRC)	LENGTH (INCHES)	DEPTH (a/t,%)*	SIDE
02AD-F12	28	1.359	CIRC	1	17	PIPE
02AD-S6	28	1.359	CIRC	3	7	ELBOW
02AS-F14	28	1.203	CIRC	42.5	12	PIPE
02AS-S12	28	1.203	CIRC	8	8	PIPE
02BD-F8	28	1.359	CIRC	3	25	ELBOW
			CIRC	3	26	ELBOW
			CIRC	3.5	26	ELBOW
02BS-S12	28	1.203	CIRC	36	13	PIPE

*Flaw depth "a", as % of pipe wall thickness "t"

TABLE 3-2

Flaw Characterization in 6 inch and 12 inch Locations

- 1988 Outage -

WELD NUMBER	PIPE O.D. (INCHES)	PIPE THICKNESS (INCHES)	FLAW INDICATION ORIENTATION (AXIAL OR CIRC)	LENGTH (INCHES)	DEPTH (a/t,%)*	SIDE
02D-S3	12.75	0.585	CIRC	1.5	41	PIPE
			CIRCS(3)	4	26	ELBOW
			AXIALS(2)	---	41	PIPE
			AXIAL	---	24	ELBOW
02E-S3	12.75	0.585	AXIALS(2)	---	24	PIPE
02F-S3	12.75	0.585	CIRC	0.5	48	PIPE
			CIRC	1	22	PIPE
			AXIAL	---	38	PIPE
			AXIALS(4)	---	22	ELBOW
02G-S4	12.75	0.585	AXIALS(2)	---	55	PIPE
02H-S3	12.75	0.585	AXIALS(2)	---	51	PIPE
02J-S3	12.75	0.585	AXIAL	---	17	ELBOW
02J-S4	12.75	0.585	CIRC	2.5	26	PIPE
02K F6	12.75	0.585	CIRC	0.4	54	PIPE
			AXIAL	---	50	PIPE
02L-S3	12.75	0.585	AXIALS(2)	---	17	ELBOW
02L-S4	12.75	0.585	AXIAL	---	43	ELBOW
02M-S4	12.75	0.585	CIRC	1.3	17	ELBOW
			CIRC	0.7	17	ELBOW
12S-S24	6.625	0.432	CIRC	3.75	51	PIPE
			CIRC	6.2	49	PIPE
			AXIALS(2)	---	100	PIPE
12S-F26AR	6.625	0.432	CIRC	0.75	23	UPSTREAM

*Flaw depth "a", as % of pipe wall thickness "t"

Table 3-3

Stress Components for 28 inch Pipe Locations

Weld Number	Pressure (psi)	Deadweight (psi)	Thermal (psi)	OBE (psi)	Shrinkage (psi)*
02AD-F12	6439	57	266	1506	1000
02AD-S6	6439	48	226	569	1000
02AS-F14	6692	55	103	246	1000
02AS-S12	6692	52	205	249	1000
02BD-F8	6439	26	1687	608	1000
02BS-S12	6692	70	859	92	1000

* Assumed - Analysis to be done later

Table 3-4

Stress Components for 12 inch and 6 inch Pipe Locations

Weld Number	Pressure (psi)	Deadweight (psi)	OBE (psi)
02D-S3	6811	737	813
02E-S3	6811	93	1348
02F-S3	6811	155	1169
02G-S4	6811	54	1318
02H-S3	6811	20	948
02J-S3	6811	135	795
02J-S4	6811	77	1277
02K-F6	6811	211	3649
02L-S3	6811	266	1718
02L-S4	6811	168	1804
02M-S4	6811	867	1371
12S-S24	4793	1589	7352
12S-F26AR	4793	171	6693

Table 3-5

Flaw Evaluation Summary for 28 inch Pipe

Weld Number	Initial FLaw Orientation (psi)	Length (in.)	Depth (a/t,%)	Allowable Depth (a/t,%)	End of Cycle L/C*(%)	Time to Reach Allow. Depth (years)
02AD-F12	CIRC	1	17	60	15	4.00
02AD-S6	CIRC	3	7	49	100	3.54
02AS-F14	CIRC	42.5	12	49	100	3.08
02AS-S12	CIRC	8	8	49	100	3.31
02BD-F8	CIRC(3)	3 3 3.5	25 26 26	49	100	1.61
02BS-S12	CIRC	36	13	49	100	2.63

* Final flaw length, in accordance with NUREG-0313, Rev. 2, as % of nominal pipe circumference.

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Table 3-6

Weld Overlay Repair Designs

- 1988 Outage -

Weld Number	Design Length (inches)	Design Thickness (inches)
02D-S3	4.5	0.22
02E-S3	4.5	0.21
02F-S3	4.5	0.21
02G-S4	4.5	0.21
02H-S3	4.5	0.21
02J-S3	4.5	0.21
02J-S4	4.5	0.21
02K-F6	Note 1	0.25
02L-S3	4.5	0.22
02L-S4	4.5	0.22
02M-S4	4.5	0.22
12S-S24	2.4	0.23
12S-F26AR (& 12S-S26R)	Note 2	0.20

Note 1: This is a pipe-to-sweepolet weld. On the pipe side, the full thickness design length is 2.5 inch from weld centerline. On the sweepolet side, the design length is 1.5 inch, or blended into the sweepolet transition, whichever occurs first.

Note 2: Two welds (12S-F26AR and 12S-S26R) are less than 1 inch apart. Upstream of 12S-F26AR, a sockolet has been removed and plugged. The overlay is designed to cover both welds and the plug (see Appendix C).

4.0 DISCUSSION

A discussion of the UT flaw indications found during this outage (Appendix A), especially in view of IHSI treatments and prior inspections, is included in this section. During the current examination program, nine 12 inch welds and one 28 inch weld which were IHSI treated in 1984 were evaluated as containing new IGSCC-like flaw indications. IGSCC flaw growth was also observed in one 28 inch recirculation weld and in two 12 inch diameter riser welds. The UT examination data, the IHSI treatment records and the original fabrication history/radiographs were reviewed for a large majority of these welds, (nine of the eleven 12 inch welds and both of the 28 inch welds). In summary, the observations from this review include the following.

4.1 12 inch Recirculation Riser Welds

Six of the nine newly flawed recirculation riser welds contained only a very limited number (1 or 2) of axial IGSCC indications. The observations related to these welds include:

- the IHSI treatment records showing no evidence that the treatments were outside of the EPRI guidelines,
- the presence of "flat topped" weld crowns for UT examination which make the examination for shallow axially oriented flaws more difficult,
- evidence from the original construction radiographs of wide weld roots and weld crowns, further exacerbating the problems with detecting axially oriented flaws, and
- the presence of evidence in the original construction radiographs that substantial ID grinding was performed on the weld root and counterbore regions of these welds.

From these observations, it is felt that there are sufficient reasons to believe that shallow axially-oriented IGSCC may have been present in these six weldments or may have initiated in the cold worked ground layer in service. It is also believed that it has been difficult to detect these shallow axial flaws in prior examinations due to the weld contour.

Relatively short circumferential flaws were identified in three 12 inch risers, one also containing axial flaws. Flaw growth was observed in the two 12 inch welds which were previously reported as flawed. Review of the IHSI treatment records and original construction radiographs reveal similar observations of successful IHSI treatments, ID grinding and wide weld roots.

4.2 Large Diameter Recirculation Welds

In general, there was no adverse change in the flaw characterization of the previously reported flawed 28 inch weldments. In one case (02BD-F8), flaw growth and new flaws were identified. A short, very shallow (7% through-wall) circumferential flaw was also observed in weld 02AD-S6. The original construction radiographs of this weld showed evidence of ID grinding during construction and root geometry. The IHSI treatment records for these welds showed no evidence that the treatments were outside of the EPRI guidelines.

In summary, new IGSCC-like flaw indications have been observed in a number of IHSI treated welds previously reported as unflawed. In addition, flaw growth in a limited number of welds previously reported as flawed has also been observed. An initial review of the IHSI treatment records, original construction radiographs and prior UT examination history indicates that:

- the IHSI treatments were all within the current EPRI guidelines, and

- there is strong evidence of ID grinding and/or wide weld roots in each of these welds.

Additional work is underway to further investigate these observations as part of an industry-wide research effort under the auspices of the Electric Power Research Institute (EPRI).

5.0 CONCLUSIONS

During the 1988 refueling outage at Quad Cities Unit 2, augmented inspection of piping for IGSCC and post-MSIP UT resulted in the UT inspection of 143 welds and 14 previously applied weld overlays. This report documents the disposition of the flaw indications found in piping welds during the above inspection. The disposition of UT inspection results of prior and current weld overlays will be discussed in Volume 2 of this report, along with "as-built" overlay dimensions and a repair shrinkage stress analysis, after the weld overlays are completed.

All flaw evaluations and weld overlay repair designs are in accordance with NUREG-0313, Revision 2 [2]. A total of six 28 inch pipe recirculation system welds with UT flaw indications were evaluated as being acceptable without repair for at least one additional 18-month fuel cycle. As-welded residual stress distributions [2] were assumed (although IHSI had been performed in 1984) and repair shrinkage stresses of 1 ksi were conservatively employed to evaluate these flaws.

Standard design [2], full structural weld overlay repairs were designed for each of the eleven 12 inch recirculation riser weldments with flaw indications, and for the two 6 inch piping locations with flaw indications in the RWCU system.

In addition to the above flaw evaluations and weld overlay designs, Structural Integrity Associates investigated the flaw indications found in previously IHSI treated welds. IHSI treatment records show no evidence that the treatments may have been outside of the EPRI guidelines. However, there is evidence of ID grinding and/or wide weld roots in these welds; therefore, shallow axial cracks may have initiated in this ground layer and been difficult to detect during prior UT examinations due to the weld contour. Additional work is underway to further investigate these observations as part of an industry-wide research effort under the auspices of the Electric Power Research Institute (EPRI).

6.0 REFERENCES

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APPENDIX A

Flaw Characterization by Ultrasonic (UT) Examination

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
6 inch Reactor Water Cleanup (RWCU) Welds

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 12S-S24 (6 inch flued head-to-pipe)				
1983 - 1986	Not examined			
1988	circumferential	3-3/4	51	pipe
	circumferential	6.2	49	pipe
	2 axials	-	100	pipe
Weld 12S-F26AR (6 inch pipe-to-pipe)				
1986	No reportable indications	-	-	-
1988	circumferential	3/4	23	pipe (upstrm.)

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
12 inch Recirculation Riser Welds (Note 1)

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02D-S3	(12 inch pipe-to-elbow)			
1983	circumferential	1/2	25	pipe
1985	circumferential	1/2	26-28	pipe
1986	circumferential	0.6	17	pipe
1988	circumferential	1.5	41	pipe*
	3 circumferentials	4	26	elbow**
	2 axials	-	41	pipe
	axial	-	24	elbow

* = w/axial component
** = 2 w/axial components

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02E-S3	(12 inch pipe-to-elbow)			
1983	ID and OD geometry			
1985	not examined			
1986	intermittent root geometry			
1988	2 axials	-	24	pipe
Weld 02F-S3	(12 inch pipe-to-elbow)			
1983	no reportable indications			
1985	not examined			
1986	no reportable indications			
1988	circumferential	1/2	48	pipe
	circumferential	1	22	pipe
	axial	-	38	pipe
	4 axials	-	22	elbow

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
12 inch Recirculation Riser Welds (Note 1)
(continued)

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02G-S4	(12 inch pipe-to-elbow)			
1983	OD geometry			
1985	ID & OD geometry			
1986	no reportable indications			
1988	2 axials	-	55	pipe
Weld 02H-S3	(12 inch pipe-to-elbow)			
1983	OD geometry			
1985	not examined			
1986	OD geometry			
1988	2 axials	-	51	pipe
Weld 02J-S3	(12 inch pipe-to-elbow)			
1983	OD geometry			
1985	not examined			
1986	no reportable indications			
1988	axial	-	17	elbow
Weld 02J-S4	(12 inch pipe-to-elbow)			
1983	ID geometry			
1985	not examined			
1986	no reportable indications			
1988	circumferential	2-1/2	26	pipe

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
12 inch Recirculation Riser Welds (Note 1)
(continued)

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02K-F6	(12 inch pipe-to-sweepolet)			
1983	ID geometry			
1985	not examined			
1986	no reportable indications			
1988	circumferential	0.4	54	pipe
	axial	-	50	pipe
Weld 02L-S3	(12 inch pipe-to-elbow)			
1983	OD geometry			
1985	not examined			
1986	no reportable indications			
1988	2 axials	-	17	elbow
Weld 02L-S4	(12 inch pipe-to-elbow)			
1983	no reportable indications			
1985	not examined			
1986	no reportable indications			
1988	axial	-	43	elbow
Weld 02M-S4	(12 inch pipe-to-elbow)			
1983	circumferential	1/2	9	elbow
1985	circumferential	1/2	15	elbow
1986	circumferential	1/2	12	elbow
1988	circumferential*	1.3	17	elbow
	circumferential	0.7	17	elbow

* = w/axial component

Notes:
(1) All welds were IHSI treated in 1984

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
28 inch Recirculation Welds - Note 3

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02AS-S6 (28 inch pipe-to-pipe)				
1983	circumferential	7-1/2	21	upstrm.
1985	circumferential	8	18	upstrm.
1986	circumferential	8	18	upstrm.
1988	no IGSCC reported			
Weld 02AS-F14 (28 inch pipe-to-elbow)				
1983	circumferential	43	20	pipe
	spot	-	30	elbow
1985	circumferential	43 intermit.	13	pipe
1986	circumferential	43 intermit.	14	pipe
1988	circumferential (Note 1)	42-1/2 intermit.	12	pipe
Weld 02AS-S12 (28 inch elbow-to-pipe)				
1983	circumferential	8	14	pipe
	circumferential	4	11	pipe
	circumferential	1	8	elbow
	circumferential	2	9	elbow
1985	circumferential	8	4	pipe
	circumferential	6-1/2	5	pipe
	circumferential	2-1/2	15	elbow
1986	circumferential	6	4	pipe
	circumferential	5	13	pipe
	circumferential	2	22	elbow
1988	circumferential	8	8	pipe

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
28 inch Recirculation Welds - Note 3
(continued)

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02AD-F12	(28 inch pump-to-pipe)			
1983	circumferential	24 total	10	pipe
1985	circumferential	1	18	pipe
1986	circumferential	1	17	pipe
1988	circumferential	1	17	pipe
	(By manual ultrasonic examination - automated ultrasonic examination showed no IGSCC)			
Weld 02BD-F8	(28 inch valve-to-elbow)			
1983	root geometry			
1985	not examined			
1986	circumferential	4-1/2 total	15	elbow
1988	circumferential	3	25	elbow
	circumferential	3	26	elbow
	circumferential	3-1/2	26	elbow
	root geometry			
Weld 02BS-S12	(28 inch pipe-to-elbow) - Note 2			
1983	circumferential	32	16	pipe
	root geometry			pipe
1985	circumferential	36	21	pipe
	root geometry			pipe
1986	circumferential	36	13	pipe
	root geometry			pipe
1988	circumferential	36	13	pipe
	root geometry			pipe
	(By manual ultrasonic examination - automated ultrasonic examination showed no IGSCC)			

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
28 inch Recirculation Welds - Note 3
(continued)

Year Examined	Orientation	Length (inch)	Depth (%tw)	Side
Weld 02AD-S6 (28 inch pipe-to-elbow)				
1983	ID geometry			
1985	not examined			
1986	root geometry			
1988	circumferential	3	7	elbow
Weld 02BS-F14 (28 inch pipe-to-elbow)				
1983	circumferential	5-1/4	18	pipe
1985	circumferential ID root geometry	1	10	pipe
1986	ID root geometry			
1988	no IGSCC reported			

Notes:

(1) 42-1/2 inches is the total extent of the flaws with a combined length of 34-1/2 inches.

(2) Weld 02BS-S12 has previously been reported as flawed based on manual ultrasonic examinations. A metallurgical plug sample removed in 1983 showed the presence of a backwelded root and no indication of IGSCC.

(3) All welds were IHSI treated in 1984.

APPENDIX B

Flaw Evaluation Analyses

STRUCTURAL INTEGRITY ASSOCIATES, INC.

tm
pc-CRACK

VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, RECIRC DISCHARGE, WELD 02BD-F8

WALL THICKNESS= 1.3590
MEMBRANE STRESS= 6439.0000
BENDING STRESS= 634.0000
EXPANSION STRESS= 2687.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.4935
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

pc-CRACK[tm]

VERSION 1.2

STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC DISCHARGE, WELD 02BD-F8

INITIAL CRACK SIZE= 0.3533
WALL THICKNESS= 1.3590
MAX CRACK SIZE FOR SCCG= 1.0872

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	K1C
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
DSCHGRESID	30.1467	-155.3298	150.9371	-17.2023
PRESSURE	6.4390	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000
DEAD WT	0.0260	0.0000	0.0000	0.0000
THERMAL	1.6870	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
DSCHGRESID	1.00
PRESSURE	1.00
SHRINKAGE	1.00
DEAD WT	1.00
THERMAL	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	STRESS INTENSITY FACTOR CASE DSCHGRESID	CASE PRESSURE	CASE SHRINKAGE	CASE DEAD WT	CASE THERMAL
0.0217	8.176	1.867	0.290	0.007	0.489
0.0435	10.841	2.652	0.412	0.011	0.695
0.0652	12.418	3.262	0.507	0.013	0.855
0.0870	13.376	3.784	0.588	0.015	0.991
0.1087	13.908	4.249	0.660	0.017	1.113
0.1305	14.123	4.675	0.726	0.019	1.225
0.1522	14.172	5.100	0.792	0.021	1.336

0.1740	14.045	5.515	0.857	0.022	1.445
0.1957	13.747	5.917	0.919	0.024	1.550
0.2174	13.304	6.308	0.980	0.025	1.653
0.2392	12.734	6.691	1.039	0.027	1.753
0.2609	12.055	7.066	1.097	0.028	1.851
0.2827	11.323	7.456	1.158	0.030	1.953
0.3044	10.547	7.863	1.221	0.032	2.060
0.3262	9.693	8.269	1.284	0.033	2.166
0.3479	8.770	8.675	1.347	0.035	2.273
0.3696	7.788	9.081	1.410	0.037	2.379
0.3914	6.753	9.487	1.473	0.038	2.486
0.4131	5.744	9.915	1.540	0.040	2.598
0.4349	4.910	10.411	1.617	0.042	2.728
0.4566	4.055	10.912	1.695	0.044	2.859
0.4784	3.186	11.419	1.773	0.046	2.992
0.5001	2.311	11.932	1.853	0.048	3.126
0.5219	1.435	12.449	1.933	0.050	3.262
0.5436	0.566	12.973	2.015	0.052	3.399
0.5653	-0.278	13.530	2.101	0.055	3.545
0.5871	-1.111	14.094	2.189	0.057	3.692
0.6088	-1.926	14.664	2.277	0.059	3.842
0.6306	-2.715	15.241	2.367	0.061	3.993
0.6523	-3.473	15.824	2.457	0.064	4.146
0.6741	-4.192	16.413	2.549	0.066	4.300
0.6958	-4.956	17.045	2.647	0.069	4.466
0.7176	-5.710	17.696	2.748	0.071	4.636
0.7393	-6.421	18.354	2.850	0.074	4.809
0.7610	-7.081	19.020	2.954	0.077	4.983
0.7828	-7.682	19.694	3.059	0.079	5.160
0.8045	-8.217	20.375	3.164	0.082	5.338
0.8263	-8.384	21.090	3.275	0.085	5.525
0.8480	-8.145	21.838	3.392	0.088	5.722
0.8698	-7.776	22.596	3.509	0.091	5.920
0.8915	-7.268	23.361	3.628	0.094	6.121
0.9132	-6.611	24.135	3.748	0.097	6.323
0.9350	-5.798	24.918	3.870	0.101	6.528
0.9567	-5.065	25.727	3.995	0.104	6.740
0.9785	-4.919	26.601	4.131	0.107	6.969
1.0002	-4.621	27.484	4.268	0.111	7.201
1.0220	-4.157	28.378	4.407	0.115	7.435
1.0437	-3.516	29.280	4.547	0.118	7.671
1.0655	-2.684	30.192	4.689	0.122	7.910
1.0872	-1.649	31.114	4.832	0.126	8.152

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	20.51	2.4569E-05	0.0002	0.3785	0.279
2000.0	20.04	2.3356E-05	0.0002	0.4024	0.296
3000.0	19.77	2.2675E-05	0.0002	0.4254	0.313
4000.0	19.62	2.2327E-05	0.0002	0.4479	0.330

5000.0	19.48	2.1963E-05	0.0002	0.4700	0.346
6000.0	19.33	2.1604E-05	0.0002	0.4918	0.362
7000.0	19.19	2.1265E-05	0.0002	0.5132	0.378
8000.0	19.06	2.0961E-05	0.0002	0.5343	0.393
9000.0	18.98	2.0766E-05	0.0002	0.5552	0.409
10000.0	18.94	2.0671E-05	0.0002	0.5759	0.424
11000.0	18.92	2.0628E-05	0.0002	0.5965	0.439
12000.0	18.93	2.0649E-05	0.0002	0.6172	0.454
13000.0	18.97	2.0749E-05	0.0002	0.6378	0.469
14000.0	19.05	2.0942E-05	0.0002	0.6587	0.485
15000.0	19.17	2.1224E-05	0.0002	0.6798	0.500
16000.0	19.31	2.1563E-05	0.0002	0.7011	0.516
17000.0	19.49	2.2008E-05	0.0002	0.7229	0.532
18000.0	19.74	2.2617E-05	0.0002	0.7452	0.548
19000.0	20.07	2.3432E-05	0.0002	0.7682	0.565
20000.0	20.49	2.4515E-05	0.0002	0.7922	0.583
21000.0	21.24	2.6486E-05	0.0003	0.8175	0.602
22000.0	22.75	3.0722E-05	0.0003	0.8459	0.622
23000.0	25.06	3.7854E-05	0.0004	0.8799	0.647
24000.0	28.54	5.0167E-05	0.0005	0.9233	0.679
25000.0	33.17	6.9397E-05	0.0007	0.9831	0.723
26000.0	40.37	1.0611E-04	0.0011	1.0678	0.786

CRACK DEPTH EXCEEDED 1.0872 AT TIME 2.6180E+04

END OF pc-CRACK

pc-CRACK[tm]
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STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, WELD 02AD-F12

WALL THICKNESS= 1.3590
MEMBRANE STRESS= 6439.0000
BENDING STRESS= 1563.0000
EXPANSION STRESS= 1266.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.5190
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM 0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

tm
pc-CRACK
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VERSION 1.2

STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC DISCHARGE, WELD 02AD-F12

INITIAL CRACK SIZE= 0.2310
WALL THICKNESS= 1.3590
MAX CRACK SIZE FOR SCCG= 1.0872

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	K1C
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
DSCHGRESID	30.1467	-155.3298	150.9371	-17.2023
PRESSURE	6.4390	0.0000	0.0000	0.0000
DEAD WT	0.0570	0.0000	0.0000	0.0000
THERMAL	0.2660	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
DSCHGRESID	1.00
PRESSURE	1.00
DEAD WT	1.00
THERMAL	1.00
SHRINKAGE	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	STRESS INTENSITY FACTOR: CASE DSCHGRESID	CASE PRESSURE	CASE DEAD WT	CASE THERMAL	CASE SHRINKAGE
0.0217	8.176	1.867	0.016	0.077	0.290
0.0435	10.841	2.652	0.023	0.109	0.412
0.0652	12.418	3.262	0.029	0.135	0.507
0.0870	13.376	3.784	0.033	0.156	0.588
0.1087	13.908	4.249	0.038	0.175	0.660
0.1305	14.123	4.675	0.041	0.193	0.726
0.1522	14.172	5.100	0.045	0.211	0.792

STRUCTURAL INTEGRITY ASSOCIATES, INC.

0.1740	14.045	5.515	0.049	0.228	0.857
0.1957	13.747	5.917	0.052	0.244	0.919
0.2174	13.304	6.308	0.056	0.261	0.980
0.2392	12.734	6.691	0.059	0.276	1.039
0.2609	12.055	7.066	0.063	0.292	1.097
0.2827	11.323	7.456	0.066	0.308	1.158
0.3044	10.547	7.863	0.070	0.325	1.221
0.3262	9.693	8.269	0.073	0.342	1.284
0.3479	8.770	8.675	0.077	0.358	1.347
0.3696	7.788	9.081	0.080	0.375	1.410
0.3914	6.753	9.487	0.084	0.392	1.473
0.4131	5.744	9.915	0.088	0.410	1.540
0.4349	4.910	10.411	0.092	0.430	1.617
0.4566	4.055	10.912	0.097	0.451	1.695
0.4784	3.186	11.419	0.101	0.472	1.773
0.5001	2.311	11.932	0.106	0.493	1.853
0.5219	1.435	12.449	0.110	0.514	1.933
0.5436	0.566	12.973	0.115	0.536	2.015
0.5653	-0.278	13.530	0.120	0.559	2.101
0.5871	-1.111	14.094	0.125	0.582	2.189
0.6088	-1.926	14.664	0.130	0.606	2.277
0.6306	-2.715	15.241	0.135	0.630	2.367
0.6523	-3.473	15.824	0.140	0.654	2.457
0.6741	-4.192	16.413	0.145	0.678	2.549
0.6958	-4.956	17.045	0.151	0.704	2.647
0.7176	-5.710	17.696	0.157	0.731	2.748
0.7393	-6.421	18.354	0.162	0.758	2.850
0.7610	-7.081	19.020	0.168	0.786	2.954
0.7828	-7.682	19.694	0.174	0.814	3.059
0.8045	-8.217	20.375	0.180	0.842	3.164
0.8263	-8.384	21.090	0.187	0.871	3.275
0.8480	-8.145	21.838	0.193	0.902	3.392
0.8698	-7.776	22.596	0.200	0.933	3.509
0.8915	-7.268	23.361	0.207	0.965	3.628
0.9132	-6.611	24.135	0.214	0.997	3.748
0.9350	-5.798	24.918	0.221	1.029	3.870
0.9567	-5.065	25.727	0.228	1.063	3.995
0.9785	-4.919	26.601	0.235	1.099	4.131
1.0002	-4.621	27.484	0.243	1.135	4.268
1.0220	-4.157	28.376	0.251	1.172	4.407
1.0437	-3.516	29.280	0.259	1.210	4.547
1.0655	-2.684	30.192	0.267	1.247	4.689
1.0872	-1.649	31.114	0.275	1.285	4.832

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	20.62	2.4858E-05	0.0002	0.2562	0.189
2000.0	20.34	2.4118E-05	0.0002	0.2807	0.207
3000.0	20.03	2.3333E-05	0.0002	0.3044	0.224
4000.0	19.65	2.2378E-05	0.0002	0.3272	0.241

5000.0	19.21	2.1311E-05	0.0002	0.3491	0.257
6000.0	18.73	2.0196E-05	0.0002	0.3698	0.272
7000.0	18.24	1.9070E-05	0.0002	0.3894	0.287
8000.0	17.82	1.8117E-05	0.0002	0.4080	0.300
9000.0	17.56	1.7561E-05	0.0002	0.4258	0.313
10000.0	17.37	1.7146E-05	0.0002	0.4432	0.326
11000.0	17.17	1.6729E-05	0.0002	0.4601	0.339
12000.0	16.98	1.6320E-05	0.0002	0.4766	0.351
13000.0	16.78	1.5925E-05	0.0002	0.4927	0.363
14000.0	16.60	1.5549E-05	0.0002	0.5085	0.374
15000.0	16.42	1.5195E-05	0.0002	0.5238	0.385
16000.0	16.26	1.4867E-05	0.0001	0.5389	0.397
17000.0	16.13	1.4607E-05	0.0001	0.5536	0.407
18000.0	16.01	1.4387E-05	0.0001	0.5681	0.418
19000.0	15.91	1.4192E-05	0.0001	0.5824	0.429
20000.0	15.82	1.4022E-05	0.0001	0.5965	0.439
21000.0	15.74	1.3871E-05	0.0001	0.6104	0.449
22000.0	15.68	1.3757E-05	0.0001	0.6242	0.459
23000.0	15.64	1.3670E-05	0.0001	0.6379	0.469
24000.0	15.60	1.3605E-05	0.0001	0.6516	0.479
25000.0	15.60	1.3591E-05	0.0001	0.6652	0.489
26000.0	15.59	1.3583E-05	0.0001	0.6787	0.499
27000.0	15.59	1.3580E-05	0.0001	0.6923	0.509
28000.0	15.60	1.3606E-05	0.0001	0.7059	0.519
29000.0	15.63	1.3650E-05	0.0001	0.7195	0.529
30000.0	15.68	1.3749E-05	0.0001	0.7332	0.540
31000.0	15.75	1.3890E-05	0.0001	0.7471	0.550
32000.0	15.85	1.4066E-05	0.0001	0.7610	0.560
33000.0	15.98	1.4330E-05	0.0001	0.7752	0.570
34000.0	16.15	1.4649E-05	0.0001	0.7897	0.581
35000.0	16.34	1.5035E-05	0.0002	0.8046	0.592
36000.0	16.84	1.6031E-05	0.0002	0.8201	0.603
37000.0	17.58	1.7607E-05	0.0002	0.8368	0.616
38000.0	18.61	1.9907E-05	0.0002	0.8555	0.630
39000.0	19.92	2.3048E-05	0.0002	0.8769	0.645
40000.0	21.65	2.7603E-05	0.0003	0.9021	0.664
41000.0	24.05	3.4639E-05	0.0003	0.9330	0.687
42000.0	26.78	4.3713E-05	0.0004	0.9723	0.715
43000.0	29.97	5.5754E-05	0.0006	1.0214	0.752

CRACK DEPTH EXCEEDED 1.0872 AT TIME 4.3990E+04

END OF pc-CRACK

tm
pc-CRACK

SAN JOSE, CA (408)978-8200
VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, WELD 02AD-S6

WALL THICKNESS= 1.3590
MEMBRANE STRESS= 6439.0000
BENDING STRESS= 617.0000
EXPANSION STRESS= 1226.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.4601
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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pc-CRACK

VERSION 1.2

STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC DISCHARGE, WELD 02AD-S6

INITIAL CRACK SIZE= 0.0951
WALL THICKNESS= 1.3590
MAX CRACK SIZE FOR SCCG= 1.0872

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	K1C
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
DSCHGRESID	30.1467	-155.3298	150.9371	-17.2023
PRESSURE	6.4390	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000
DEAD WT	0.0480	0.0000	0.0000	0.0000
THERMAL	0.2260	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
DSCHGRESID	1.00
PRESSURE	1.00
SHRINKAGE	1.00
DEAD WT	1.00
THERMAL	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	---STRESS INTENSITY FACTOR--- CASE DSCHGRESID	CASE PRESSURE	CASE SHRINKAGE	CASE DEAD WT	CASE THERMAL
0.0217	8.176	1.867	0.290	0.014	0.065
0.0435	10.841	2.652	0.412	0.020	0.093
0.0652	12.418	3.262	0.507	0.024	0.114
0.0870	13.376	3.784	0.588	0.028	0.133
0.1087	13.903	4.249	0.660	0.032	0.149
0.1305	14.123	4.675	0.726	0.035	0.164
0.1522	14.172	5.100	0.792	0.038	0.179

STRUCTURAL INTEGRITY ASSOCIATES, INC

0.1740	14.045	5.515	0.857	0.041	0.194
0.1957	13.747	5.917	0.919	0.044	0.208
0.2174	13.304	6.308	0.980	0.047	0.221
0.2392	12.734	6.691	1.039	0.050	0.235
0.2609	12.055	7.066	1.097	0.053	0.248
0.2827	11.323	7.456	1.158	0.056	0.262
0.3044	10.547	7.863	1.221	0.059	0.276
0.3262	9.693	8.269	1.284	0.062	0.290
0.3479	8.770	8.675	1.347	0.065	0.304
0.3696	7.788	9.081	1.410	0.068	0.319
0.3914	6.753	9.487	1.473	0.071	0.333
0.4131	5.744	9.915	1.540	0.074	0.348
0.4349	4.910	10.411	1.617	0.078	0.365
0.4566	4.055	10.912	1.695	0.081	0.383
0.4784	3.186	11.419	1.773	0.085	0.401
0.5001	2.311	11.932	1.853	0.089	0.419
0.5219	1.435	12.449	1.933	0.093	0.437
0.5436	0.566	12.973	2.015	0.097	0.455
0.5653	-0.278	13.530	2.101	0.101	0.475
0.5871	-1.111	14.094	2.189	0.105	0.495
0.6088	-1.926	14.664	2.277	0.109	0.515
0.6306	-2.715	15.241	2.367	0.114	0.535
0.6523	-3.473	15.824	2.457	0.118	0.555
0.6741	-4.192	16.413	2.549	0.122	0.576
0.6958	-4.956	17.045	2.647	0.127	0.598
0.7176	-5.710	17.696	2.748	0.132	0.621
0.7393	-6.421	18.354	2.850	0.137	0.644
0.7610	-7.081	19.020	2.954	0.142	0.668
0.7828	-7.682	19.694	3.059	0.147	0.691
0.8045	-8.217	20.375	3.164	0.152	0.715
0.8263	-8.384	21.090	3.275	0.157	0.740
0.8480	-8.145	21.838	3.392	0.163	0.766
0.8698	-7.776	22.596	3.509	0.168	0.793
0.8915	-7.268	23.361	3.628	0.174	0.820
0.9132	-6.611	24.135	3.748	0.180	0.847
0.9350	-5.798	24.918	3.870	0.186	0.875
0.9567	-5.065	25.727	3.995	0.192	0.903
0.9785	-4.919	26.601	4.131	0.198	0.934
1.0002	-4.621	27.484	4.268	0.205	0.965
1.0220	-4.157	28.378	4.407	0.211	0.996
1.0437	-3.516	29.280	4.547	0.218	1.028
1.0655	-2.684	30.192	4.689	0.225	1.060
1.0872	-1.649	31.114	4.832	0.232	1.092

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	19.22	2.1332E-05	0.0002	0.1154	0.085
2000.0	19.90	2.3012E-05	0.0002	0.1376	0.101
3000.0	20.43	2.4363E-05	0.0002	0.1614	0.119
4000.0	20.75	2.5195E-05	0.0003	0.1862	0.137

5000.0	20.85	2.5459E-05	0.0003	0.2116	0.156
6000.0	20.76	2.5216E-05	0.0003	0.2370	0.174
7000.0	20.51	2.4560E-05	0.0002	0.2619	0.193
8000.0	20.21	2.3797E-05	0.0002	0.2861	0.211
9000.0	19.88	2.2970E-05	0.0002	0.3095	0.228
10000.0	19.49	2.1991E-05	0.0002	0.3320	0.244
11000.0	19.04	2.0916E-05	0.0002	0.3534	0.260
12000.0	18.57	1.9805E-05	0.0002	0.3738	0.275
13000.0	18.08	1.8713E-05	0.0002	0.3930	0.289
14000.0	17.67	1.7792E-05	0.0002	0.4113	0.303
15000.0	17.45	1.7323E-05	0.0002	0.4288	0.316
16000.0	17.25	1.6906E-05	0.0002	0.4459	0.328
17000.0	17.06	1.6490E-05	0.0002	0.4626	0.340
18000.0	16.86	1.6085E-05	0.0002	0.4789	0.352
19000.0	16.67	1.5692E-05	0.0002	0.4943	0.364
20000.0	16.49	1.5321E-05	0.0002	0.5103	0.375
21000.0	16.31	1.4970E-05	0.0001	0.5254	0.387
22000.0	16.15	1.4645E-05	0.0001	0.5402	0.398
23000.0	16.02	1.4393E-05	0.0001	0.5547	0.408
24000.0	15.90	1.4174E-05	0.0001	0.5690	0.419
25000.0	15.80	1.3978E-05	0.0001	0.5831	0.429
26000.0	15.71	1.3809E-05	0.0001	0.5970	0.439
27000.0	15.63	1.3656E-05	0.0001	0.6107	0.449
28000.0	15.57	1.3540E-05	0.0001	0.6243	0.459
29000.0	15.52	1.3449E-05	0.0001	0.6378	0.469
30000.0	15.48	1.3381E-05	0.0001	0.6512	0.479
31000.0	15.47	1.3361E-05	0.0001	0.6646	0.489
32000.0	15.47	1.3348E-05	0.0001	0.6779	0.499
33000.0	15.46	1.3340E-05	0.0001	0.6913	0.509
34000.0	15.47	1.3356E-05	0.0001	0.7046	0.518
35000.0	15.49	1.3386E-05	0.0001	0.7180	0.528
36000.0	15.54	1.3476E-05	0.0001	0.7314	0.538
37000.0	15.60	1.3596E-05	0.0001	0.7449	0.548
38000.0	15.69	1.3761E-05	0.0001	0.7586	0.558
39000.0	15.81	1.3995E-05	0.0001	0.7725	0.568
40000.0	15.96	1.4276E-05	0.0001	0.7866	0.579
41000.0	16.14	1.4640E-05	0.0001	0.8011	0.589
42000.0	16.55	1.5449E-05	0.0002	0.8161	0.600
43000.0	17.17	1.6730E-05	0.0002	0.8321	0.612
44000.0	18.11	1.8764E-05	0.0002	0.8438	0.625
45000.0	19.28	2.1494E-05	0.0002	0.8699	0.640
46000.0	20.82	2.5382E-05	0.0003	0.8932	0.657
47000.0	22.93	3.1258E-05	0.0003	0.9214	0.678
48000.0	25.73	4.0097E-05	0.0004	0.9568	0.704
49000.0	28.34	4.9401E-05	0.0005	1.0012	0.737
50000.0	32.83	6.7881E-05	0.0007	1.0583	0.779

END OF pc-CRACK

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pc-CRACK

VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, RECIRC SUCTION, WELD 02AS-F14

WALL THICKNESS= 1.2030
MEMBRANE STRESS= 6692.0000
BENDING STRESS= 301.0000
EXPANSION STRESS= 1103.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.4535
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

tm
pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 1.2

STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC SUCTION, WELD 02AS-F14

INITIAL CRACK SIZE= 0.1444
WALL THICKNESS= 1.2030
MAX CRACK SIZE FOR SCCG= 0.9624

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	KIC
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
SUCRESID	30.1468	-175.4735	192.6252	-24.8033
PRESSURE	6.6920	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000
DEAD WT	0.0550	0.0000	0.0000	0.0000
THERMAL	0.1030	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
SUCRESID	1.00
PRESSURE	1.00
SHRINKAGE	1.00
DEAD WT	1.00
THERMAL	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	STRESS INTENSITY FACTOR CASE SUCRESID	CASE PRESSURE	CASE SHRINKAGE	CASE DEAD WT	CASE THERMAL
0.0192	7.692	1.825	0.273	0.015	0.028
0.0385	10.200	2.593	0.387	0.021	0.040
0.0577	11.684	3.190	0.477	0.026	0.049
0.0770	12.585	3.700	0.553	0.030	0.057
0.0962	13.085	4.155	0.621	0.034	0.064
0.1155	13.288	4.572	0.683	0.038	0.070
0.1347	13.333	4.987	0.745	0.041	0.077

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0.1540	13.214	5.393	0.806	0.044	0.083
0.1732	12.934	5.786	0.865	0.048	0.089
0.1925	12.517	6.168	0.922	0.051	0.095
0.2117	11.981	6.542	0.978	0.054	0.101
0.2310	11.342	6.909	1.032	0.057	0.106
0.2502	10.653	7.290	1.089	0.060	0.112
0.2695	9.923	7.689	1.149	0.063	0.118
0.2887	9.120	8.086	1.208	0.066	0.124
0.3080	8.252	8.483	1.268	0.070	0.131
0.3272	7.327	8.879	1.327	0.073	0.137
0.3465	6.354	9.277	1.386	0.076	0.143
0.3657	5.404	9.695	1.449	0.080	0.149
0.3850	4.620	10.180	1.521	0.084	0.157
0.4042	3.816	10.670	1.594	0.088	0.164
0.4235	2.998	11.166	1.669	0.092	0.172
0.4427	2.174	11.667	1.743	0.096	0.180
0.4620	1.350	12.173	1.819	0.100	0.187
0.4812	0.533	12.685	1.896	0.104	0.195
0.5004	-0.262	13.230	1.977	0.109	0.204
0.5197	-1.046	13.781	2.059	0.113	0.212
0.5389	-1.812	14.339	2.143	0.118	0.221
0.5582	-2.555	14.903	2.227	0.122	0.229
0.5774	-3.268	15.473	2.312	0.127	0.238
0.5967	-3.944	16.049	2.398	0.132	0.247
0.6159	-4.663	16.667	2.490	0.137	0.256
0.6352	-5.373	17.303	2.586	0.142	0.266
0.6544	-6.041	17.947	2.682	0.147	0.276
0.6737	-6.662	18.599	2.779	0.153	0.286
0.6929	-7.228	19.257	2.878	0.158	0.296
0.7122	-7.731	19.923	2.977	0.164	0.307
0.7314	-7.888	20.622	3.082	0.169	0.317
0.7507	-7.663	21.354	3.191	0.175	0.329
0.7699	-7.316	22.095	3.302	0.182	0.340
0.7892	-6.838	22.843	3.413	0.188	0.352
0.8084	-6.220	23.600	3.527	0.194	0.363
0.8277	-5.455	24.365	3.641	0.200	0.375
0.8469	-4.766	25.156	3.759	0.207	0.387
0.8662	-4.628	26.011	3.887	0.214	0.400
0.8854	-4.347	26.875	4.016	0.221	0.414
0.9047	-3.911	27.748	4.146	0.228	0.427
0.9239	-3.308	28.631	4.278	0.235	0.441
0.9432	-2.525	29.523	4.412	0.243	0.454
0.9624	-1.551	30.424	4.546	0.250	0.468

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	19.66	2.2406E-05	0.0002	0.1665	0.138
2000.0	19.75	2.2629E-05	0.0002	0.1891	0.157
3000.0	19.66	2.2407E-05	0.0002	0.2116	0.176
4000.0	19.41	2.1815E-05	0.0002	0.2337	0.194

5000.0	19.14	2.1152E-05	0.0002	0.2552	0.212
6000.0	18.83	2.0423E-05	0.0002	0.2760	0.229
7000.0	18.46	1.9555E-05	0.0002	0.2960	0.246
8000.0	18.04	1.8607E-05	0.0002	0.3151	0.262
9000.0	17.59	1.7624E-05	0.0002	0.3332	0.277
10000.0	17.15	1.6681E-05	0.0002	0.3503	0.291
11000.0	16.77	1.5894E-05	0.0002	0.3666	0.305
12000.0	16.59	1.5537E-05	0.0002	0.3823	0.318
13000.0	16.41	1.5173E-05	0.0002	0.3977	0.331
14000.0	16.23	1.4813E-05	0.0001	0.4127	0.343
15000.0	16.05	1.4461E-05	0.0001	0.4273	0.355
16000.0	15.88	1.4121E-05	0.0001	0.4416	0.367
17000.0	15.71	1.3802E-05	0.0001	0.4555	0.379
18000.0	15.55	1.3503E-05	0.0001	0.4692	0.390
19000.0	15.40	1.3229E-05	0.0001	0.4826	0.401
20000.0	15.30	1.3032E-05	0.0001	0.4957	0.412
21000.0	15.20	1.2854E-05	0.0001	0.5086	0.423
22000.0	15.11	1.2692E-05	0.0001	0.5214	0.433
23000.0	15.04	1.2559E-05	0.0001	0.5340	0.444
24000.0	14.98	1.2449E-05	0.0001	0.5465	0.454
25000.0	14.93	1.2358E-05	0.0001	0.5589	0.465
26000.0	14.90	1.2307E-05	0.0001	0.5713	0.475
27000.0	14.88	1.2281E-05	0.0001	0.5835	0.485
28000.0	14.88	1.2281E-05	0.0001	0.5958	0.495
29000.0	14.89	1.2287E-05	0.0001	0.6081	0.505
30000.0	14.90	1.2306E-05	0.0001	0.6204	0.516
31000.0	14.92	1.2348E-05	0.0001	0.6327	0.526
32000.0	14.97	1.2436E-05	0.0001	0.6451	0.536
33000.0	15.03	1.2554E-05	0.0001	0.6576	0.547
34000.0	15.13	1.2724E-05	0.0001	0.6702	0.557
35000.0	15.25	1.2955E-05	0.0001	0.6831	0.568
36000.0	15.41	1.3236E-05	0.0001	0.6962	0.579
37000.0	15.60	1.3597E-05	0.0001	0.7096	0.590
38000.0	16.03	1.4412E-05	0.0001	0.7235	0.601
39000.0	16.69	1.5740E-05	0.0002	0.7385	0.614
40000.0	17.66	1.7781E-05	0.0002	0.7552	0.628
41000.0	18.90	2.0586E-05	0.0002	0.7744	0.644
42000.0	20.54	2.4636E-05	0.0002	0.7968	0.662
43000.0	22.82	3.0920E-05	0.0003	0.8244	0.685
44000.0	25.47	3.9220E-05	0.0004	0.8596	0.715
45000.0	28.53	5.0104E-05	0.0005	0.9037	0.751

CRACK DEPTH EXCEEDED 0.9624 AT TIME 4.5980E+04

END OF pc-CRACK

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SAN JOSE, CA (408)978-8200
VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, RECIRC SUCTION, WELD 02AS-S12

WALL THICKNESS= 1.2030
MEMBRANE STRESS= 6692.0000
BENDING STRESS= 301.0000
EXPANSION STRESS= 1205.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.4558
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

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STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC SUCTION, WELD 02AS-S12

INITIAL CRACK SIZE= 0.0962
WALL THICKNESS= 1.2030
MAX CRACK SIZE FOR SCCG= 0.9624

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	K1C
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
SUCRESID	30.1468	-175.4735	192.6252	-24.8033
PRESSURE	6.6920	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000
DEAD WT	0.0520	0.0000	0.0000	0.0000
THERMAL	0.2050	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
SUCRESID	1.00
PRESSURE	1.00
SHRINKAGE	1.00
DEAD WT	1.00
THERMAL	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	STRESS INTENSITY FACTOR CASE SUCRESID	CASE PRESSURE	CASE SHRINKAGE	CASE DEAD WT	CASE THERMAL
0.0192	7.692	1.825	0.273	0.014	0.056
0.0385	10.200	2.593	0.387	0.020	0.079
0.0577	11.684	3.190	0.477	0.025	0.098
0.0770	12.585	3.700	0.553	0.029	0.113
0.0962	13.085	4.155	0.621	0.032	0.127
0.1155	13.288	4.572	0.683	0.035	0.140
0.1347	13.333	4.987	0.745	0.039	0.153

0.1540	13.214	5.393	0.806	0.042	0.165
0.1732	12.934	5.786	0.865	0.045	0.177
0.1925	12.517	6.168	0.922	0.048	0.189
0.2117	11.981	6.542	0.978	0.051	0.200
0.2310	11.342	6.909	1.032	0.054	0.212
0.2502	10.653	7.290	1.089	0.057	0.223
0.2695	9.923	7.689	1.149	0.060	0.235
0.2887	9.120	8.086	1.208	0.063	0.248
0.3080	8.252	8.483	1.268	0.066	0.260
0.3272	7.327	8.879	1.327	0.069	0.272
0.3465	6.354	9.277	1.386	0.072	0.284
0.3657	5.404	9.695	1.449	0.075	0.297
0.3850	4.620	10.180	1.521	0.079	0.312
0.4042	3.816	10.670	1.594	0.083	0.327
0.4235	2.998	11.166	1.669	0.087	0.342
0.4427	2.174	11.667	1.743	0.091	0.357
0.4620	1.350	12.173	1.819	0.095	0.373
0.4812	0.533	12.685	1.896	0.099	0.389
0.5004	-0.262	13.230	1.977	0.103	0.405
0.5197	-1.046	13.781	2.059	0.107	0.422
0.5389	-1.812	14.339	2.143	0.111	0.439
0.5582	-2.555	14.903	2.227	0.116	0.456
0.5774	-3.268	15.473	2.312	0.120	0.474
0.5967	-3.944	16.049	2.398	0.125	0.492
0.6159	-4.663	16.667	2.490	0.129	0.511
0.6352	-5.373	17.303	2.586	0.134	0.530
0.6544	-6.041	17.947	2.682	0.139	0.550
0.6737	-6.662	18.599	2.779	0.144	0.570
0.6929	-7.228	19.257	2.878	0.150	0.590
0.7122	-7.731	19.923	2.977	0.155	0.610
0.7314	-7.888	20.622	3.082	0.160	0.632
0.7507	-7.663	21.354	3.191	0.166	0.654
0.7699	-7.316	22.095	3.302	0.172	0.677
0.7892	-6.838	22.843	3.413	0.177	0.700
0.8084	-6.220	23.600	3.527	0.183	0.723
0.8277	-5.455	24.365	3.641	0.189	0.746
0.8469	-4.766	25.156	3.759	0.195	0.771
0.8662	-4.628	26.011	3.887	0.202	0.797
0.8854	-4.347	26.875	4.016	0.209	0.823
0.9047	-3.911	27.748	4.146	0.216	0.850
0.9239	-3.308	28.631	4.278	0.222	0.877
0.9432	-2.525	29.523	4.412	0.229	0.904
0.9624	-1.551	30.424	4.546	0.236	0.932

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	18.71	2.0144E-05	0.0002	0.1155	0.096
2000.0	19.28	2.1500E-05	0.0002	0.1364	0.113
3000.0	19.66	2.2417E-05	0.0002	0.1584	0.132
4000.0	19.82	2.2815E-05	0.0002	0.1810	0.150

5000.0	19.79	2.2738E-05	0.0002	0.2039	0.169
6000.0	19.60	2.2266E-05	0.0002	0.2264	0.188
7000.0	19.34	2.1629E-05	0.0002	0.2483	0.206
8000.0	19.06	2.0955E-05	0.0002	0.2696	0.224
9000.0	18.70	2.0113E-05	0.0002	0.2902	0.241
10000.0	18.29	1.9175E-05	0.0002	0.3098	0.258
11000.0	17.85	1.8184E-05	0.0002	0.3285	0.273
12000.0	17.39	1.7187E-05	0.0002	0.3461	0.288
13000.0	16.99	1.6351E-05	0.0002	0.3629	0.302
14000.0	16.78	1.5915E-05	0.0002	0.3790	0.315
15000.0	16.60	1.5554E-05	0.0002	0.3947	0.328
16000.0	16.42	1.5193E-05	0.0002	0.4101	0.341
17000.0	16.24	1.4839E-05	0.0001	0.4251	0.353
18000.0	16.07	1.4496E-05	0.0001	0.4398	0.366
19000.0	15.90	1.4173E-05	0.0001	0.4541	0.377
20000.0	15.74	1.3871E-05	0.0001	0.4681	0.389
21000.0	15.60	1.3591E-05	0.0001	0.4819	0.401
22000.0	15.49	1.3396E-05	0.0001	0.4954	0.412
23000.0	15.40	1.3220E-05	0.0001	0.5087	0.423
24000.0	15.31	1.3063E-05	0.0001	0.5218	0.434
25000.0	15.24	1.2933E-05	0.0001	0.5348	0.445
26000.0	15.19	1.2832E-05	0.0001	0.5477	0.455
27000.0	15.14	1.2751E-05	0.0001	0.5605	0.466
28000.0	15.12	1.2708E-05	0.0001	0.5732	0.476
29000.0	15.11	1.2700E-05	0.0001	0.5859	0.487
30000.0	15.12	1.2710E-05	0.0001	0.5986	0.498
31000.0	15.13	1.2729E-05	0.0001	0.6113	0.508
32000.0	15.15	1.2771E-05	0.0001	0.6241	0.519
33000.0	15.19	1.2834E-05	0.0001	0.6369	0.529
34000.0	15.25	1.2952E-05	0.0001	0.6497	0.540
35000.0	15.34	1.3116E-05	0.0001	0.6628	0.551
36000.0	15.45	1.3324E-05	0.0001	0.6760	0.562
37000.0	15.61	1.3609E-05	0.0001	0.6895	0.573
38000.0	15.80	1.3974E-05	0.0001	0.7032	0.585
39000.0	16.11	1.4582E-05	0.0001	0.7175	0.596
40000.0	16.66	1.5680E-05	0.0002	0.7326	0.609
41000.0	17.61	1.7662E-05	0.0002	0.7492	0.623
42000.0	18.81	2.0362E-05	0.0002	0.7682	0.639
43000.0	20.37	2.4198E-05	0.0002	0.7904	0.657
44000.0	22.56	3.0186E-05	0.0003	0.8174	0.679
45000.0	25.39	3.8950E-05	0.0004	0.8518	0.708
46000.0	28.31	4.9270E-05	0.0005	0.8954	0.744
47000.0	33.65	7.1587E-05	0.0007	0.9543	0.793

CRACK DEPTH EXCEEDED 0.9624 AT TIME 4.7120E+04

END OF pc-CRACK

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pc-CRACK

VERSION 1.2

ALLOWABLE FLAW SIZE EVALUATION

ALLOWABLE FLAW SIZE FOR CIRCUMF. CRACK,FLUX WELD

CECO-09Q, RECIRC SUCTION, WELD 02BS-S12

WALL THICKNESS= 1.2030
MEMBRANE STRESS= 6692.0000
BENDING STRESS= 162.0000
EXPANSION STRESS= 1859.0000
PIPE OUTSIDE DIAMETER= 28.0000
FLUX WELD TYPE-SMAW(1)/SAW(2)=1
STRESS RATIO= 0.4617
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

STRESS RATIO IS LESS THAN 0.6000WHICH WILL BE USED IN THE ANALYSIS.

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE A/T	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

END OF pc-CRACK

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STRESS CORROSION CRACK GROWTH ANALYSIS

CECO-09Q, RECIRC SUCTION, WELD 02BS-S12

INITIAL CRACK SIZE= 0.1564
WALL THICKNESS= 1.2030
MAX CRACK SIZE FOR SCCG= 0.9624

STRESS CORROSION CRACK GROWTH LAW(S)

LAW ID	C	N	Kthres	K1C
NRC	3.5900E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
SUCRESID	30.1468	-175.4735	192.6252	-24.8033
PRESSURE	6.6920	0.0000	0.0000	0.0000
SHRINKAGE	1.0000	0.0000	0.0000	0.0000
DEAD WT	0.0700	0.0000	0.0000	0.0000
THERMAL	0.8590	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
SUCRESID	1.00
PRESSURE	1.00
SHRINKAGE	1.00
DEAD WT	1.00
THERMAL	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	10.0	1000.0

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK DEPTH	STRESS INTENSITY FACTOR: CASE SUCRESID	CASE PRESSURE	CASE SHRINKAGE	CASE DEAD WT	CASE THERMAL
0.0192	7.692	1.825	0.273	0.019	0.234
0.0385	10.200	2.593	0.387	0.027	0.333
0.0577	11.684	3.190	0.477	0.033	0.409
0.0770	12.585	3.700	0.553	0.039	0.475
0.0962	13.085	4.155	0.621	0.043	0.533
0.1155	13.288	4.572	0.683	0.048	0.587
0.1347	13.333	4.987	0.745	0.052	0.640

0.1540	13.214	5.393	0.806	0.056	0.692
0.1732	12.934	5.786	0.865	0.060	0.743
0.1925	12.517	6.168	0.922	0.064	0.792
0.2117	11.981	6.542	0.978	0.068	0.840
0.2310	11.342	6.909	1.032	0.072	0.887
0.2502	10.653	7.290	1.089	0.076	0.936
0.2695	9.923	7.689	1.149	0.080	0.987
0.2887	9.120	8.086	1.208	0.085	1.038
0.3080	8.252	8.483	1.268	0.089	1.089
0.3272	7.327	8.879	1.327	0.093	1.140
0.3465	6.354	9.277	1.386	0.097	1.191
0.3657	5.404	9.695	1.449	0.101	1.244
0.3850	4.620	10.180	1.521	0.106	1.307
0.4042	3.816	10.670	1.594	0.112	1.370
0.4235	2.998	11.166	1.669	0.117	1.433
0.4427	2.174	11.667	1.743	0.122	1.498
0.4620	1.350	12.173	1.819	0.127	1.563
0.4812	0.533	12.685	1.896	0.133	1.628
0.5004	-0.262	13.230	1.977	0.138	1.698
0.5197	-1.046	13.781	2.059	0.144	1.769
0.5389	-1.812	14.339	2.143	0.150	1.841
0.5582	-2.555	14.903	2.227	0.156	1.913
0.5774	-3.268	15.473	2.312	0.162	1.986
0.5967	-3.944	16.049	2.398	0.168	2.060
0.6159	-4.663	16.667	2.490	0.174	2.139
0.6352	-5.373	17.303	2.586	0.181	2.221
0.6544	-6.041	17.947	2.682	0.188	2.304
0.6737	-6.662	18.599	2.779	0.194	2.387
0.6929	-7.228	19.257	2.878	0.201	2.472
0.7122	-7.731	19.923	2.977	0.208	2.557
0.7314	-7.888	20.622	3.082	0.216	2.647
0.7507	-7.663	21.354	3.191	0.223	2.741
0.7699	-7.316	22.095	3.302	0.231	2.836
0.7892	-6.838	22.843	3.413	0.239	2.932
0.8084	-6.220	23.600	3.527	0.247	3.029
0.8277	-5.455	24.365	3.641	0.255	3.128
0.8469	-4.766	25.156	3.759	0.263	3.229
0.8662	-4.628	26.011	3.887	0.272	3.339
0.8854	-4.347	26.875	4.016	0.281	3.450
0.9047	-3.911	27.748	4.146	0.290	3.562
0.9239	-3.308	28.631	4.278	0.299	3.675
0.9432	-2.525	29.523	4.412	0.309	3.790
0.9624	-1.551	30.424	4.546	0.318	3.905

TIME	KMAX	DA/DT	DA	A	A/THK
1000.0	20.42	2.4318E-05	0.0002	0.1805	0.150
2000.0	20.43	2.4352E-05	0.0002	0.2049	0.170
3000.0	20.26	2.3923E-05	0.0002	0.2290	0.190
4000.0	20.02	2.3311E-05	0.0002	0.2527	0.210

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5000.0	19.74	2.2608E-05	0.0002	0.2756	0.229
6000.0	19.37	2.1711E-05	0.0002	0.2978	0.248
7000.0	18.95	2.0695E-05	0.0002	0.3190	0.265
8000.0	18.48	1.9619E-05	0.0002	0.3392	0.282
9000.0	18.06	1.8650E-05	0.0002	0.3583	0.298
10000.0	17.81	1.8094E-05	0.0002	0.3766	0.313
11000.0	17.65	1.7756E-05	0.0002	0.3945	0.328
12000.0	17.49	1.7409E-05	0.0002	0.4121	0.343
13000.0	17.33	1.7067E-05	0.0002	0.4293	0.357
14000.0	17.17	1.6737E-05	0.0002	0.4462	0.371
15000.0	17.03	1.6428E-05	0.0002	0.4628	0.385
16000.0	16.89	1.6150E-05	0.0002	0.4791	0.398
17000.0	16.81	1.5974E-05	0.0002	0.4951	0.412
18000.0	16.74	1.5838E-05	0.0002	0.5110	0.425
19000.0	16.69	1.5734E-05	0.0002	0.5268	0.438
20000.0	16.66	1.5666E-05	0.0002	0.5425	0.451
21000.0	16.64	1.5639E-05	0.0002	0.5582	0.464
22000.0	16.66	1.5674E-05	0.0002	0.5738	0.477
23000.0	16.71	1.5766E-05	0.0002	0.5895	0.490
24000.0	16.77	1.5887E-05	0.0002	0.6054	0.503
25000.0	16.84	1.6037E-05	0.0002	0.6213	0.516
26000.0	16.94	1.6239E-05	0.0002	0.6373	0.530
27000.0	17.07	1.6524E-05	0.0002	0.6538	0.544
28000.0	17.26	1.6918E-05	0.0002	0.6706	0.557
29000.0	17.50	1.7434E-05	0.0002	0.6877	0.572
30000.0	17.81	1.8101E-05	0.0002	0.7055	0.586
31000.0	18.39	1.9401E-05	0.0002	0.7241	0.602
32000.0	19.47	2.1941E-05	0.0002	0.7447	0.619
33000.0	21.03	2.5937E-05	0.0003	0.7685	0.639
34000.0	23.24	3.2165E-05	0.0003	0.7973	0.663
35000.0	26.48	4.2677E-05	0.0004	0.8343	0.694
36000.0	30.11	5.6306E-05	0.0006	0.8837	0.735
37000.0	36.39	8.4817E-05	0.0008	0.9520	0.791

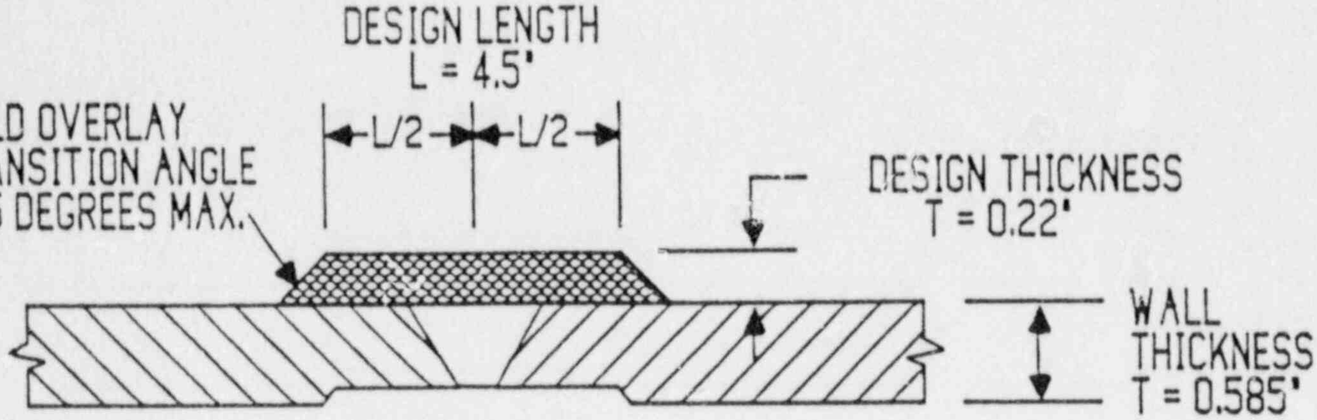
CRACK DEPTH EXCEEDED 0.9624 AT TIME 3.7120E+04

END OF pc-CRACK

APPENDIX C

Weld Overlay Repair Designs

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02D-S3

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-001 REVISION: 1 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88
REVIEWED BY/DATE [signature] 5/4/88
ISSUED BY/DATE J. F. Copeland 5/4/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

tm
pc-CRACK

VERSION 1.2

STRUCTURAL REINFORCEMENT SIZING EVALUATION

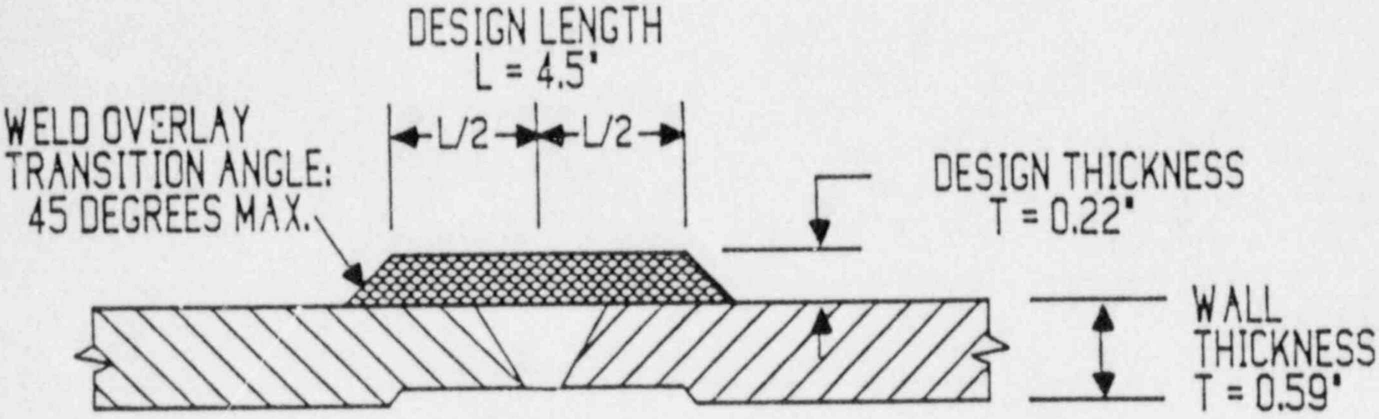
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

QUAD CITIES UNIT 2, WELD 02D-S3

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1550.0000
STRESS RATIO= 0.4933
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7368
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2090

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02L-S3

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-002 REVISION: 1 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88

REVIEWED BY/DATE [illegible] 5/4/88

ISSUED BY/DATE J. F. [illegible] 5/4/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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                         tm
                   pc-CRACK
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                 VERSION 1.2

    STRUCTURAL REINFORCEMENT SIZING EVALUATION

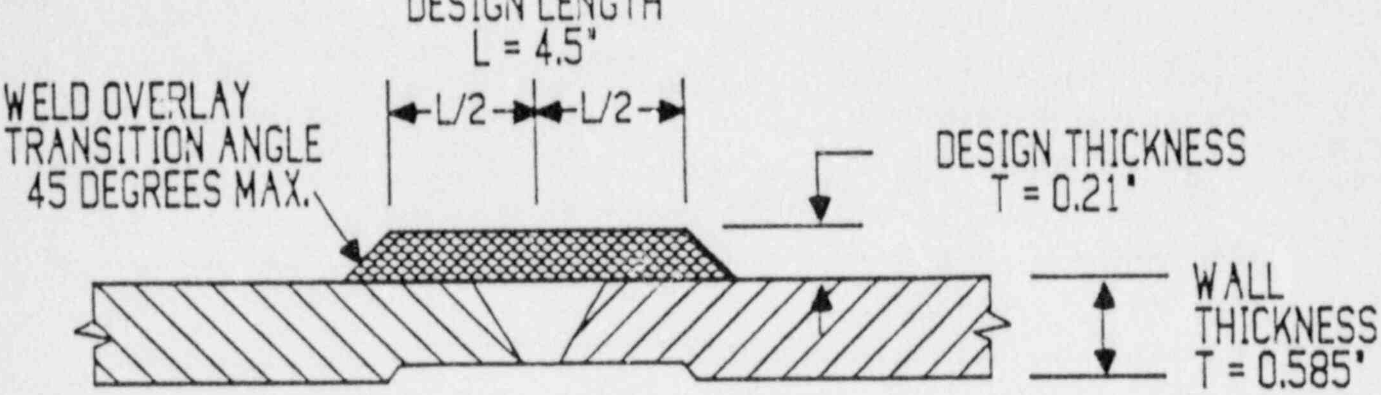

STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS


QUAD CITIES UNIT 2, WELD 02L-S3

WALL THICKNESS=      0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS=  1985.0000
STRESS RATIO=     0.5189
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000
```

	L/CIRCUM 0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7334
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2127

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02J-S4

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-003 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Dustin 5/4/88

REVIEWED BY/DATE [signature] 5/4/88

ISSUED BY/DATE J.F. Copeland 5/4/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

tm
pc-CRACK

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

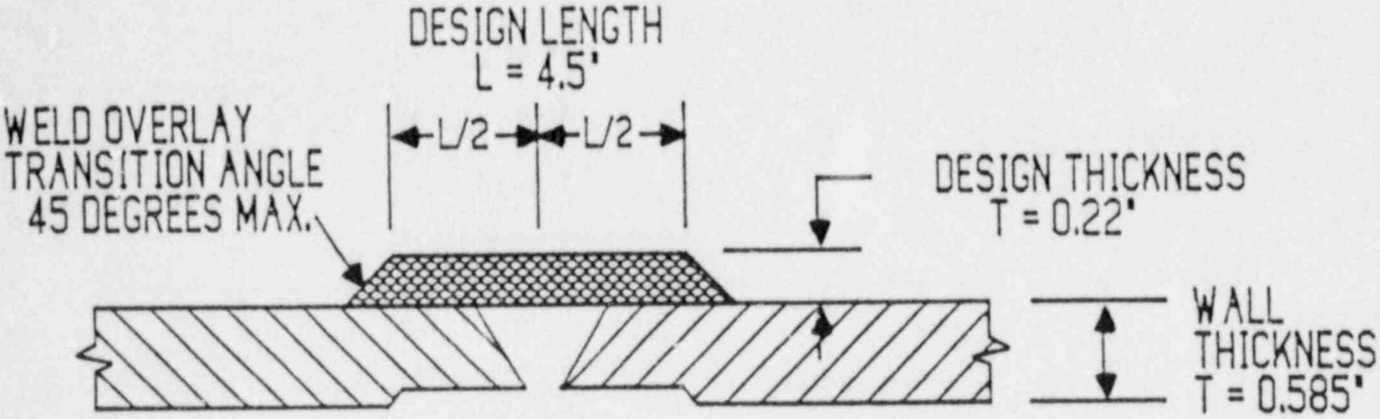
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

QUAD CITIES UNIT 2, WELD 02J-S4

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1354.0000
STRESS RATIO= 0.4817
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7383
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2074

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02L-S4

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-004 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88

REVIEWED BY/DATE [signature] 5/4/88

ISSUED BY/DATE J. F. Copeland 5/4/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

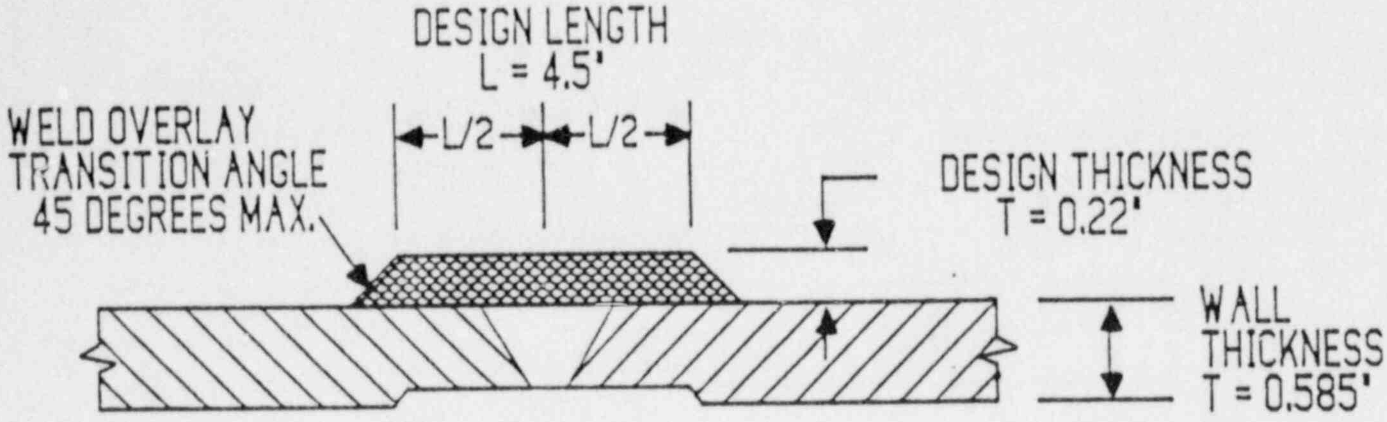
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

QUAD CITIES UNIT 2, WELD 02L-S4

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1973.0000
STRESS RATIO= 0.5182
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7334
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2127

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02M-S4

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-005 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88

REVIEWED BY/DATE [signature] 5/4/88

ISSUED BY/DATE J. F. Copeland 5/4/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

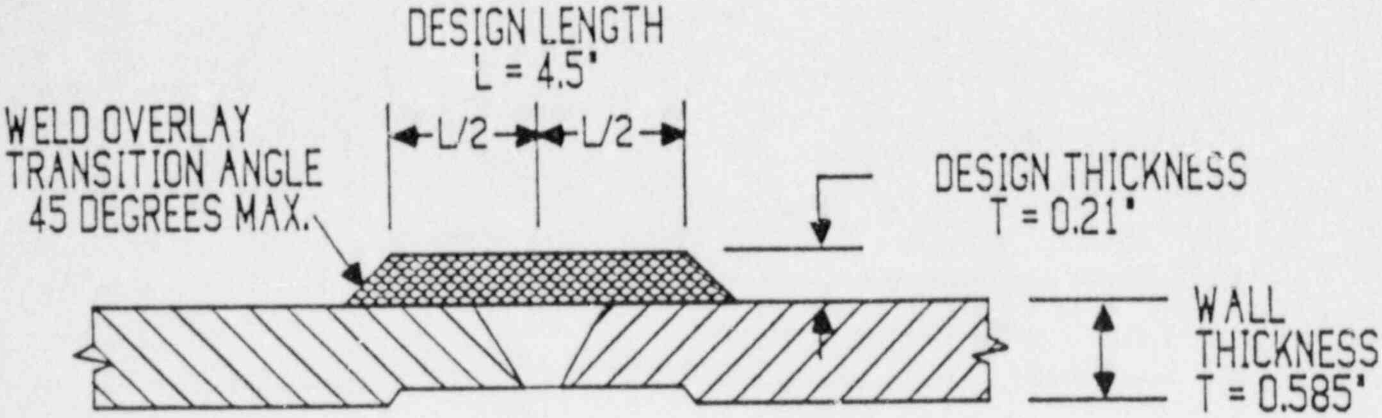
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

QUAD CITIES UNIT 2, WELD 02M-S4

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 2239.0000
STRESS RATIO= 0.5339
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7314
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2148

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02E-S3

NOTES:

1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-006 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Dustin 5/4/88

REVIEWED BY/DATE [signature] 5/4/88

ISSUED BY/DATE J. F. Copeland 5/4/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

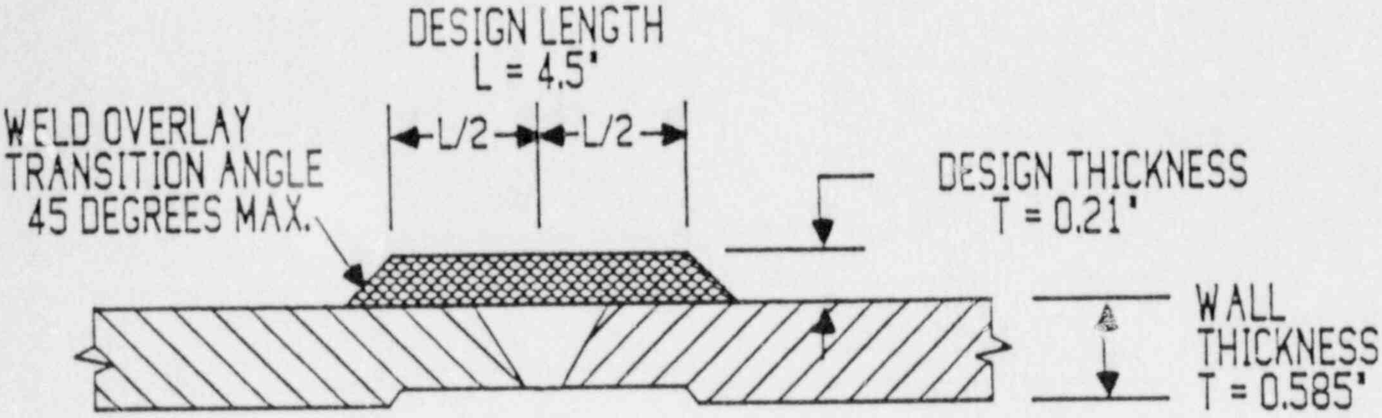
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

CECO-09Q, QUAD CITIES UNIT 2, WELD 02E-S3

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1441.0000
STRESS RATIO= 0.4868
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7373
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2084

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02F-S3

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-007 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88

REVIEWED BY/DATE [illegible] 5/4/88

ISSUED BY/DATE J. F. Copeland 5/4/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

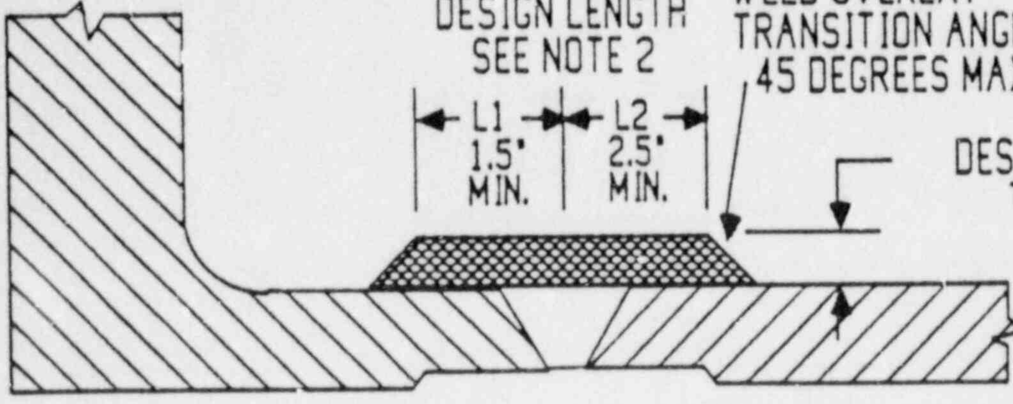
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

CECO-09Q, QUAD CITIES UNIT 2, WELD 02F-S3

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1325.0000
STRESS RATIO= 0.4800
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7383
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2074

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02K-F6

NOTES:

1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH. LENGTH ON THE SWEEPOLET SIDE IS RESTRICTED BY THE SWEEPOLET GEOMETRY. THE FULL THICKNESS LENGTH OF THE REPAIR IS TO BE AT LEAST 1.5" ON THE SWEEPOLET SIDE, UNLESS THE REPAIR CAN BE BLENDED INTO THE SWEEPOLET TRANSITION PRIOR TO ACHIEVING THAT LENGTH. LENGTH ON THE PIPE SIDE SHALL BE AT LEAST 2.5".

DRAWING NUMBER: CECO-09-008 REVISION: 1 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Dustin 5/12/88

REVIEWED BY/DATE [illegible] 5/12/88

ISSUED BY/DATE J. F. Copeland 5/12/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

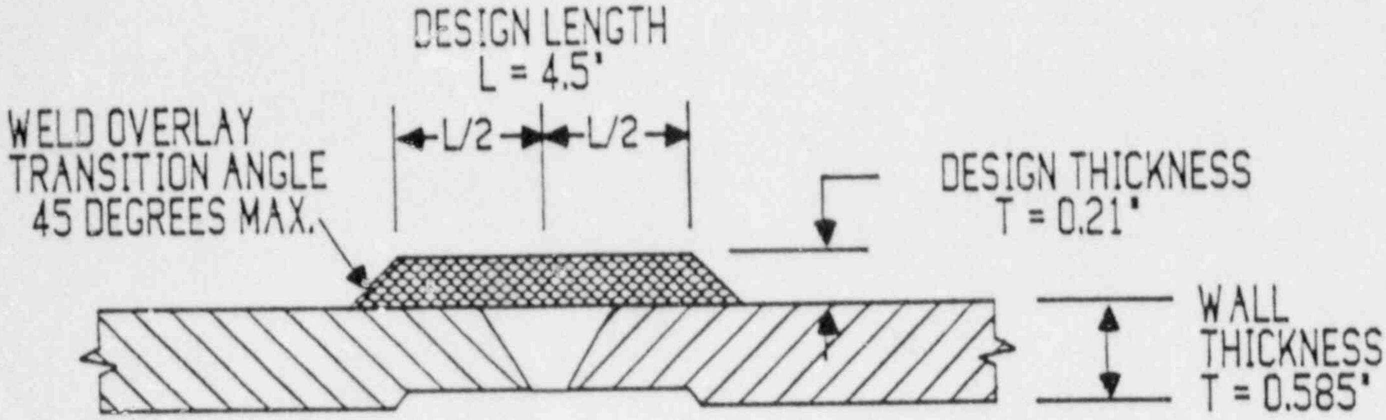
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

CECO-09Q, QUAD CITIES UNIT 2, WELD 02K-F6

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 3860.0000
STRESS RATIO= 0.6296
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

L/CIRCUM	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7070
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2424

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02J-S3

NOTES:

1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-009 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/4/88

REVIEWED BY/DATE [illegible] 5/4/88

ISSUED BY/DATE J. F. Copeland 5/4/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

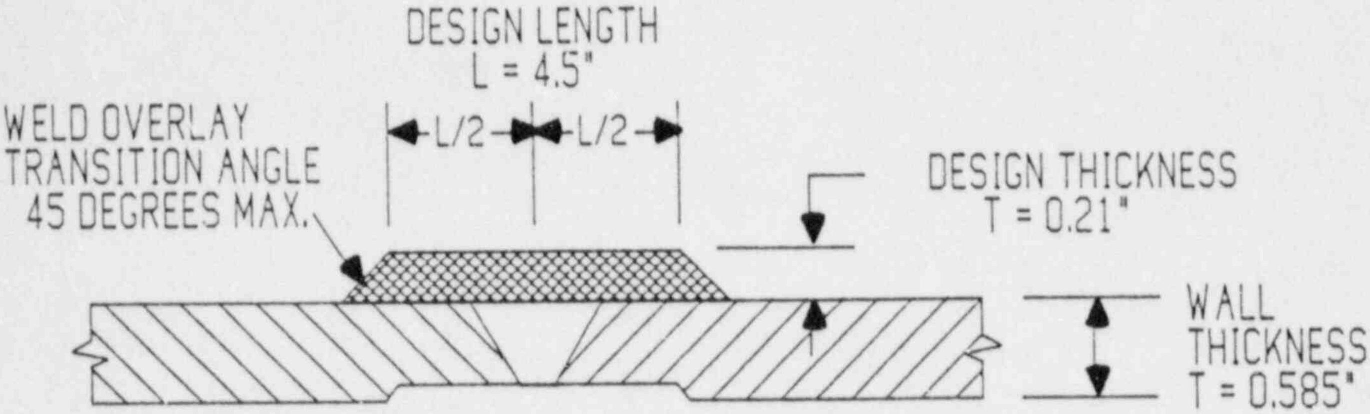
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

CECO-09Q, QUAD CITIES UNIT 2, WELD 02J-S3

[illegible] THICKNESS= 0.5850
[illegible]ANE STRESS= 6811.0000
BENDING STRESS= 930.0000
STRESS RATIO= 0.4567
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7422
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2032

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02H-S3

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-010 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/6/88

REVIEWED BY/DATE [signature] 5/6/88

ISSUED BY/DATE J.F. Copeland 5/6/88

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

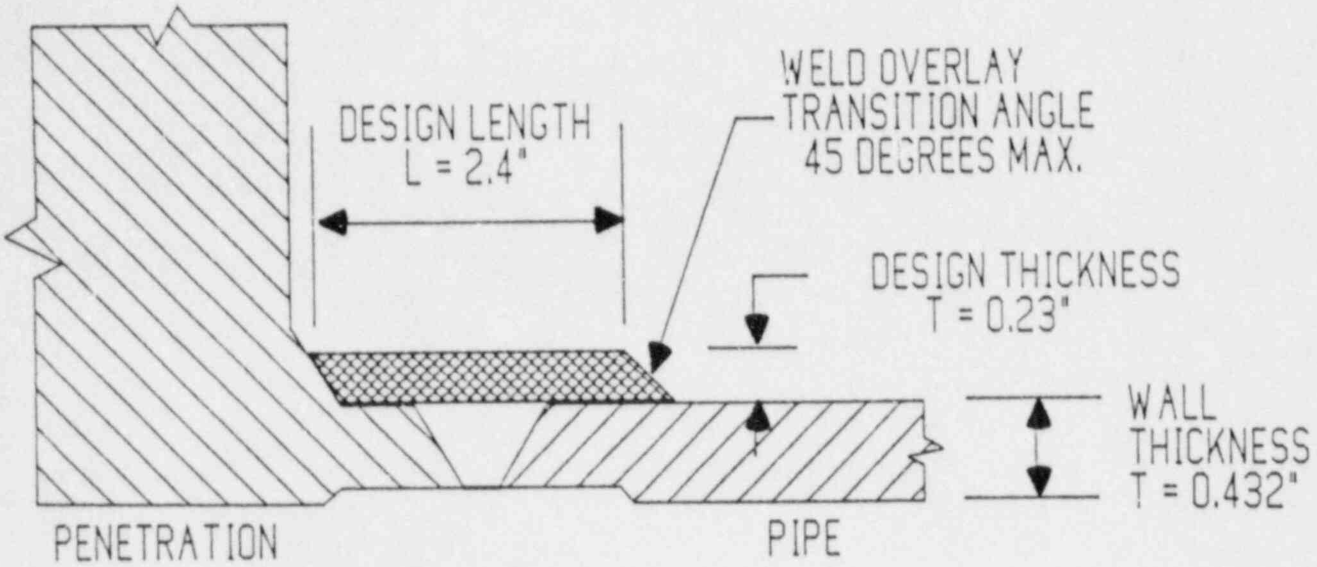
STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

QUAD CITIES UNIT 2, WELD 02H-S3

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 968.0000
STRESS RATIO= 0.4589
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7412
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2042

END OF pc-CRACK



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 12S-S24

NOTES:
1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH FOR REINFORCEMENT. ADDITIONAL LENGTH MAY BE REQUIRED FOR INSPECTION.
3. FIRST LAYER TO BE WELDED WITH PIPE EMPTY. DELTA FERRITE MEASUREMENT AND LIQUID PENETRANT EXAM. OF COMPLETED FIRST LAYER IS REQUIRED.
4. FIRST LAYER IS NOT CONSIDERED IN DESIGN THICKNESS.
5. SUBSEQUENT LAYERS TO BE WELDED WITH PIPE FULL.
6. WELD TO BE BLENDED SMOOTHLY INTO PENETRATION.

DRAWING NUMBER: CECO-09-011 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Dunton 5/6/88

REVIEWED BY/DATE [signature] 5/6/88

ISSUED BY/DATE J.F. Copeland 5/6/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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STRUCTURAL REINFORCEMENT SIZING EVALUATION

STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

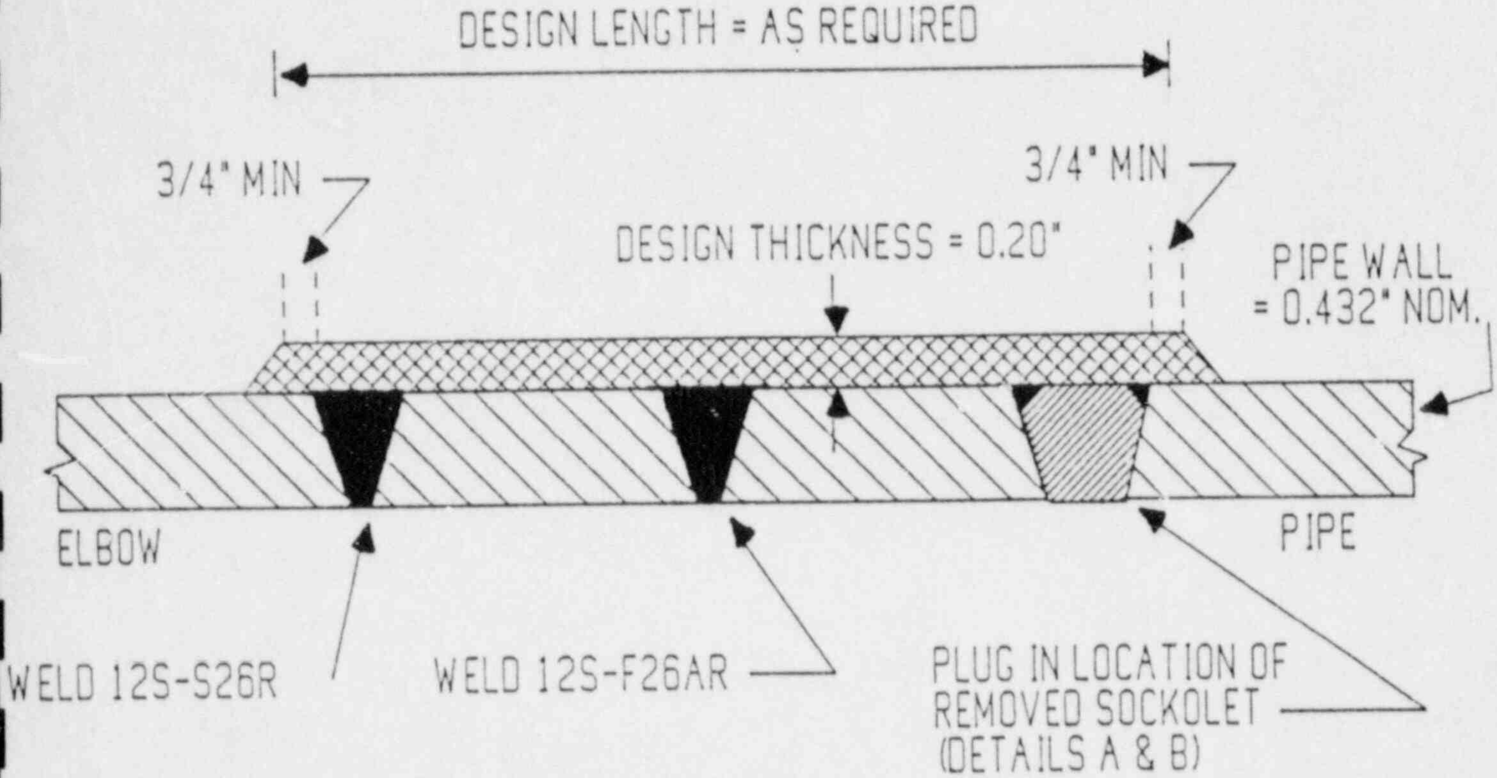
QUAD CITIES UNIT 2, WELD 12S-S24

WALL THICKNESS= 0.4320
MEMBRANE STRESS= 4793.0000
BENDING STRESS= 8942.0000
STRESS RATIO= 0.8103
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM 0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.6616
REINFORCEMENT THICK.	0.1440	0.1440	0.1440	0.1440	0.1440	0.2209

END OF pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBERS 12S-S26R & 12S-F26AR

NOTES:

1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. ADDITIONAL NOTES ON PAGE 4 OF THIS DRAWING

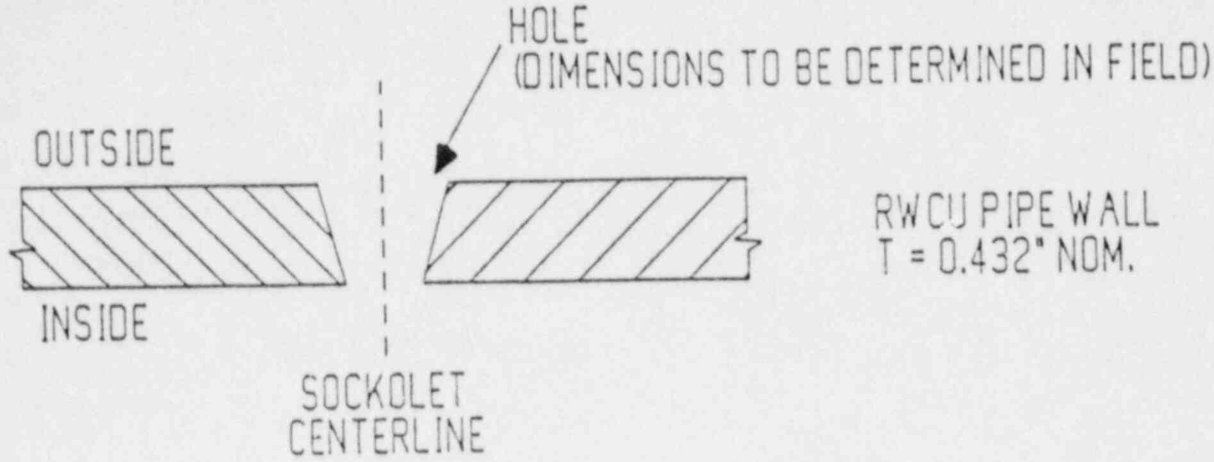
DRAWING NUMBER: CECO-09-012 REVISION: 1 PAGE: 1 OF 4
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE N L Dustin 5/19/88

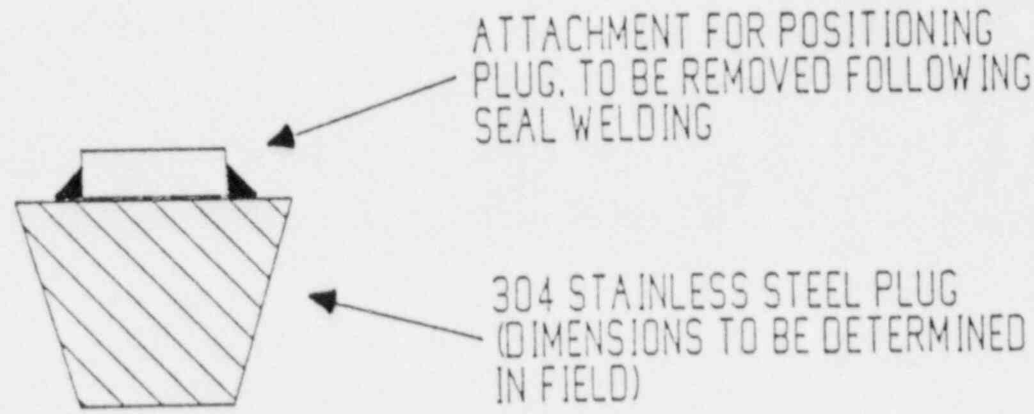
REVIEWED BY/DATE J.F. Copeland 5/19/88

ISSUED BY/DATE J. F. Copeland 5/19/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.



DETAIL A
TAPERED HOLE FOLLOWING SOCKOLET REMOVAL



DETAIL B
TAPERED PLUG FOR SOCKOLET HOLE

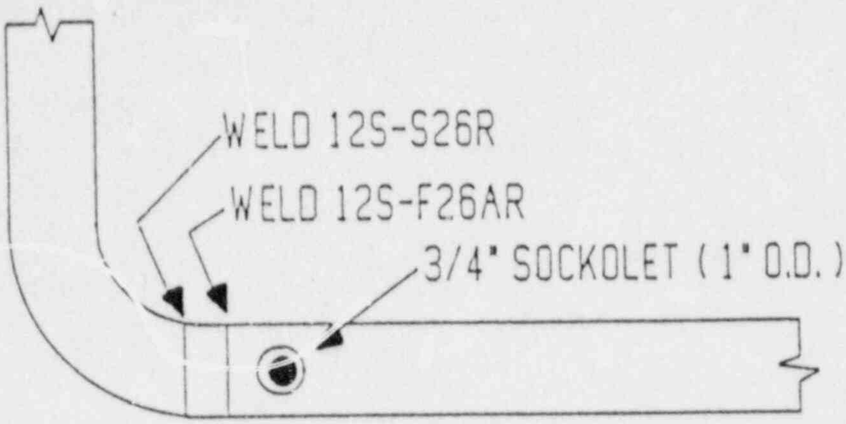
DRAWING NUMBER: CECO-09-012 REVISION: 1 PAGE: 2 OF 4
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Suter 5/19/88

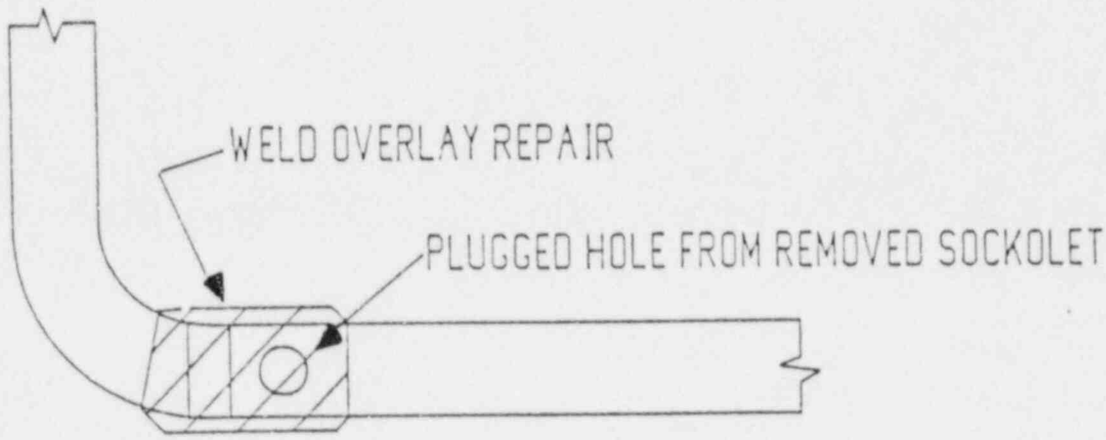
REVIEWED BY/DATE J. F. Copeland 5/19/88

ISSUED BY/DATE J. F. Copeland 5/19/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.



CONFIGURATION BEFORE REPAIR



CONFIGURATION AFTER REPAIR

DRAWING NUMBER: CECO-09-012 REVISION: 1 PAGE: 3 OF 4
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE N L Dusten 5/19/88

REVIEWED BY/DATE J.F. Copeland 5/19/88

ISSUED BY/DATE J.F. Copeland 5/19/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

NOTES:

1. EXISTING SOCKOLET TO BE REMOVED (BY GRINDING, ETC.).

2. HOLE FROM SOCKOLET REMOVAL TO BE CLEANED BY CUTTING OR GRINDING AND TAPERED - DETAIL A.

3. TAPERED PLUG OF 304 STAINLESS TO BE FABRICATED FOR INSTALLATION IN TAPERED HOLE. TEMPORARY ATTACHMENT TO BE WELDED TO PLUG FOR EASE OF INSTALLATION - DETAIL B.

4. PLUG TO BE FIT INTO HOLE FLUSH WITH PIPE SURFACE, AND SEAL WELDED FOR 100% OF HOLE CIRCUMFERENCE.

5. TEMPORARY ATTACHMENT TO BE GROUND OFF FLUSH WITH PIPE SURFACE.

6. OTHER METHODS OF REMOVAL OF SOCKOLET AND REPAIR OF RESULTING HOLE MAY BE ACCEPTABLE, BUT WILL REQUIRE PRIOR APPROVAL BY COMMONWEALTH EDISON COMPANY AND STRUCTURAL INTEGRITY ASSOCIATES.

7. WELD OVERLAY IS TO BE AT LEAST 0.20" THICK.

8. WELD OVERLAY SHALL EXTEND AT LEAST 3/4" UPSTREAM OF THE PLUG SEAL WELD, AND AT LEAST 3/4" DOWNSTREAM OF THE DOWNSTREAM EDGE OF WELD 12S-S26R, BOTH AT FULL DESIGN THICKNESS.

9. WELD OVERLAY TRANSITION ANGLE IS 45° MAX.

10. THE FIRST OVERLAY WELD LAYER IS TO BE MADE WITH THE PIPE DRAINED, TO MINIMIZE THE POTENTIAL FOR WELDING PROBLEMS DURING REPAIR. THE FIRST LAYER IS NOT TO BE CONSIDERED AS PART OF THE REQUIRED DESIGN THICKNESS.

DRAWING NUMBER: CECO-09-012 REVISION: 1 PAGE: 4 OF 4
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/19/88

REVIEWED BY/DATE J. F. Copeland 5/19/88

ISSUED BY/DATE J. F. Copeland 5/19/88

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SAN JOSE, CA (408)978-8200
VERSION 1.2

STRUCTURAL REINFORCEMENT SIZING EVALUATION

STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

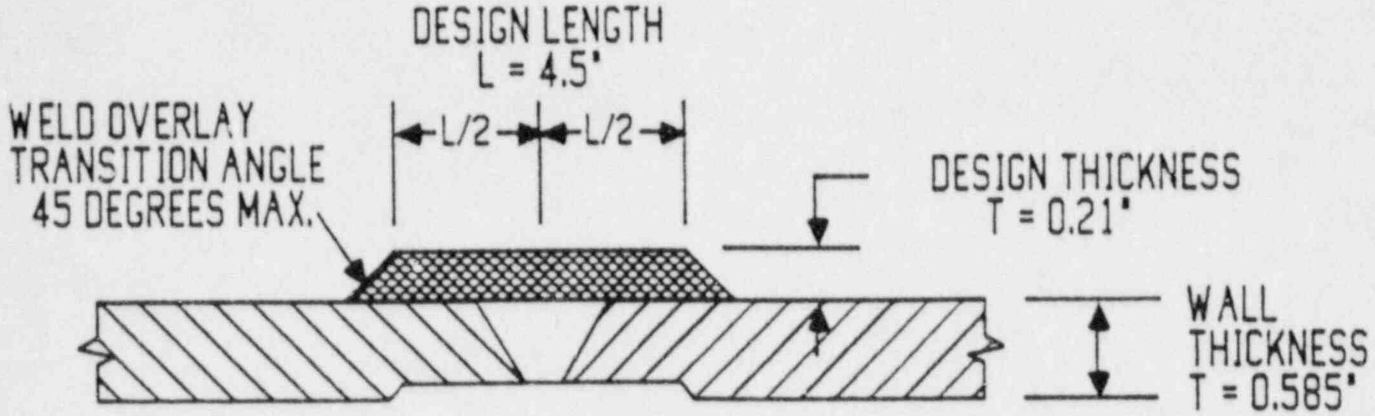
QUAD CITIES UNIT 2, WELDS 12S-S26R AND 12S-F26AR

WALL THICKNESS= 0.4320
MEMBRANE STRESS= 4793.0000
BENDING STRESS= 6864.0000
STRESS RATIO= 0.6877
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.6914
REINFORCEMENT THICK.	0.1440	0.1440	0.1440	0.1440	0.1440	0.1928

END OF pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY DESIGN SKETCH
COMMONWEALTH EDISON COMPANY
QUAD CITIES UNIT 2
WELD NUMBER 02G-S4

NOTES:

1. THIS SKETCH TO BE WORKED WITH SPECIFICATION SIS-88-001, LATEST REVISION.
2. DESIGN LENGTH SHOWN IS FULL THICKNESS LENGTH.

DRAWING NUMBER: CECO-09-015 REVISION: 0 PAGE: 1 OF 1
SI PROJECT NUMBER: CECO-09Q

PREPARED BY/DATE H L Gustin 5/12/88

REVIEWED BY/DATE [signature] 5/12/88

ISSUED BY/DATE J. F. Copeland 5/12/88

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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VERSION 1.2

STRUCTURAL REINFORCEMENT SIZING EVALUATION

STRUCTURAL REINFORCEMENT SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

CECO-09Q, QUAD CITIES UNIT 2, WELD 02G-S4

WALL THICKNESS= 0.5850
MEMBRANE STRESS= 6811.0000
BENDING STRESS= 1371.0000
STRESS RATIO= 0.4827
ALLOWABLE STRESS=16950.0000
FLOW STRESS=50850.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7383
REINFORCEMENT THICK.	0.1950	0.1950	0.1950	0.1950	0.1950	0.2074

END OF pc-CRACK

ENCLOSURE 1

Ultrasonic Examination of IGSCC Susceptible Stainless Steel Weldments Quad Cities Unit 2 - 1988 Refueling Outage

Introduction

This enclosure provides a report of the ultrasonic (UT) examinations performed on IGSCC susceptible stainless steel weldments during the Quad Cities Unit 2 1988 refueling outage. Enclosure 2 (Structural Integrity SIR-88-018, Volume 1) provides the detailed report on the analyses and repair activities associated with flawed weldments.

In addition to the UT examination results, this enclosure also provides discussion on:

- the "prioritization" study which was used to both select and schedule weldments for UT examinations,
- a description and UT examination history of welds which contain IGSCC-like flaw indications,
- a comparison of the current UT examination results with those of the 1986 refueling outage for the weld overlay repairs examined during the 1988 refueling outage, and
- a description of the repair activities to the end cap-to-header weld overlay repair performed last outage (02A-S10) which was evaluated as containing UT flaw indications.

Discussions on the effectiveness of prior IHSI treatments (1984) and the design of weld overlay repairs in the reactor water cleanup (RWCU) system are described in Enclosure 2.

Examination Scope

As shown in Table 1, a total of 157 weldments were ultrasonically examined during the current Quad Cities Unit 2 refueling outage. These include:

- 66 welds and 14 weld overlay repairs which were the initial examination scope, and
- 77 welds which were part of the expanded sample or post-MSIP UT examinations.

Due to IGSCC-like flaw indications evaluated in the initial examination sample (12 inch recirculation risers and 6 inch RWCU piping), 100% of the 12 inch and larger recirculation system (exclusive of nozzle-to-safe end welds) and 100% of the accessible Class 1 IGSCC susceptible RWCU piping was examined as an expanded sample.

A total of 47 welds in the core spray, residual heat removal (LPCI), and recirculation systems were stress improved using the mechanical stress improvement process (MSIP). Of these 47 welds, 33 were not included in either the initial or expanded UT examination scopes.

Twelve (12) new weldments were identified during the current outage as containing IGSCC-like flaw indications. Additionally, seven (7) weldments have previously been reported to the NRC as flawed as a result of UT examinations performed during prior outages. One 28 inch weldment, 02BS-S12, was originally reported as flawed based on UT examination in 1983. A metallurgical plug sample was removed during that outage, as well as a visual examination of the ID surface and single wall radiographic examination. These examinations did not reveal the presence of any IGSCC-like indiciations, but rather the presence of a backwelded root condition leading to the UT signal. In subsequent outages, the same UT signal has been observed. Conservatively, this evaluation has been treated as an IGSCC flaw. The flaw characteristics and past UT examination history of each of these weldments is shown in Tables 2, 3 and 4 for 6 inch RWCU, 12 inch recirculation and 28 inch recirculation system welds respectively.

TABLE 1

Ultrasonic Examination Scope
Quad Cities Unit 2 - 1988 Refueling Outage
(Note 1)

System/Size	Examinations Performed Welds	Weld Overlays	New Flaws
Recirculation			
28 inch	24	6	1
28 inch nozzle-to-safe end	1	0	0
22 inch	20	2	0
12 inch	34	5	9
12 inch nozzle-to-safe end	2	0	0
Residual Heat Removal			
20 inch SDC	3	1	0
16 inch LPCI	23	0	0
Core Spray			
10 inch	21	0	0
Jet Pump Instr.			
4 to 12 inch	2	0	0
Small Diameter			
6 inch	6	0	2
4 inch	7	0	0
TOTALS	143	14	12

NOTES: (1) Includes initial examination sample, expanded sample and post-MSIP examinations.

TABLE 2

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
6 inch Reactor Water Cleanup (RWCU) Welds

Year Examined	Orientation	Length inch	Depth %tw	Side
Weld 12S-S24	(6 inch flued head-to-pipe)			
1983 - 1986	Not examined			
1988	circumferential	3-3/4	51	pipe
	circumferential	6.2	49	pipe
	2 axials	-	100	pipe
Weld 12S-F26AR	(6 inch pipe-to-pipe)			
1986	No reportable indications	-	-	-
1988	circumferential	3/4	23	pipe (upstr.)

TABLE 3

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
12 inch Recirculation Riser Welds (Note 1)

Year Examined	Orientation	Length inch	Depth %tw	Side
Weld 02D-S3	(12 inch pipe-to-elbow)			
1983	circumferential	1/2	25	pipe
1985	circumferential	1/2	26-28	pipe
1986	circumferential	0.6	17	pipe
1988	circumferential	1.5	41	pipe*
	3 circumferentials	4	26	elbow*
	2 axials	-	41	pipe
	axial	-	24	elbow

* = w/axial component
** = 2 w/axial components

Year Examined	Orientation	Length inch	Depth %tw	Side
Weld 02E-S3	(12 inch pipe-to-elbow)			
1983	ID and OD geometry			
1985	not examined			
1986	intermittent root geometry			
1988	2 axials	-	24	pipe
Weld 02F-S3	(12 inch pipe-to-elbow)			
1983	no reportable indications			
1985	not examined			
1986	no reportable indications			
1988	circumferential	1/2	48	pipe
	circumferential	1	22	pipe
	axial	-	38	pipe
	4 axials	-	22	elbow

Table 3 (cont'd)

Year Examined		Orientation	Length inch	Depth %tw	Side
Weld 02G-S4	(12 inch pipe-to-elbow)				
1983		OD geometry			
1985		ID & OD geometry			
1986		no reportable indications			
1988		2 axials	-	55	pipe
Weld 02H-S3	(12 inch pipe-to-elbow)				
1983		OD geometry			
1985		not examined			
1986		OD geometry			
1988		2 axials	-	51	pipe
Weld 02J-S3	(12 inch pipe-to-elbow)				
1983		OD geometry			
1985		not examined			
1986		no reportable indications			
1988		axial	-	17	elbow
Weld 02J-S4	(12 inch pipe-to-elbow)				
1983		ID geometry			
1985		not examined			
1986		no reportable indications			
1988		circumferential	2½	26	pipe

Table 3 (cont'd)

Year Examined		Orientation	Length inch	Depth %tw	Side
Weld 02K-F6	(12 inch pipe-to-sweepolet)				
1983		ID geometry			
1985		not examined			
1986		no reportable indications			
1988		circumferential	0.4	54	pipe
		axial	-	50	pipe
Weld 02L-S3	(12 inch pipe-to-elbow)				
1983		OD geometry			
1985		not examined			
1986		no reportable indications			
1988		2 axials	-	17	elbow
Weld 02L-S4	(12 inch pipe-to-elbow)				
1983		no reportable indications			
1985		not examined			
1986		no reportable indications			
1988		axial	-	43	elbow
Weld 02M-S4	(12 inch pipe-to-elbow)				
1983		circumferential	1/2	9	elbow
1985		circumferential	1/2	15	elbow
1986		circumferential	1/2	12	elbow
1988		circumferential*	1.3	17	elbow
		circumferential	0.7	17	elbow

* = w/axial component

NOTES:
(1) All welds were IHSI treated in 1984

TABLE 4

Flaw Characterization Comparisons
Currently and Previously Reported Flawed Welds
Quad Cities Unit 2 - 1988 Refueling Outage
28 inch Recirculation Welds - Note 3

Year Examined	Orientation	Length inch	Depth %tw	Side
Weld 02AS-S6	(28 inch pipe-to-pipe)			
1983	circumferential	7½	21	upstrm.
1985	circumferential	8	18	upstrm.
1986	circumferential	8	18	upstrm.
1988	no IGSCC reported			
Weld 02AS-F14	(28 inch pipe-to-elbow)			
1983	circumferential	43	20	pipe
	spot	-	30	elbow
1985	circumferential	43 intermit.	13	pipe
1986	circumferential	43 intermit.	14	pipe
1988	circumferential	42-1/2 intermit.	12	pipe
Weld 02AS-S12	(28 inch elbow-to-pipe)			
1983	circumferential	8	14	pipe
	circumferential	4	11	pipe
	circumferential	1	8	elbow
	circumferential	2	9	elbow
1985	circumferential	8	4	pipe
	circumferential	6-1/2	5	pipe
	circumferential	2-1/2	15	elbow
1986	circumferential	6	4	pipe
	circumferential	5	13	pipe
	circumferential	2	22	elbow
1988	circumferential	8	8	pipe

Table 4 (cont'd)

Year Examined		Orientation	Length inch	Depth %tw	Side
Weld 02AD-F12	(28 inch pump-to-pipe)				
1983		circumferential	24 total	10	pipe
1985		circumferential	1	18	pipe
1986		circumferential	1	17	pipe
1988		circumferential	1	17	pipe
		(By manual ultrasonic examination - automated ultrasonic examination showed no IGSCC)			
Weld 02BD-F8	(28 inch valve-to-elbow)				
1983		root geometry			
1985		not examined			
1986		circumferential	4-1/2 total	15	elbow
1988		circumferential	3	25	elbow
		circumferential	3	26	elbow
		circumferential	3-1/2	26	elbow
		root geometry			
Weld 02BS-S12	(28 inch pipe-to-elbow) - Note 2				
1983		circumferential	32	16	pipe
		root geometry			pipe
1985		circumferential	36	21	pipe
		root geometry			pipe
1986		circumferential	36	13	pipe
		root geometry			pipe
1988		circumferential	36	13	pipe
		root geometry			pipe
		(By manual ultrasonic examination - automated ultrasonic examination showed no IGSCC)			

Table 4 (cont'd)

Year Examined		Orientation	Length inch	Depth %tw	Side
Weld 02AD-S6	28 inch pipe-to-elbow)				
1983		ID geometry			
1985		not examined			
1986		root geometry			
1988		circumferential	3	7	elbow
Weld 02BS-F14	(28 inch pipe-to-elbow)				
1983		circumferential	5-1/4	18	pipe
1985		circumferential ID root geometry	1	10	pipe
1986		ID root geometry			
1988		no IGSCC reported			

Notes:

(1) 42-1/2 inches is the total extent of the flaws with a combined length of 34-1/2 inches.

(2) Weld 02BS-S12 has previously been reported as flawed based on manual ultrasonic examinations. A metallurgical plug sample removed in 1983 showed the presence of a backwelded root and no indication of IGSCC.

(3) All welds were IHSI treated in 1984.

Weld Selection and Scheduling

Intergranular stress corrosion cracking (IGSCC) of austentic stainless steel piping weldments has been a perceived issue since the mid-1970s and an economic burden on the Utilities. As a result of such flaws, a large number of potentially IGSCC susceptible weldments have been ultrasonically (UT) examined since 1982.

Regulatory guidance (Generic Letters 84-11 and 88-01) require that a reasonably large number of potentially IGSCC susceptible welds be UT examined during each plant refueling outage to augment the normal ASME Section XI inservice inspections. The initial scope of the augmented UT examination program of stainless steel welds is established under this NRC guidelines and requirements. If new IGSCC-like are evaluated or existing flaws propagate such that repairs are required, this initial sample is further expanded.

One of the "lessons learned" from prior Quad Cities outages is that it is important from an outage scheduling standpoint to identify any such flawed welds, and therefore any repairs, early in the outage.

Prior to the current Quad Cities Unit 2 refueling outage, a "weld prioritization" study was performed by Structural Integrity for Commonwealth Edison with the objectives of:

- providing a technical basis for weld selection and scheduling for augmented UT examination of IGSCC susceptible welds,
- prioritizing by specific weld the IGSCC susceptibility of that weld, and
- establishing, by system and size, the recommended priority of scheduling within the overall plan.

The study considered all IGSCC susceptible stainless steel welds four (4) inch and larger.

Using the extensive past industry experience and research, it is possible to subjectivly rank the IGSCC susceptibility of individual weldments by considering several factors. These include:

- fabrication history (e.g., review of original construction radiographs, repair records, etc.),
- prior UT examination history and examination results,
- application of any IGSCC remedies (e.g., stress improvement, materials, and water chemistry),
- system considerations (e.g., process fluid flow, temperature, etc.), and
- industry experience.

Once the individual weldments have been prioritized within a piping system/size, the prior history and economic consequences of IGSCC evaluation (repairs) are considered to schedule the individual welds for examination. By performing such a study, the weldments with the highest "risk" of IGSCC are examined first and any flaws which may require repairs are identified early in the outage.

The outputs of the Structural Integrity study (Attachment 1) were used by Commonwealth Edison to both select the weldments in the initial examination sample and schedule the weld examinations. The result of this approach was that the IGSCC flawed welds were identified early during the outage. This allowed early evaluations and analyses, as well as the design of repairs.

In review, the study considered postweld ID grinding in the prioritization as a relatively strong factor. The welds which were evaluated as containing IGSCC-like flaws confirmed this, especially in the recirculation system which had received stress improvement (IHSI) in 1984. On the other hand, the previous Unit 1 results in the core spray system were not repeated in Unit 2.

The Quad Cities Unit 2 prioritization study proved to be useful in the selection and scheduling of potentially IGSCC susceptible welds for UT examination. The extent of required evaluations, analyses and, most importantly repairs were identified early in the outage; thereby minimizing outage schedule impact.

The technical "lessons learned" from this study and the examination results confirms the strong causative effect on flaw initiation of postweld ID grinding.

Flawed Weld Description

There are total of nineteen (19) weldments which have not previously been weld overlay repaired which have been evaluated as containing IGSCC-like flaw indications during the current refueling outage's UT examination program. As shown in Table 1, twelve (12) weldments were reported this outage as containing IGSCC-like flaw indications. Seven (7) weldments which are reported as flawed have previously been reported.

Two (2) 6 inch reactor water cleanup (RWCU) system welds outside of the drywell were evaluated as flawed during the current examination program. These are detailed in Table 2.

All of the 12 inch recirculation riser welds not previously weld overlay repaired were examined this outage. Of these, eight (8) pipe-to-elbow welds and one (1) pipe-to-sweepolet weld were evaluated as containing IGSCC-like indications this outage. Two (2) welds were previously reported as flawed. The flaw characterization and UT examination history for each of these welds is shown in Table 3. All of these flawed welds were IHSI treated in 1984 and it is noted that six (6) of the new flawed welds contained only a very limited number (1 or 2) of axial flaws.

All of the 28 inch recirculation pump suction and discharge welds which are not weld overlay repaired have also been examined this outage. Of these, six (6) welds have been evaluated as containing IGSCC-like flaw indications. Of the previously reported flawed welds, significant changes in the flaw characterization have been reported in one (1) weld and one (1) newly flawed weld has been identified this outage. The flaw characterization and UT examination history of each of these welds is shown in Table 4.

UT Examination of Weld Overlay Repairs

During the 1986 Quad Cities Unit 2 refueling outage, the fourteen (14) previously applied weld overlay repairs and six (6) new weld overlays were built up to the "standard" weld overlay design basis of NUREG-0313, Revision 2. The twenty (20) weld overlays repairs were surface conditioned and ultrasonically examined in accordance with Commonwealth Edison procedures which complied with the EPRI-developed weld overlay examination techniques. Examiners, then as well as now, were also trained and "qualified" at the EPRI NDE Center.

Fourteen (14) of these twenty (20) weld overlay repairs were re-examined as part of the augmented stainless steel UT examination program during the current Unit 2 refueling outage.

Table 5 provides a comparison of the UT examination results between the 1986 and the current (1988) examinations for the 14 weld overlay repairs which were re-examined during the current refueling outage.

Generally, these examinations were performed using manual techniques. (In the cases of the end cap-to-header weld overlay, both automated and manual techniques were used.)

Eleven (11) of the fourteen (14) weld overlay examinations performed during the current outage reported no indications in the weld overlay material.

Specific detailed data comparisons and summaries are included for weld overlay 02B-S9 and 02BS-S3. The investigations during the removal and repair of weld overlay 02A-S10 are discussed elsewhere in this enclosure.

Table 5

Comparison of Ultrasonic Examination Results
Quad Cities Unit 2
Weld Overlay Repairs

Weld Number	Examination Results 1986	1988
28 inch Recirculation		
02AS-S4	No flaws in WOR	No flaws in WOR (M)
02AS-S9	No flaws in WOR	No flaws in WOR (M)
02BD-S6	No flaws in WOR	No flaws in WOR (M) Note 1
02BS-F2	No flaws in WOR	No flaws in WOR (A)
02BS-F7	No flaws in WOR	No flaws in WOR (A)
02BS-S3	No flaws in WOR	Flaw rl> design thk. Note 2 (M)
22 inch Recirculation		
02B-S9	No flaws in WOR	Flaw rl> design thk. Note 3 (A)
02A-S10	circumferential multiple axials	No significant change - Note 4 (A)
12 inch Recirculation		
0[illegible]	No flaws in WOR	No flaws in WOR Note 5 (M)
02F-F6	No flaws in WOR	No flaws in WOR (M)
02J-F5	No flaws in WOR	No flaws in WOR
02M-F5	No flaws in WOR	No flaws in WOR
02M-S3	No flaws in WOR	No flaws in WOR (A) Note 6
20 inch Shutdown Cooling		
10S-F5	No flaws in WOR	No flaws in WOR

(A) = Automated UT Exam (M) = Manual UT Exam

Notes:

(1) Circumferential flaw 2-3/4" long with rl = 0.58" reported on pipe side. Weld overlay thickness is 0.462 (upstream) and 0.550 (downstream) inch and design thickness is 0.47 inch.

(2) Two (2) circumferential indications (l = 0.3" with rl = 0.48" and l = 0.5" with rl = 0.44"). The average thickness of weld overlay 02BS-S3 is 0.492 inch. The required minimum design thickness is 0.42 inch.

(3) Eight (8) axial and two (2) circumferential flaws observed in UT examination. The remaining ligaments of all flaws exceed the weld overlay thickness. One (1) axial flaw in low delta ferrite first layer not included in design thickness.

(4) Flawed portion of WOR removed by machining and reapplied during 1988 refueling outage. New UT baseline established.

(5) Axial flaw reported with a rl = 0.61 inch. As-built weld overlay thickness = 0.329 inch and design thickness = 0.25 inch.

(6) One circumferential flaw on the pipe side (length = 0.6" with rl = 0.7") and four (4) axials on the elbow side (rl = 0.45" to 0.7") reported. As-built weld overlay thickness = 0.479 inch (pipe) and 0.331 inch (elbow). The design thickness = 0.25 inch.

Weld overlay 02B-S9 (22 inch end cap-to-header) was examined in both 1986 and in 1988. Indications, not in the weld overlay material itself, have been observed in both examinations. The details of each examination are shown in Table 6.

With the exception of slight changes in the remaining ligaments reported for two (2) of the axial flaws, the UT examination results reported in 1988 are identical with those reported in 1986.

The average thickness of weld overlay 02B-S9 is 0.448 inches. The observations from the examinations of this weld overlay include:

- In general, there is an excellent agreement, both in location and remaining ligament, between the 1986 and the 1988 examinations.

- In two cases, the remaining ligament has decreased, but is still greater than the thickness of the deposited weld overlay.

Table 6

Comparison of Ultrasonic Examination Results
Weld Overlay 02B-S9

Circumferential Indications

Location	1986 Examination Length	1986 Examination Remaining Ligament, in.	1988 Examination Length	1988 Examination Remaining Ligament, in.
59.5	2.5	0.60	2.5	0.60
30.5	2.5	0.56	2.5	0.56

Axial Indications

1986 Examination Location	1986 Examination Remaining Ligament, in.	1988 Examination Location	1988 Examination Remaining Ligament, in.
60	0.55	60	0.55
61	0.58	61	0.58
44	0.60	44	0.46
3	0.62	3	0.50
3	0.70	3	0.70
3.5	0.58	3.5	0.58
7	0.55	7	0.55
7.5	0.60	7.5	0.60

Weld overlay 02BS-S3 (28 inch pipe-to-elbow) was applied in the 1983 refueling outage and was surface conditioned and UT examined in the 1986 outage. This weld overlay has a design thickness of 0.42 inch and an average as-built thickness of 0.493 inch.

No indications were reported in the 1986 examinations of this weld overlay.

In the current examination, two (2) short circumferential indications were reported as follows:

0.3" long x 0.48" remaining ligament and
0.5" long x 0.44" remaining ligament

The flaws are not connected or in the same plane and separated by approximately 1/2 inch.

Two (2) circumferential flaws, most likely interbead lack of fusion at the interface or in the first layer, were observed in the current UT examination of weld overlay 02BS-S3. These flaws were not observed in the 1986 UT examination of this weld overlay.

The remaining ligaments of these two very short flaws exceeds the design thickness of this weld overlay.

Conclusions -

The following conclusions have been drawn from a comparison of the weld overly UT examination data:

- Typically, flaws have not been reported in the weld overlay material (or in the base material examined).

- In those cases where flaws have been observed both in 1986 and 1988, the data correlates quite well.

- In one weld overlay (02BS-S3), two very short circumferential flaws have been observed in the current examination which were not detected in 1986. The remaining ligament of weld overlay exceeds the full structural design thickness of this weld overlay. Therefore the repair is acceptable for continued service. It is planned to re-examine this weld overlay repair next outage.

Flaw Analyses

Flawed pipe analyses have been performed by Structural Integrity Associates on all large diameter (28 inch) flawed stainless steel weldments in accordance with NUREG-0313, Revision 2. (SIR-88-018, Volume 1 - Enclosure 2)

Several conservati e assumptions were used in the flawed pipe analyses of the large diameter fl.wed pipe welds, including:

- The as-welded residual stress distribution, as shown in NUREG-0313, Revision 2, has been used in all of the analyses of 'arge diameter flawed weldments. (Note that IHSI was applied to . ese welds in 1984.)

- An assumed 1000 psi weld overlay shrinkage stress was used along with pressure, dead weight and thermal stresses in the crack growth calculations. This value is more than twice the maximum value reported in prior analyses.

All large diameter flawed welds were found to be acceptable for continuous service. (See Enclosure 2)

Commonwealth Edison elected to repair all 6 and 12 inch flawed weldments.

Repair Description

A standard design bases weld overlay repair, in accordance with NUREG-0313, Revision 2, will be applied to each of the 11 flawed 12 inch recirculation riser weldments and the 6 inch RWCU weldments.

In accordance with the technical specification covering the weld overlay application, the surface of the 12 inch recirculation riser welds to be weld overlay repaired will be liquid penetrant (PT) examined and any indications repaired prior to weld overlay application. The first weld overlay layer will contain a minimum delta ferrite content of 7.5 FN. Each of these weld overlays will be surface conditioned to allow for UT examination using the EPRI developed weld overlay examination techniques.

The specific RWCU weld overlay repairs are discussed later.

Weld Overlay 02A-S10 Investigation and Repair

During the last refueling outage (1986), a weld overlay was applied to weld 02A-S10 - a 22 inch recirculation header-to-end cap weld. The UT examination of the completed weld overlay repair detected several axially oriented flaws and a circumferential flaw in the weld overlay. These flaws were demonstrated analytically to be acceptable for continued service. This weld overlay was UT examined before any repair activities this outage and the current results compared with those from last outage. This comparison showed a generally good correlation of the flaws and no adverse change in the flaw depth (i.e., no decrease in remaining ligaments).

During the current outage, Commonwealth Edison planned repair activities of this weld overlay during the current refueling outage. The repair consisted of the removal by machining of a band of the weld overlay containing the flaws and extending approximately 1/4 inch into the original component base metal.

The machining operation was stopped at three levels corresponding to the remaining ligaments of the flaws observed by UT examination. No linear indications were observed in any of the PT examinations corresponding to the deepest flaws, a level approximately at the full structural weld overlay thickness had been removed and at the original base metal outside surface. Very few small rounded indications were observed, most likely porosity from the SMAW "steam blow out" repairs. At least two of these PT examinations were witnessed by NRC Region 3. Commonwealth Edison is continuing to study these results.

RWCU Weld Overlay Repairs

IGSCC-like flaws were evaluated in two 6 inch RWCU system weldments outside of the drywell (See Table 2). Several repair options were evaluated and, based on a successfully hydrostatic testing of the inaccessible welds, a standard design basis weld overlay in accordance with NUREG-0313, Revision 2 was chosen. Two differences in these weld overlay repairs have been presented to the NRC Staff and found acceptable. These being application of a "dry first layer" and the final weld overlay surface finish.

Due to repair considerations associated with the through-wall axial and the presence of the other flaws, a first weld overlay layer, not considered in the design thickness, will be applied to the weldment with the system drained. This layer is intended to provide an additional "barrier" against welding problems. This layer will be PT examined and any repairs made prior to refilling the system. The weld overlay will then be applied in the normal manner in accordance with the Structural Integrity technical specification.

The weld overlay repairs applied to the RWCU system will not be surface conditioned for ultrasonic examination at this time for ALARA and other reasons. If the service life of these repairs are intended to be longer than two fuel cycles of operation, the weld overlays will be surface conditioned and UT examined using the EPRI developed weld overlay UT examination techniques.

IHSI Investigation

During the current examination program, nine (9) 12 inch welds and one (1) 28 inch weld which were IHSI treated in 1984 were evaluated as containing IGSCC-like flaw indications. IGSCC flaw growth was also observed in one (1) 28 inch recirculation weld. The UT examination data, the IHSI treatment records and the original fabrication history/radiographs were reviewed for a large number of these welds. The review of this data is documented in Structural Integrity Report SIR-88-018, Volume 1 (Enclosure 2).

An initial review of the IHSI treatment records, original construction radiographs and prior UT examination history indicates that:

- the IHSI treatments were all within the current EPRI guidelines, and
- there is strong evidence of ID grinding and/or wide weld roots in these welds.

Additional work is planned to further investigate these observations as part of an industry-wide research effort under the auspices of the Electric Power Research Institute (EPRI).

STRUCTURAL INTEGRITY ASSOCIATES, INC.

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January 13, 1988
DRP-88-001

Mr. D. G. Wilgus
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Subject: Quad Cities Unit 2
Prioritization of IGSCC Susceptible Stainless Steel
Welds for Ultrasonic Examination
1988 Refueling Outage

Reference: Letter DRP-87-054 to Mr. R. Bax from D. Pitcairn (SI) dated December 8, 1987

Dear Dan:

Data was collected and a prioritization study conducted of IGSCC susceptible welds for Quad Cities Unit 2 during the week of January 4, 1988. The data collected included inservice inspection history, system considerations and information regarding original construction (radiograph review).

For each of the 200+ welds, the data was reviewed to qualitatively determine the potential for IGSCC flaw detection (and repairs) during the upcoming 1988 refueling outage.

Attachment 1 to this letter is a description of the program and prioritization "criteria." The results of this study are summarized in this letter (Table One) and are presented in detail in Attachments 2, 3 and 4. The results are listed by system and size, hopefully consistent with the planned examination categories.

The results are grouped as follows:

Priority 1 - Welds with existing or previously reported flaws (or other concerns)

Priority 2 - Welds whose examination history, fabrication or other data trends make them strong candidates for IGSCC.

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Priority 3 - Welds whose examination history, fabrication or other data trends make them moderate candidates for IGSCC.

Priority 4 - Welds whose examination history, fabrication or other conditions which make them unlikely candidates for IGSCC.

If you have any questions or require further clarification, please feel free to contact me.

Very truly yours,

David Pitcairn, P.E.

cc: R. Bax (Quad Cities) w/att
R. Tamminga/ H. Do (Prod. Services) w/att
D. Thayer (Quad Cities) w/att

STRUCTURAL INTEGRITY ASSOCIATES, INC.

Table One

Summary of Prioritization Study
IGSCC Susceptible Welds
Quad Cities Unit 2

System	Category/ Size	Priority 1	Priority 2	Priority 3
Recirc.	28-inch	7 Note 1	2	12
	22-inch	0	0	4
	12-inch	2	4	7
	Bypass	0	0	0
	Safe End	0	0	0
SDC	20-inch	0	2	3
LPCI	16-inch	0	3	3
Core Spray	10-inch	0	2	6 (approx)
RWCU	6-inch	0	0	1
CRD Return		0	0	1
JPI		0	0	0
Head Spray		0	0	0
Head Vent		0	0	0
	Totals	9	13	37

Note 1 - Five flawed welds and two previously reported as flawed

ATTACHMENT 1

Prioritization of Stainless Steel Welds
Susceptible to IGSCC for Inservice Inspection

Introduction and Background

Intergranular Stress Corrosion Cracking (IGSCC) has been an economic and technical issue associated with the stainless steel primary piping of Boiling Water Reactors (BWR) since the mid 1970s. The IGSCC issue has resulted in the requirement to ultrasonically (UT) examine large augmented samples of potentially susceptible stainless steel welds during each refueling outage. These extensive augmented examinations have been performed at each Quad Cities Unit 2 refueling outage since 1983. Currently, Commonwealth Edison (CECo) is in the planning process for the augmented UT examination program for the Spring 1988 refueling outage.

When IGSCC flaw indications are evaluated as a result of the UT examinations, they require analysis for acceptability and potentially repair. The most common "repair" for IGSCC is the weld overlay. If flaw indications are discovered early in the examination program, increased examination samples and weld overlay application can usually be accommodated within the outage schedule. Conversely, flaw indications discovered late in the program have resulted in schedule delays due to required increased sample sizes and repairs. It therefore seems prudent to attempt to prioritize the potentially IGSCC susceptible stainless steel welds by their probability of being flawed and the impact of potential repairs.

This prioritization can be used in two ways - sample selection and examination scheduling.

Sample Selection -

The NRC "regulations" - Generic Letter 84-11 and NUREG-0313-contain the requirements for the number of each "category" of welds which must be examined. The current CECo augmented examination program is based on Generic Letter 84-11 which requires approximately 80 welds (of the approximately 240 IGSCC susceptible welds) to be UT examined as an initial sample. If flaw indications are detected in this sample, there are requirements for sample expansion up to the examination of all welds. Commonwealth Edison has elected to utilize the prioritization approach to select welds for examination in order to have the highest probability of identifying flaws in a timely fashion and facilitate repairs within the outage schedule.

Examination Scheduling -

Once the examination sample is selected, the individual welds will be scheduled for examination based on several factors. The prime factors used in scheduling will be the probability of flaw indications as determined by the prioritization process and the probability/duration of repairs. Other factors include the deinsulation of the welds, availability of examination equipment, etc.

Approach/Methodology

The prioritization process is not a precise science or analysis, but rather a common sense experience-based approach which considers:

- Industry research efforts,
- Prior examination history,
- Fabrication history,
- Repair duration (i.e. pipe size),
- The application of IGSCC remedies, such as stress improvement, heat sink welding or the use of "conforming" material, and
- System operation, most importantly temperature.

Examples of important variables considered include weld ID grinding, past examination results and current examination techniques.

Lessons learned from the recently completed Quad Cities Unit 1 examinations demonstrated the importance of considering the grinding (abusive) of the weld root region during fabrication. The resultant cold worked inside surface serves as a strong initiator of IGSCC, even after stress improvement. This consideration is further supported by the large number of flawed shop welds that have been observed.

There have been flaw indications identified by the UT examination organizations contracted by CECo which have been "reversed" by the CECo-SMAD Level IIIs after re-examination. Many of these reversed calls are the result of the re-evaluation of the signal by then more sophisticated equipment (e.g., ID creeping wave, etc.). These re-evaluations were typically limited to welds originally identified as flawed. The current examination techniques more commonly utilize these sophisticated transducers and the potential then exists for some prior "ID or root geometry" evaluations to be re-evaluated today as flaws.

The state of examiner training and qualification within the nuclear industry has shown dramatic changes since 1983. The current examination personnel are more "tuned in" to identifying IGSCC. This has manifested itself in the identification of more axially-oriented IGSCC, which for most situations requires weld overlay repairs. The use of automated UT equipment compounds this observation. Other than the observation of a large number of axially flawed welds associated with "wide" weld crowns in 12-inch pipe welds, little can be done to predict the occurrence of axial flaws. The only "positive" approach to identifying axial flaws is flush grinding welds prior to examination.

The prioritization has been accomplished by listing all potentially IGSCC susceptible welds, their examination history, available fabrication observations, IGSCC remedy history, etc. From these observations, the a ranking was developed using the following "criteria."

Prioritization "Criteria"

<u>Larger diameter welds (> 16 inch diameter)</u>

lower risk of unacceptable IGSCC flaws

Longer repair duration

Risk factor high for 28 inch recirculation welds (shop > field)

Risk factor lowered if:
conforming material
stress improvement
temperature

16, (RHR) 20 (RHR) and 22 (Recirc) inch welds considered on case-by-case

<u>Mid-diameter welds (10 and 12-inch diameter)</u>

12-inch recirc welds - data trends associated with weld width, etc.

High risk of axial IGSCC flaw(s) which dictate repair

Repair duration/impact typically minimal

10-inch core spray - history shows little difference with Unit 1, therefore similar problems may be reasonably "expected."

Potential risk for detection of axial flaw(s) which dictate repair

Repair duration/impact may be high if several observed along with other actions on same line

<u>Small diameter welds (< 10-inch)</u>

Historical criteria from prior examinations

A rather straightforward "analysis" considering the probability of IGSCC flaw detection, the probability of the flaw requiring repair and the impact of a repair effort was performed. The welds should be scheduled as follows:

- Priority 1 "flawed" welds
- 02A-S10 (end cap) weld overlay
- 12-inch recirculation shop welds
- A sample of 10-inch core spray (SI optional)
- 28-inch recirculation shop welds
- 12-inch recirculation field welds
- large diameter welds ("hot systems, no SI), 28-inch recirculation system field welds, and large diameter welds ("hot" systems w/SI)
- large diameter welds "cold" systems
- nozzle-to-safe end welds
- others

ATTACHMENT 2

Discussion Regarding
Flawed and IHSI-Mitigated Welds
Quad Cities Unit 2

Of the nine (9) flawed and previously reported as flawed welds, seven (7) of the welds at Quad Cities Unit 2 were analyzed in 1986 and found acceptable for service considering the residual stress redistribution from stress improvement (IHSI). Of these welds, two (2) are 12-inch riser welds and six (6) are 28-inch welds.

Some considerations in these analyses were:

- The EPRI post-IHSI residual stress distribution was used in all analyses
- The flaws were conservatively characterized as 360o by the maximum measured depth.
- Actual applied stresses, including weld overlay shrinkage stresses, were utilized in the analyses.
- A limit load analysis was performed for each flawed weld and demonstrated acceptable margins.

Draft Revision 2 of NUREG-0313 has provided the NRC "position" on the effectiveness of stress improvement (SI) as a "repair" for flawed welds. This position limits the use of SI to flaws which are less than or equal to 10% of the circumference and whose depth is less than or equal to 30% through-wall. Additionally, the NRC has recently questioned IHSI due to field observations at Quad Cities Unit 1 and other plants. As a result, flawed pipe analyses assuming an "as-welded" residual stress distribution have also been "required." A review of each of these flawed welds has been performed with conclusions as follows:

<u>02D-S3</u> The reported flaw length and depth meet the NRC criteria and the flaw has been examined since 1983 with little change in the flaw characteristics. The flaw depth reported in 1985 was 28% though-wall, close to the NRC criteria. An analysis with the as-welded residual stress pattern would most likely require weld overlay repair.

Action - Examine early and plan for potential weld overlay.

02M-S4 The reported flaw length and depth meet the NRC criteria and the flaw has been examined since 1983 with little change in the flaw characteristics. The applied stresses, most notably weld overlay shrinkage, are high for this weld. An analysis with the as-welded residual stress pattern would require weld overlay repair.

Action - Examine early and plan for potential weld overlay repair

02AS-S6 This weld has been examined since 1983 with no significant change in the flaw length or depth. The flaw length is approximately 8% of the pipe circumference, making it "marginal" if the 1988 flaw characteristic is any longer.

Action - Examine early

02AS-S12 This weld has been examined since 1983 with no significant changes observed. The flaw length exceeds the NRC criteria. An analysis which considers the relatively low applied stresses and an as-welded residual stress pattern should show the weld to be acceptable for additional service.

Action - Examine early

Recommendation - Perform analysis to determine maximum acceptable flaw depth, thereby allowing for "real time" weld overlay repair decisions during outage.

02AS-F14 This weld has been examined since 1983 with no significant changes observed. The flaw length exceeds the NRC criteria. An analysis which considers the relatively low applied stresses and an as-welded residual stress pattern should show the weld to be acceptable for additional service.

Action - Examine early

Recommendation - Perform analysis to determine maximum acceptable flaw depth, thereby allowing for "real time" weld overlay repair decisions during outage.

O2AD-F12 This weld was identified as flawed and IHSI-treated in 1983, the flaw being characterized as relatively long (24 inches) and shallow (10% maximum through-wall). The 1985 and 1986 UT examinations have evaluated the flaw as short (1 inch) and less than 25% through-wall (16 and 17%). In all likelihood, the 1983 flaw length was due to problems associated with flaw discrimination from the ID or root geometry present in this weld.

Action - Examine early

O2BD-F8 This weld was IHSI treated in 1983 and post-IHSI UT examined. Root geometry (ID) was reported. There was no examination performed on this weldment in 1985. In 1986, a relatively short (4-1/2 inch), shallow (15% maximum through-wall) flaw was evaluated.

Similar observations have been made of flaws in large diameter stress improved welds, most notably during the recent Quad Cities Unit 1 outage.

Action - Examine early

The following two (2) welds were not evaluated as flawed based on the 1986 examinations, but have previously been reported as flawed. They are included in this discussion due to their "potential for concern" in the next augmented examinations.

O2BS-S12 This weld has been reported as flawed since 1983. The flaw characteristics (flaw length) would exceed the NRC criteria. A plug sample was removed in 1983 which demonstrated that the "flaw" is a geometric signal from a backwelded root.

Action - Examine early

O2BS-F14 This weld was reported as flawed (short, shallow) in 1983 and 1985. In the 1986 examination, the UT signal was evaluated as ID geometry.

Recommendation - Examine this weld as a Priority 2 this outage.

Conclusions

Of the eight (8) welds which have been reported as flawed since 1983, no significant changes have been reported. There have been some changes in the NRC position on stress improvement effectiveness and analytical techniques over the last year or so which must be addressed for these welds.

It is recommended that:

- these welds be examined early in the outage to assess any potential changes in the flaw characteristics.,

- scoping flawed pipe analyses be performed for selected welds to minimize the decision making process in the outage, and

- bid designs be prepared for these welds to obtain the "lowest cost" if weld overlay repairs are required.

ATTACHMENT 3

Discussion Regarding
Prioritization of IGSCC Susceptible
Reactor Recirculation System

Recirculation Riser Welds

Based on the 1983, 1985 and 1986 ultrasonic examinations, there are twelve (12) flawed 12-inch recirculation riser welds - ten (10) of which are repaired using weld overlays. The two (2) remaining flawed welds are "repaired" by stress improvement (IHSI) and have been observed as not exhibiting any significant change with service. The flaw characteristics in these welds (02D-S3 and 02M-S4) are short (<5% circumference) and shallow (<25% through-wall), therefore comply with the NRC position expressed in Revision 2 of NUREG-0313.

Shop weld radiographs were reviewed for the presence of the weld root (i.e., absence of ID grinding), major repaired areas and the presence of "wide" weld roots/crowns.

The radiographic review data was then compared with the presence of flaws reported in prior examinations. As was noted with the Unit 1 results, all prior flaws were identified in "wide" welds. The additional wide weld examination history was reviewed for the unflawed and wide welds. Welds with reported ID geometry in at least one prior examination were identified as high priority welds.

Review of a sample of the riser field welds showed the presence of an identified root, scattered weld repairs and "normal" weld fit-up. Specific weld data is not possible at this time.

Priority 1

02D-S3
02M-S4

Priority 2

02D-S4
02E-S3
02E-S4
02H-S3

Priority 3

O2C-S4
O2H-S4
O2L-S4
O2C-F2
O2D-F2
O2F-F2
O2B-F6 (riser to header)

Priority 4 - Remainder

Recirculation Header Welds

The only flawed 22-inch welds in the recirculation header are the two (2) end caps, both of which have been weld overlay repaired. It should be noted that while not definitive, it is believed that the eight (8) sweepolet-to- header welds are solution heat treated and therefore not susceptible to IGSCC.

Priority 1 and 2 - None

Priority 3 -

O2A-S4
O2B-F1
O2F-1E
O2-F2

Priority 4 - Remainder

Recirculation Pump Suction/Discharge

Thirteen (13) 28-inch welds have been reported as flawed during the 1983, 1985 and 1986 ultrasonic examinations, six (6) of which have been weld overlay repaired. Two (2) welds which have been reported as flawed have been re-evaluated as geometric indications from a "backwelded" root, one by UT and one via a "plug sample." The remaining five (5) welds are "repaired" by stress improvement (IHSI).

Of these five (5) welds, four (4) have been examined each outage since 1983 (3 times each) and have shown no significant changes in the flaws. One flawed weld was discovered in the most recent (1986) examinations.

While demonstrated to be acceptable by fracture mechanics in 1986, some large diameter flawed welds do not met the current NRC criteria for the use of stress improvement as a "repair" due to length. This is discussed further in Attachment 2.

The examination priorities therefore are as follows:

Priority 1 -

O2AS-S6 (flawed)
O2AS-S12 (flawed)
O2AS-F14 (flawed)
O2AD-F12 (flawed)
O2BD-F8 (flawed)

O2BS-S12 (previously reported as flawed)
O2BS-F14 (previously reported as flawed)

Priority 2 -

O2AD-S6
O2AS-S3

Priority 3 -

O2AD-S2
O2AS-S9
O2BD-S1A
O2BD-S2
O2BS-S9
O2BS-S5
O2AD-F1
O2AD-F8
O2AD-F9
O2AS-F5
O2BD-F9
O2BS-F14

Priority 4 - Remainder

Other Recirculation System Welds

There have been no flawed welds in the 4-inch recirculation bypass lines which were repaired in the mid- and late-1970s. These have not been shown on previous CECo submittals to the NRC, though they were all successfully examined in 1983 (one in 1985, none in 1986). It might be advisable to examine selected bypass welds during the 1988 outage. The recommended selections might include to end cap-to-pipe and/or terminal ends.

ATTACHMENT 4

Discussion Regarding
Prioritization of IGSCC Susceptible Welds
(Systems Other Than Recirculation)

In the past, there has been limited IGSCC remedy application to stainless steel weldments in systems other than the recirculation system at Quad Cities Unit 2. Remedy application has been limited to IHSI application to primary welds (inboard of the first isolation valve) and IHSI and HSSW on the RWCU system. There has also been material replacement in the RWCU and core spray systems.

The current study has generally been limited to an historical review of ultrasonic (UT) examination results, comparisons with Unit 1 and general review of radiographs for the larger diameter systems (16- and 20-inch). The results are presented by system.

RHR - Shutdown Cooling System (SDC)

IGSCC flaws have been identified in the SDC system inboard and adjacent to the first isolation valve (2 of 4 welds). The remainder of this system is generally lower in temperature as one moves upstream from the isolation valve, therefore diminishing IGSCC susceptibility. Both the unflawed welds inboard of the first isolation valve were IHSI treated in 1983 and have not been examined since then.

The general radiographic review indicated a general absence of grinding in field welds and some limited repairs.

The welds have been prioritized as follows:

Priority 1 - None

Priority 2 - 10S-S3 and 10S-F4

Priority 3 - 10S-S6, 10S-S7 and 10S-S8

Priority 4 - Remainder

RHR - Low Pressure Core Injection (LPCI)

Historically, IGSCC has not been observed in the LPCI system in either unit at Quad Cities (one observation last Unit 1 outage).

The field weld radiographs indicated limited repays and minimal, if any, grinding. IHSI treatment was applied to a limited number of LPCI welds inboard of the first valve in 1983.

The welds have been prioritized as follows:

Priority 1 - None

Priority 2 - 10AD-F1, 10BD-F1 and 10AD-S5

Priority 3 - 10AD-S4 (or F4), 10AD-F12 and 10BD-S4 (or F4)

Priority 4 - Remainder

Core Spray

The Quad Cities core spray systems (both units) were found flawed in 1979 and 1980. Many significant (leaking) axial flaws were detected, some traversing the weld. The affected sections were replaced with carbon steel.

As part of the pre-MSIP examinations during the 1987 Unit 1 refueling outage, IGSCC (mostly axial flaws) were detected by UT in several (6) welds. Based on these observations and the history of the core spray system, it is recommended that a sample of these welds are examined early in the Unit 2 outage.

The welds have been prioritized as follows:

Priority 1 - None

Priority 2 - 14A-F2 and 14B-F2

Priority 3 - Remainder inboard of first closed valve (exclusive of 14A-F4R,to F10R and 14B-F4R to F11R)

Priority 4 - Remainder outboard of first closed valve and the clad carbon steel to existing stainless steel welds

Jet Pump Instrument Nozzles (JPI)

The jet pump instrument nozzle welds were all examined in 1985 and no evidence of IGSCC was detected. One weld was re-examined in 1986 and confirmed the 1985 results.

Based on the history of these welds, IGSCC is not expected to be discovered during the 1988 outage. The most likely welds for IGSCC though would be the S5 and F1 welds in each assembly.

Reactor Water Cleanup (RWCU)

The Unit 2 RWCU system has exhibited IGSCC in the past and has mostly been replaced with low carbon material and has been remedied by either heat sink welding or IHSI. Based on this, there is little likelihood of IGSCC in the system other than in the 12S-F1 (or S1) and the 12S-F1R welds. The attachment weld may not be able to be examined due to its configuration (reinforcing plate).

CRD Return

The control rod drive return system has historically been free of IGSCC. Current plans include system removal and capping, therefore the weld which would remain (O?-SO) is recommended for examination during the 1988 outage.

Head Spray and Head Vent

The head spray and head vent systems have historically been free from IGSCC at Quad Cities. Ultrasonic examination results from prior outages has been reviewed and does not indicate any anomalies which would suggest that there are no welds with high priority in either system.