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U-603386
8G.120
July 17, 2000

Docket No. 50-461

Document Control Desk
Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Clinton Power Station Revised Response to Generic Letter (GL) 94-03, "Intergranular Stress Corrosion Cracking of Core Shrouds in Boiling Water Reactors"

Dear Madam or Sir:

Clinton Power Station (CPS) provided its response to NRC GL 94-03 in letters U-602516, dated November 22, 1995; U-602334, dated August 24, 1994; and U-602369, dated December 14, 1994. The purpose of this letter is to revise the response to NRC GL 94-03 regarding the schedule for inspection of the core shroud at CPS. Specifically, in letter U-602516, CPS committed to inspect the core shroud during the seventh refueling outage (RF-7) which is scheduled to begin October 15, 2000. Pursuant to a July 5, 2000 teleconference with members of the NRC staff, this letter is being submitted to inform the NRC of a change to that schedular commitment, based on completion of a safety/technical analysis that supports deferring the core shroud inspection to the eighth refueling outage at CPS (RF-8).

In a letter dated December 11, 1995, the NRC concurred with the CPS decision to inspect the reactor core shroud in RF-7. The decision to defer the inspection to RF-7 was based on the fact that CPS was a Category A plant according to General Electric document GENE-523-113-084, "BWR Core Shroud Inspection and Evaluation Guidelines" and the fact that CPS would not exceed the criterion of eight years of hot operation until sometime in Cycle 7. (GENE-523-113-084 was the precursor to BWRVIP-01, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines.) For the current cycle (Cycle 7), and per the guidance of GENE-523-113-084 and BWRVIP-01, CPS will transition to a Category B plant as of RF-07 because the eight hot operating years criterion will be exceeded.

A001

Notwithstanding the transition to a Category B plant, a technical basis exists to support deferring the core shroud inspection of CPS. This technical basis is provided as a report in Attachment 2. The report, General Electric Nuclear Energy (GENE) Report B13-02051-00, "Justification for the Deferral of the Clinton Shroud Inspection by One Cycle," was performed for CPS pursuant to GL 94-03 using industry data that was not previously available. The analysis acknowledges the favorable conditions at CPS, including the fact that the core shroud is made from Type 304L stainless steel and that reactor coolant chemistry has been maintained well within Category A conductivity limits since initial plant operation. With regard to industry data that has been accumulated since the issuance of GL 94-03, the GE analysis of industry data from other BWRs with Type 304L shrouds that have been inspected, including all BWR-6 type reactors with similar or longer hot operating periods that have had their core shrouds inspected, indicates that the probability of identifying safety significant cracking in the CPS core shroud after Cycle 8 is extremely low. The analysis is based on crack initiation and crack growth models with consideration given to the Clinton-specific shroud design, fabrication processes, heat treatment, and seismic loads for normal and accident conditions.

Based on the attached conservative analysis of industry data and CPS specific data, deferral of the core shroud inspection to RF-8 has no significant impact on plant safety.

Sincerely yours,

M. T. Coyle

M. T. Coyle
Vice President

RWC/blf

Attachment

cc: NRC Clinton Licensing Project Manager
NRC Resident Office, V-690
Regional Administrator, Region III
Illinois Department of Nuclear Safety

Attachment 1
to U-603386

AFFIRMATION

Michael T. Coyle, being first duly sworn, deposes and says: That he is Vice President, Clinton Power Station (CPS); that this letter supplying the CPS response to Generic Letter 94-03 has been prepared under his supervision and direction; that he knows the contents thereof; and that the letter and the statements made and the facts contained therein are true and correct to the best of his knowledge and belief.

Date: This 16th day of July 2000.

Signed: Michael T Coyle
Michael T. Coyle
Vice President

" OFFICIAL SEAL "
Thomas B. Elwood
Notary Public, State of Illinois
My Commission Expires 11/29/2001

STATE OF ILLINOIS } SS.
DE WITT COUNTY

Subscribed and sworn to before me this 16th day of July 2000.

Thomas B. Elwood
(Notary Public)

Justification for the Deferral of the Clinton Shroud Inspection by One Cycle

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June 2000

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Justification for the Deferral of the Clinton Shroud Inspection by One Cycle

1. Background

BWRVIP-01, "BWR Core Shroud Inspection and Flaw Evaluation Guideline" (Ref. 1) requires inspection of L-grade stainless steel reactor core shrouds after 8 years of hot operation. The BWRVIP requirements were based in large part on GE SIL-572, Revision 1, "Core Shroud Cracks," (Ref. 2) which recommended inspection after 8 years of *power* operation. This was based on conservative, but reasonable extrapolation of field and test data. The definition of operating years was somewhat ambiguous (by intent) and the 8-year period was deemed to be conservative. BWRVIP-01 has defined the hot operating time as time at temperature above 200° F but still allows the use of on-line years. Based on the hot operating definition, Clinton will be just beyond 8 years (time at temperature above 200° F) and would be in Category B which means that limited inspection of the shroud is required. However, as discussed later in this report, there is sufficient conservatism in the 8-year threshold based on operating time at temperature above 200° F that a slightly different definition for the on-line years criteria such as effective full power years (EFPY) may be used. Thus it is reasonable to conclude that the Clinton shroud is borderline between Category A (no inspections) and Category B (limited inspection).

In order to optimize the outage activities and minimize time, the idea of deferring the shroud inspection to the following power uprate outage (RF 08) has been suggested. The purpose of this report is to determine whether delaying the shroud inspection to the next outage is technically justified. This requires answers to the following two key questions:

- Are there safety concerns resulting from delaying the Clinton shroud inspections by one cycle?
- Does delaying the inspection pose any asset protection issues or future repair implementation concerns? In other words, will the cracking at Clinton (after delaying the inspection for one more cycle) be so extensive that repair planning and implementation would take extended down time? This is focused more on the economic consequences of the deferral compared to the previous question on safety consequences.

This report considers the background and basis for the BWRVIP-01 8-year inspection approach and evaluates the potential for cracking as well as the consequences. Comparison of Clinton to the two L-grade shrouds that have been inspected recently and found to have cracking – Reference BWR/6 Plant and Limerick 2 – will be discussed. Results of inspections on other BWR/6 shrouds will also be discussed. Based on this, the safety consequences and the asset protection impact of delaying the inspection will be evaluated.

2. Cracking in Stainless Steel Shrouds

The background to the original SIL572 recommendations and the subsequent BWRVIP-01 criteria are described. The conclusion from the study is that the 8-year requirement for inspection is conservative and is somewhat flexible by intent.

2.1 Original basis for the inspection timing in SIL 572

The original GE SIL 572 (and subsequently BWRVIP-01) established recommendations for core shroud inspections. These recommendations were issued to serve as guidelines, with flexibility expected. In both documents the timing of inspections was tied to material type as well as water chemistry. It should also be acknowledged that GE recognized the need for flexibility by stating *"...In preparing these generic recommendations, GE has not considered plant unique conditions. GE recognizes that implementation at individual plants may vary as a result of many factors. Therefore, an analysis based on plant unique factors should be performed to determine applicability and an appropriate course of action based on cost, benefits and risk."*

Since the issuance of the original inspection recommendations, many inspections have been performed, leading to a better understanding of cracking behavior in core shrouds. Specifically, cracking in type 304L materials is better understood. There is also a better understanding that the extent of cracking in the depth direction is limited by the residual stress patterns created by the welding process. Also, the average depth of cracking in the L-grade materials is somewhat lower than that found in sensitized type 304 materials. This could be due to the L-grade material, or alternatively, the shorter period of operation with the newer plants with L grade shrouds. Laboratory experiments have continued to verify the strong influence of water chemistry on crack growth rates, as water conductivity is an important element of existing crack growth models that are being used by the industry: the BWRVIP-14 model as well as the GE PLEDGE model. This understanding has been included in the EPRI Water Chemistry Guidelines that limit overall conductivity as well as Chloride and Sulfate levels.

In light of this background, the basis of the original recommendation will be briefly discussed, followed by a review of the Clinton water chemistry and a discussion of the

dependencies of crack growth on water chemistry and carbon (L-grade versus high carbon stainless steel) level.

Original Basis of Inspection Timing

The original basis was developed by GENE. In the 1994/95 time frame, the age of the plant was compared to the time of detection. Many of the plants performed inspections well after the eight-year point. At that time, no L-grade plant exhibited any cracking before 10 years. This evaluation included earlier incidences of L-grade safe end cracking (creviced and uncreviced). Figure 1 captures this data. Currently, 13 of 22 Type 304L-grade shrouds have exhibited some cracking as opposed to essentially all type 304 shrouds have exhibited cracking.

The other consideration was the role of water conductivity on cracking in creviced components such as shroud head bolts. Although not made of stainless steel, the susceptibility of stainless steels under creviced conditions is the same as that for the Inconel materials. This data showed there was a clear influence of conductivity on the number of cracks and timing of cracking. Finally, there is a significant difference in the cracking behavior between sensitized high carbon and low carbon stainless steel piping welds. This clearly indicates the role of sensitization on crack growth behavior.

2.2 Basis for the Current BWRVIP-01 Requirements

Although BWRVIP-01 considers operating time over 200° F in categorizing shrouds, it recognized that this information is not readily available. Instead, per the report, the extent of cracking was plotted in terms of on-line years as shown in Fig. 2. The figure shows that *structurally significant* cracking is unlikely until a plant accumulates 10 on-line years of operation. This included mostly Type 304 shrouds, so the corresponding number for L-grade shrouds is expected to be somewhat higher.

Figure 3 shows a plot of GE data on time to cracking in BWR shrouds (minor cracking less than 2-3% of the circumference was excluded). Of the 33 shrouds inspected and found to be cracked, no cracking was seen in less than 8 years (one was found to be cracked in 8.7 years). Of the seven BWR/6 shrouds inspected, only one, the Reference BWR/6 Plant had significant cracking in one weld. Four shrouds (Perry, Leibstadt, River Bend and Grand Gulf) had no cracking, and two had minor cracking (Kuo Sheng Units 1 and 2). Table 1 shows the list of BWR shrouds with inspections, but no cracking. Again, Type 304L shrouds in BWR/6 plants have performed much better from the viewpoint of intergranular stress corrosion cracking (IGSCC).

Similarly, BWRVIP-01 also discussed susceptibility factors and ranked them in terms of the likelihood of significant cracking. Type 304 shrouds with the welded plate rings and the highest water conductivity were judged to have the highest cracking susceptibility. Type 304L grade shrouds with the lowest conductivity were judged to have the lowest

susceptibility. Clinton, with the Type 304L grade shroud, the low first five cycle average conductivity (0.18 μS/cm), and the lowest on-line years, therefore has the lowest probability of cracking. Clinton field experience with reactor internals cracking generally supports this. The only known cracking at Clinton has been in the creviced drain channel welds in the steam dryer.

Although the above analysis suggests that the probability of cracking is low, some cracking cannot be ruled and it is still difficult to predict definitively the extent of cracking. One can say with confidence that the likelihood of significant cracking that raises safety concerns is extremely low. Furthermore, extensive cracking such that repair planning and implementation would take extended down time is unlikely.

3. Clinton Shroud Assessment

The Clinton shroud assessment consists of three parts: i) basis for delaying shroud inspection based independent evaluation of the crack tolerance, susceptibility and water chemistry performance of Clinton, ii) comparison of Clinton with Reference BWR/6 Plant and iii) comparison of Clinton with Limerick 2. The last two items are useful because they represent the recent instances of cracking in L-Grade plants and therefore represent benchmarks for comparison.

3.1 Basis for delaying shroud inspection

Several features at Clinton suggest that the cracking susceptibility is lower and that the crack tolerance is higher.

Water Chemistry at Clinton

The water chemistry at Clinton has been excellent. The average conductivity is well below the 0.3 μS/cm for the first five years of operation. Figure 4 displays these averages. The Clinton conductivity was better than the BWR fleet averages. Examination of the anionic species can also provide some information on the risk of cracking. Figure 5 shows the Chloride levels for the Clinton plant. Again, the Clinton performance is excellent and the average Chloride level in the first five years is below the EPRI 5-ppb limits on average.

Crack Growth Dependence

Crack growth rate behavior has been examined in the laboratory and modeled in several different ways. In all cases there is a clear dependency on conductivity. In the BWRVIP model the crack growth rate is reduced by 35% in going from a conductivity of 0.3 μS/cm to 0.2 μS/cm and reduced by 55% in going from 0.3 μS/cm to 0.15 μS/cm. The

PLEDGE model also predicts the same influence. This is shown in Figure 6 (an historical chart as well). While the L-grade materials in shrouds may act like there is some level of sensitization, the figure displays both the clear effects of coolant conductivity and material sensitization. Both factors have a clear and important effect on crack growth rates. These data explain the differences in cracking extent (particularly depth) generally observed in the field. While the initiation behavior can be dependent on other factors such as cold work, the deepening will be affected by the presence of sensitization. Therefore, both of these important factors support the appropriateness of flexibility in planning the timing of a core shroud inspection. Essentially, it shows that the subsequent crack growth rates for the Clinton core shroud should be well below the bounding growth rates used in BWRVIP-01. It is expected that one cycle of additional operation will have only a small effect on the extent of cracking and will not have any impact on the ability to repair such cracking in a planned manner without extended down time.

Allowable Crack sizes (Crack Tolerance)

Another consideration in justifying the deferral of the shroud inspection is the structural margin (in other words, crack tolerance) if cracking is postulated in the shroud. The allowable flaw size is largely dependent on the seismic loading. Clinton is a low seismic load plant. Based on BWRVIP-38, "BWR Shroud Support Inspection and Flaw Evaluation Guidelines," (Ref. 3) only Monticello has lower seismic loading. A measure of the crack tolerance is the allowable flaw sizes given in the following table. The allowable sizes were based on another BWR/6 plant with virtually the same dimensions, but much higher seismic loading. Therefore actual allowable crack size for Clinton is much higher than that shown in the table.

Weld Location	Allowable Crack size, inches	Governing mechanism
H1-H2	430	Limit Load
H3-H6a	332	Limit Load
H3-H5	101	LEFM
H6b-H7	345	Limit Load
H8	384	Limit Load

The assumed cracking is **through thickness, continuous cracking**. For limit load, the total cumulative length should be compared with the allowable length. The allowables already include the appropriate safety factors. The linear elastic fracture mechanism (LEFM) allowable is applicable for a single crack (after including the proximity corrections). As stated earlier, the actual values for Clinton are expected to be higher. Clearly, the allowable crack length values indicate significant margins and suggest that even if some cracking were to exist, it is extremely unlikely that the predicted crack length after two cycles would exceed the allowable value. Thus, there are no safety issues associated with the deferral of inspections by one cycle.

There are other conservatisms in the inherent BWR/6 design that apply to Clinton. For example, because of the bolted design of the top guide and core plate attachment, there is no end grain exposure. End grain cracking has been a significant issue in shrouds with welded plate rings. The configuration also conservatively has redundant load paths since the shear pins and bolts provide an alternate load path.

Finally, the Clinton shroud was fabricated in two parts with a closure weld in the core region. All other welds experienced a dimensional stabilization heat treatment at approximately 750° F. While this is not high enough to relieve the weld residual stresses, there is some benefit since the peak values are smoothed out. Experience at the Reference BWR/6 Plant indicated that there was no cracking in the welds with the dimensional heat treatment. Thus, at worst, the single closure weld in the core region (which did not undergo the heat treatment) might experience cracking.

In summary, there are plant unique considerations for Clinton which suggest that cracking, if any, will not be significant. Even if some cracking is postulated, the subsequent growth will not be significant because of the excellent water chemistry and lower fluence. Thus, deferral of the shroud inspection poses no safety concerns and is unlikely to cause any adverse effects on the ability to implement future repairs.

3.2 Comparison with the Reference BWR/6 Plant

The shroud for both Clinton and the Reference BWR/6 Plant were fabricated by the same manufacturer and to the same specification, and therefore, it is appropriate to compare these two plants. Since the Reference BWR/6 Plant is a sister BWR/6 plant of similar design and experienced significant cracking at H4, the differences between Clinton and the Reference BWR/6 Plant are discussed here.

As described earlier, the Reference BWR/6 Plant cracking was somewhat unique in that all other welds (except H4) had no cracking and only H4 had significant cracking. The shroud was made of two different sections and H4 was the closure weld. Because of the distortion induced by the earlier thermal stabilization heat treatment of the two sections, it is likely that there may have been cold work at H4. Other contributing factors may be fluence, water chemistry and chlorides. However, there are substantial differences in fluence, water chemistry and seismic loads that would reduced both the likelihood and consequences of shroud cracking as discussed below.

- The water conductivity during the first five cycles was higher than that at Clinton. Chloride levels were also higher, in fact exceeding the EPRI limits. Figures 6 and 7 show the average water conductivity and chloride averages during the first five cycles. The Clinton chemistry performance was much better.
- The reference BWR/6 Plant started up in November 1984 and cracking was first seen in October 1997 after 11 EFPY. (As of RF 07, Clinton will be at an estimated 7.6 EFPY.) The fluence on the Reference BWR/6 Plant H4 weld was 1.1 E21 n/cm^2 . A

key difference is that Clinton will have much lower fluence on the shroud H4 weld as compared to the Reference BWR/6 Plant.

- Seismic loading at the Reference BWR/6 Plant is much higher than that at Clinton.

Even with the higher loading and the significant cracking at H4, the Reference BWR/6 Plant was evaluated to be acceptable for continued operation for one more cycle. At the end of this cycle, the Reference BWR/6 Plant would have operated for 13.5 years at temperature. Clinton would be less operating years than the Reference BWR/6 Plant even with the deferral of the shroud inspection.

Based on the above comparison, even if one postulates cracking of the type observed at the Reference BWR/6 Plant, continued operation would still be justified for Clinton for two more cycles. Thus delaying the inspection by one cycle will still allow one more cycle for repair implementation.

3.3 Comparison with Limerick 2

Limerick 2 is not a BWR/6 like Clinton, but has a Type 304L shroud like Clinton and has similar operating years. The water chemistry and material composition at Limerick 2 was excellent, in fact, somewhat lower than that at Clinton. A comparison between Clinton and Limerick 2 is provided here:

- Limerick 2 had good water chemistry over the first five cycles and so there is no distinction between Clinton and Limerick 2 from the water chemistry viewpoint.
- The Limerick welds did not experience the thermal stabilization heat treatment like most of the Clinton welds. Since the dimensional stabilization heat treatment has the effect of 'smoothing' of the residual stress peaks, it would suggest that the Clinton shroud welds were somewhat less susceptible to IGSCC than the Limerick shroud welds..
- Limerick 2 had shallow cracking (0.11inch maximum depth) at H4 and moderate cracking at H3 (0.39-inch maximum depth). The cracking was relatively long at H3 and was both on the ID and OD. The average depth on the ID was approximately 0.25 inch. The uninspected areas were evaluated assuming through wall cracking (with cracking assumed based on BWRVIP-07, "Guidelines for Reinspection of BWR Shrouds" (Ref. 4) statistics). Continued operation was justified for one cycle by analysis. A more realistic analysis would justify two cycles based on the less conservative criteria of BWRVIP-76, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines" (Ref. 5) and taking credit for lower crack growth rates in the low fluence regions.

Based on the above, the chemistry at Clinton and Limerick 2 are similar and cracking of the type observed at Limerick 2 cannot be ruled out for Clinton. However, using current BWRVIP criteria, even with this postulated cracking, continued operation for two cycles

can be justified. Thus, if the inspection is deferred and performed during RF-08, this will still allow one cycle to implement any repair during the next refueling outage.

4. Conclusions

The following conclusions are made based on the discussion in this report:

1. SIL 572 is based on conservative assumptions and allows some flexibility in the timing of the shroud inspections based on plant unique considerations. Since BWRVIP-01 was based largely on SIL 572, it stands to reason that there is flexibility in the eight-year inspection requirement.
2. Clinton has a Type 304L shroud and the water chemistry has been excellent. Based on this, the probability of significant cracking is low. Even if cracking is postulated, the allowable crack sizes are large since the seismic loading is very low.
3. Comparisons with the Reference BWR/6 Plant and Limerick 2 experience suggests that Clinton has some advantages – chemistry, heat treatment, number of years, cumulative fluence – and therefore is less likely to experience cracking as significant as that in the other plants. Nevertheless, some cracking cannot be ruled out. However, there is sufficient margin on crack growth and structural capability that continued operation for two cycles could still be justified. If the shroud is inspected in RF 08 and cracking is discovered, there is still time to implement a repair in RF 09.

Based on the above, it is concluded that the idea of deferring the shroud inspection to the following outage (RF 08) is reasonable. This offers the ability to optimize the length of the coming outage RF 07 without having any safety or asset protection concerns. In other words, the cracking at Clinton (after delaying the inspection for one more cycle) is unlikely to be so extensive that repair planning and implementation would take extended down time.

5. References

1. BWRVIP-01, Revision 2, "BWR Core Shroud Inspection and Flaw Evaluation Guideline," October 1996.

2. SIL 572, Revision 1, "Core Shroud Cracks," October 1993.

3. BWRVIP-38, "BWR Shroud Support Inspection and Flaw Evaluation Guidelines," September 1997.

4. BWRVIP-07, "Guidelines for Reinspection of BWR Shrouds," February 1996.

5. BWRVIP-76, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines", November 1999.

Table 1 Inspected BWRs Without Reported Shroud Cracking

	Mat'L	H1	H2	H3	H4	H5	H6	H6A	H6B	H7	H8
Duane Arnold	304L	O	O	O	O	O		O	O	O	
Fermi 2*	304L			O	O	O	O			O	
Grand Gulf	304L			O	O			O		O	
Hope Creek	304L			O	O						
KKL**	304L	O	O	O	O	O	O	O		O	
LaSalle 2	304L					O	O				O
Perry	304L			O	O						
WNP 2	304L			O	O						

O = Plant has inspected but no cracks found

* In 1994 Fermi had two small axial indications in H2 - reinspected in fall 1998

** KKL only examined 270 to 360

"L-Grade" Core Shroud and Core Spray Safe End ISI Summary for Plants With Good Visual and/or UT Inspections

Plant	On-line Years	Welds With Scc	Material Type	Maximum Fluence (nvt)
Plant A	14	None	304L	7.9E20
Plant B	12	None	304L	~5E19
Plant C	11	H-3	304L	~5E19
Plant D	10	H-1,2,3,4	304L	<1E20 to ~6E20
Plant E	8	None	304L	~3.9E20
Plant F	8	None	304L	~5.3E20
Plant G	8	None	304L	~6.7E20
Plant H	7	None	304L	~3.5E20
Plant I	6	None	304L	~3.5E20
PlantJ+	5	Minor	304L	~2.5E20
Plant K	4	None	304L	~3E20
Plant L	3	None	304L	~1.8E20
Plant M*	10	Yes	316NG	$<10^{17}$
Plant N*	10	Yes	316L	$<10^{17}$

*One minor (~2 cm long vertical ID indication) found above toe of H-2 fillet weld .

+ Safe ends.

Significant L-grade SCC only found after ~10 on-line year

Figure 1: Historical Chart used to set eight-year inspection timeframe for L-grade Shrouds

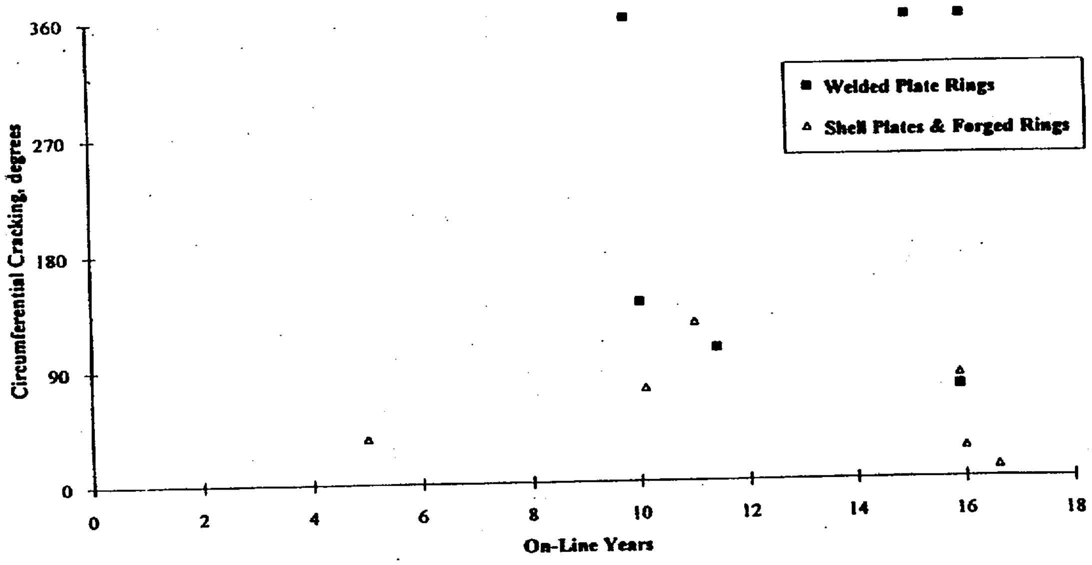

Figure 2 BWRVIP-01 Data on Shroud Cracking

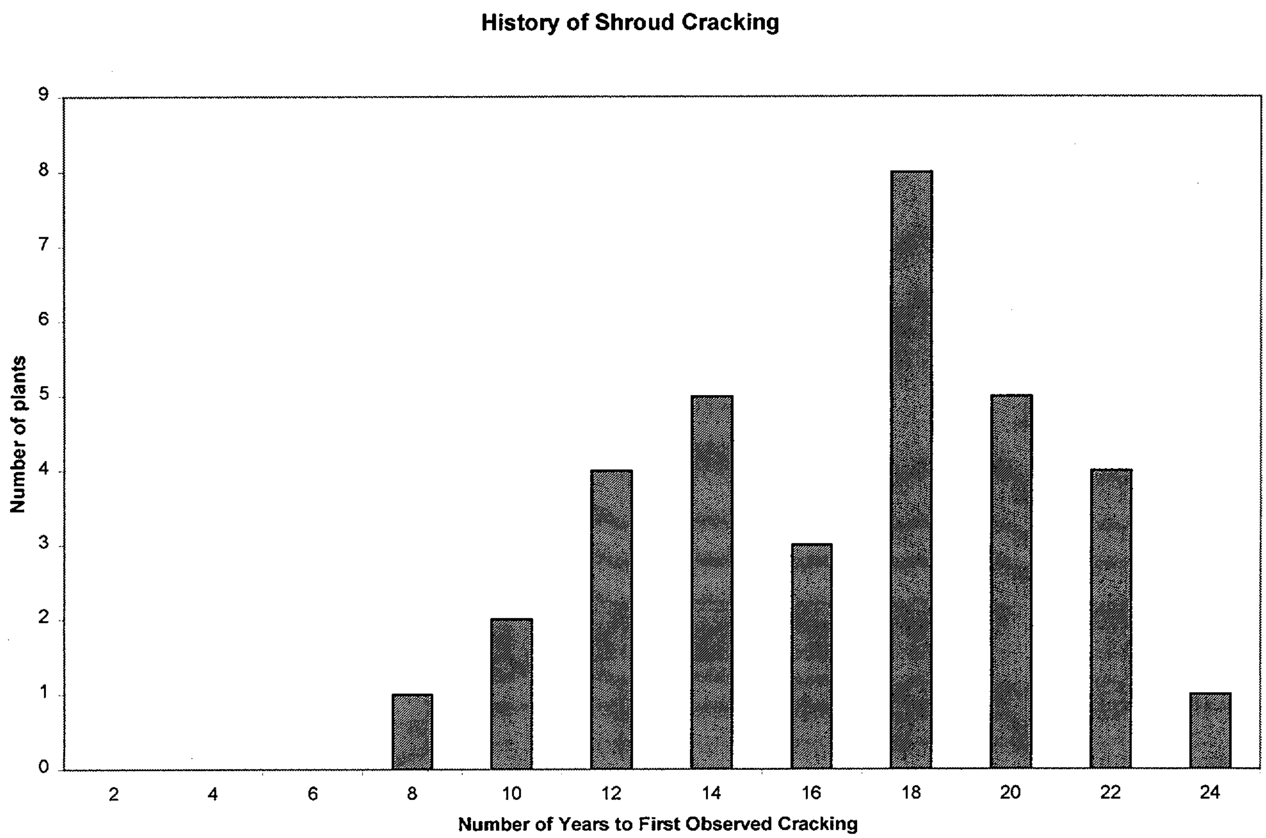

Figure 3 GE Data on Number of Years to First Observed Cracking for BWR Shrouds

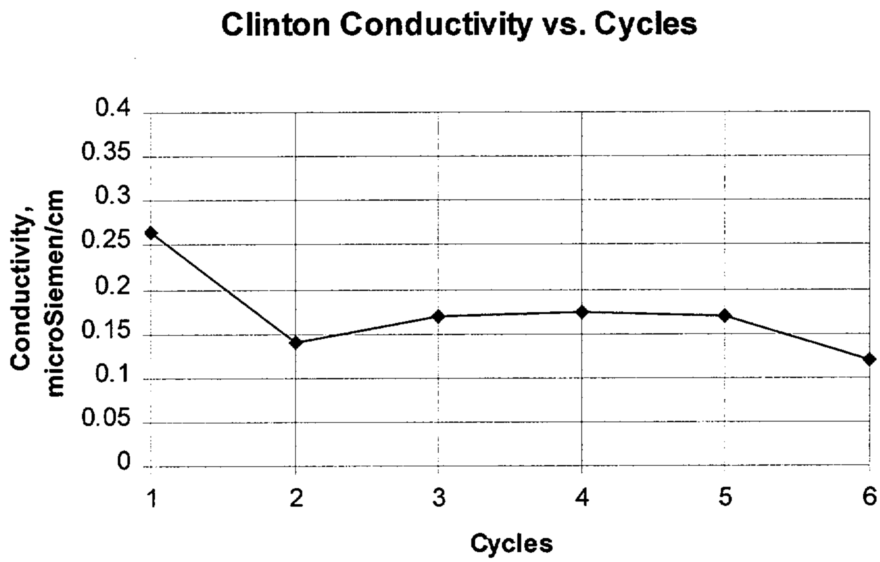

Figure 4 Clinton Cycle Average Conductivity

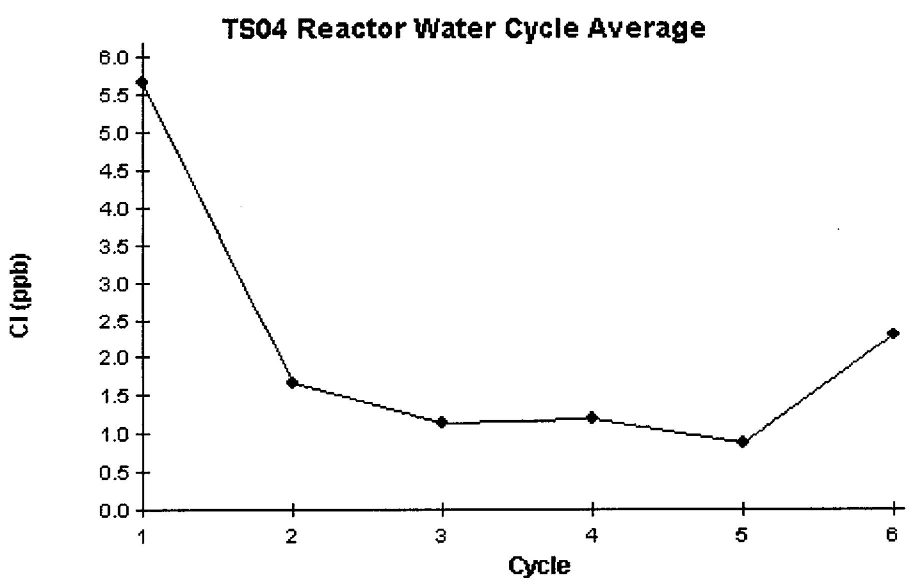

Figure 5 Clinton Cycle Chloride Average

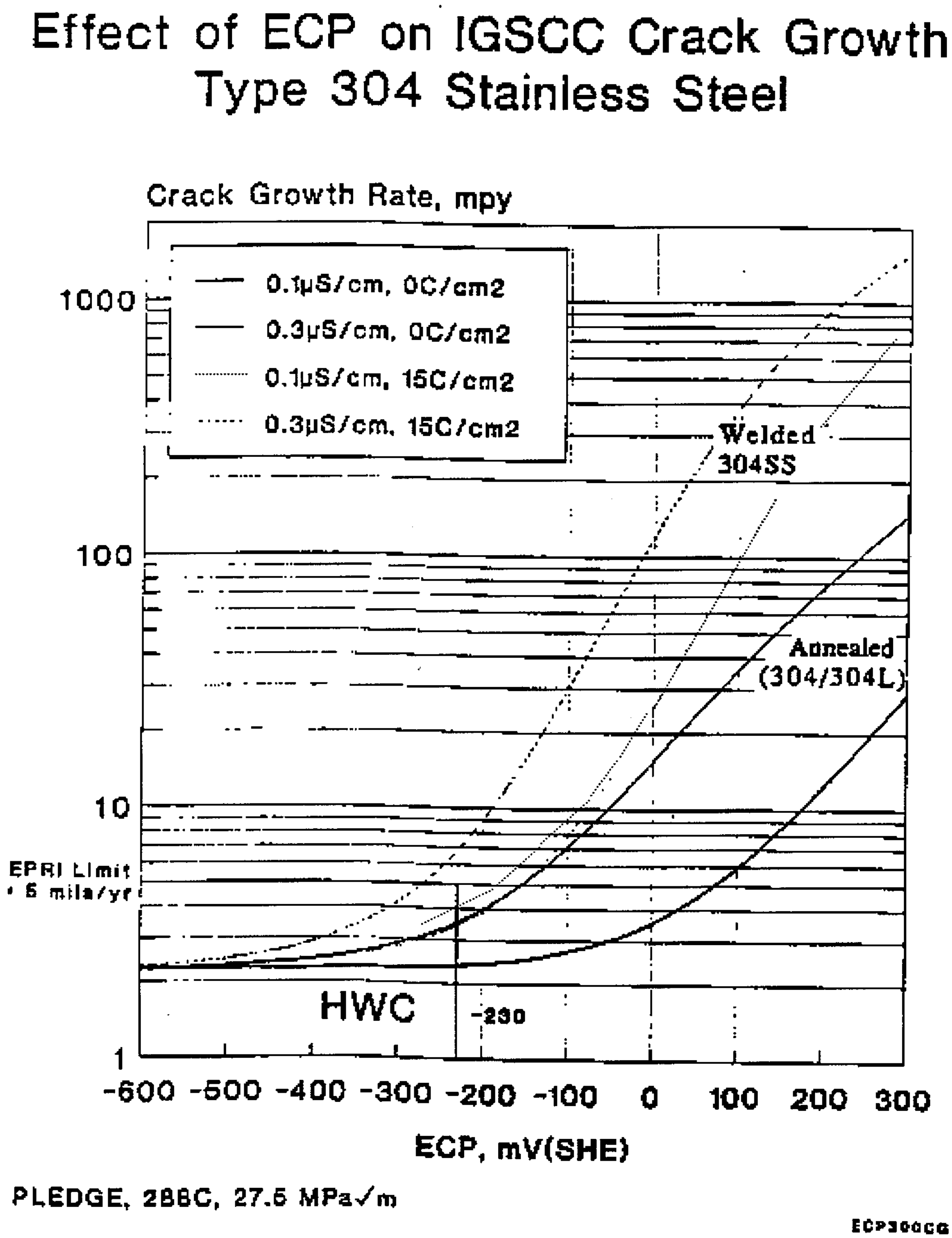

Figure 6: Comparison of Crack Growth Rates for Sensitized and Unsensitized Stainless Steel as a function of ECP and Conductivity: L-grade rates are slower

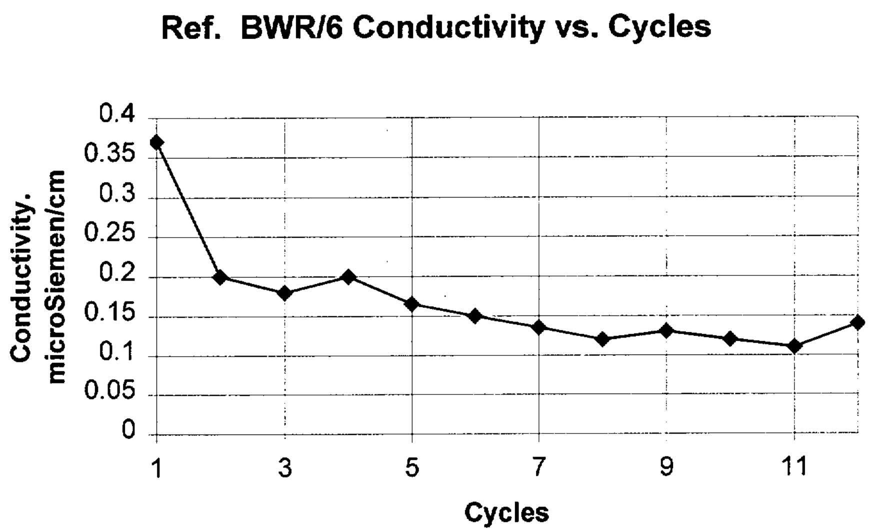

Figure 7 Reference BWR/6 Plant Cycle Average Conductivity

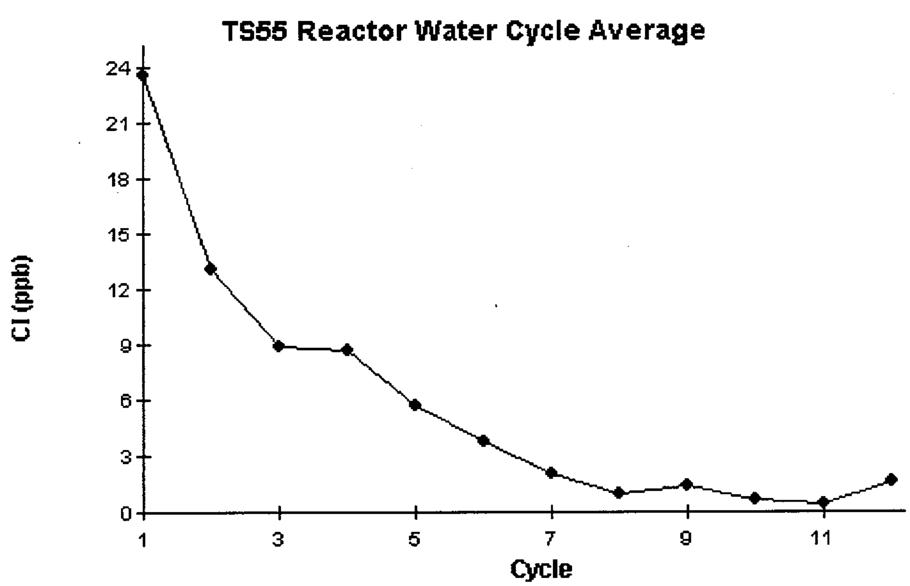

Figure 8 Reference BWR/6 Plant Cycle Chloride Average