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IGSCC Flaw Evaluations and Weld Overlay Activities During the E. I. Hatch Unit 1 Fall 1991 Outage

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1.0 INTRODUCTION

As part of the pre-outage planning process at E. I. Hatch Unit 1, Structural Integrity Associates (SI) prepared weld overlay designs meeting the requirements of the NUREG-0313, Revision 2 [1] "Standard Weld Overlay Design" for all unrepaired locations [2] prior to the Fall, 1991 outage.

During the Fall, 1991 refueling and maintenance outage at the E.I. Hatch Unit 1 Nuclear Power Station, Georgia Power (GPC) applied weld overlays to six locations in the recirculation and residual heat removal systems. The weld overlay designs were based upon the previously developed designs. Five of these weld overlays were applied in response to observed indications representative of IGSCC. The sixth overlay was applied to enhance the inspectability of the underlying weld, although no flaw was observed in this location.

When overlays were completed, SI performed analyses of the weld overlay shrinkage-induced stresses with the as-applied weld overlays. Previous bounding analyses [3] had shown that application of any combination of these overlays would not result in unacceptable shrinkage stress effects in the system.

Section 2 of this report summarizes the GPC inspection plan, initial scope and scope expansion, and the results of these inspections. Section 3 discusses the design basis weld overlays, and provides reconciliation of the design and as-built dimensions for all repairs. Section 3 also discusses the observations made regarding δ-ferrite content in each weld overlays, and the SI conclusions regarding these observations. Section 4 discusses the effects of weld overlay shrinkage on the recirculation system. Section 5 summarizes the evaluation of observed embedded flaws in weld overlays including the criteria of ASME Section XI [7]. Section 6 evaluates the effectiveness of Induction Heating Stress Improvement (IHSI) applied previously to welds in the recirculation system, considering the cumulative effects of the weld overlays applied to the system. Section 7 discusses the effectiveness of Hydrogen

Water Chemistry (HWC) at Hatch. Section 8 addresses the observed changes in flaw character under pre-existing weld overlays. Section 9 provides a summary of the report and the conclusions drawn from the previous sections.

2.0 INSPECTION RESULTS DURING 1991

During the Fall, 1991 outage at Plant Hatch Unit 1, GPC inspected intergranular stress corrosion cracking-susceptible welds in accordance with the requirements of Generic Letter 88-01 and NUREG-0313, Revision 2. The initial inspection plan included examination of 14 Category C welds, 25 Category E welds, and all 4 remaining Category F welds. As a result of the inspection results during the initial scope, the inspection scope was expanded as required by the Generic Letter. Fourteen additional Category C welds were examined, as were all 21 remaining Category E welds. The combined inspection scope therefore included 28 of 73 Category C welds, 46 of 46 Category E welds, and 4 of 4 Category F welds.

The inspection identified flaw indications in one Category C weld (28B-2) and confirmed or showed minor changes in four Category F welds. These inspection results are shown in Table 2-1.

Weld overlays meeting the design requirements of the NUREG-0313 "Standard Weld Overlay" were applied to the Category C weld (1B31-1RC-28B-2) and all four Category F welds (1B31-1RC-12BR-A4, 1B31-1RC-12BR-E4, 1B31-1RC-12AR-G4, and 1E11-1RHR-20B-D-4). In addition, a standard weld overlay was applied to an additional Category C weld (1E11-1RHR-20B-D-5) to improve inspectability of this weld, although no flaws were observed in this weld.

As a result of the weld overlay activities, the overlaid welds are now reclassified as Category E welds for the purposes of future inspection. The Hatch recirculation system with related piping in the RHR system now includes 71 Category C welds, 52 Category E welds, and no Category F welds.

Table 2-1

Results of Inspections: Flaw Characterizations

Weld	Category Before 1991	Flaw Characterization			
		#	Orientation	Length	Depth
28B-2	C	1	Circ	2.2 "	32%
		2	Circ	4.0 "	32%
		3	Circ	0.35"	19%
12BR-A-4	F	1	Circ	4.0 "	26%
12BR-E-4	F	1	Circ	4.4 "	32%
12AR-G-4	F	---------- Unable to Size -----------			
20B-D-4	F	1	Axial	-	10-15%

3.0 WELD OVERLAY DESIGNS AND RECONCILIATION WITH AS-BUILT WELD OVERLAYS

3.1 Design Basis

Piping load data for each weld location was taken from the General Electric (GE) stress report for the recirculation and RHR systems [4]. Stresses were calculated from the load data based upon conservative values of wall thickness for each location. The weld overlay designs are summarized in Table 3-1, and the design sketches are included in Appendix A.

All weld overlay designs were prepared assuming a bounding 360° circumferentially oriented through wall flaw, in accordance with the requirements of the NUREG-0313, Revision 2 "Standard Weld Overlay" design. Design thicknesses were determined using the SI computer program **pc-CRACK** [5].

The overlay lengths shown are minimums required for effective reinforcement. Greater lengths are acceptable, and may be required to allow for adequate inspection or for other reasons.

3.2 Weld Overlay Designs

Weld overlays were applied to six locations during the Hatch Unit 1 1991 outage. Three of these weld overlays were applied to 12 inch pipe to safe-end joints. Two were applied to 20 inch RHR suction welds, and one was applied to a 28 inch safe-end to pipe weld. The 28 inch location contained a newly identified flaw indication in a region where geometry indications had previously been observed. One of the 20 inch locations (weld 20B-D-5) did not contain any identified flaws, but a weld overlay was applied using Inconel 82 weld metal to improve inspectability of the location. The remaining four locations were previously classified as Category F, and contained previously identified flaw indications. Following the weld overlay of these latter four welds, there are no remaining Category F welds in the Hatch recirculation system.

3.3 Ferrite/Carbon Level Considerations

Two welds in large diameter piping (>12 inch) in the Hatch 1 recirculation and RHR systems contain flaw indications which were repaired by the weld overlay technique using Type 308L stainless steel weld metal. The weld overlay locations are welds 1B31-1RC-28B-2 and 1E11-1RHR-20B-D-4. In addition, three welds in the 12 inch recirculation discharge piping were repaired by weld overlay using Type 308L stainless steel weld metal. These welds are 1B31-1RC-12BR-A4, 1B31-1RC-12BR-E4, and 1B31-1RC-12AR-G4. Delta ferrite measurements were made following the completion of the first layer of each of these weld overlays, and in one case following the second and third layers, and the results are summarized in Table 3-2.

Austenitic stainless steel materials with delta ferrite content equal to or greater than 7.5 FN and with carbon content of 0.035 wt% max have been shown to be resistant to IGSCC. Also, where carbon content is less than or equal to 0.035 wt%, wrought austenitic stainless steels like Types 304L and 316L have been shown to be IGSCC resistant even with no delta ferrite present. If ferrite content is less than 7.5 FN but greater than 5.0 FN, it is possible to justify the IGSCC resistance of the resulting weld metal on a case by case basis, by considering a trade-off between delta ferrite content and carbon content, if the carbon level is less than 0.035 wt%. Note that the δ-ferrite issue does not apply to weld 20B-D-5.

This approach is allowed by NUREG-0313, Revision 2, and has been successfully used previously at Hatch and other plants. The purpose of such an evaluation for Hatch is to demonstrate the IGSCC resistance of the first weld layers of the weld overlays above, in order to justify including these layers in the design thickness of the overlays, when the ferrite level is above 5 FN and below 7.5 FN.

The carbon content in the underlying base metal at each of these five weld overlay locations is reported in Table 3-2, based upon data from the component CMTRs. Two heats of weld metal were available for use in these overlays. Heat # PB940, which was used for the first layers of all of the locations except the G4 weld, has a reported carbon content of 0.008 %. Heat # S57735, which was used for the G4 weld, has a carbon content of 0.014% reported in the CMTR.

For both of the above weld metal heats, the carbon content is sufficiently low that the as-deposited carbon content of the first welded layer qualifies as IGSCC resistant (< 0.035 wt %), even considering dilution of the first layer weld metal by the higher carbon base metal during the welding process. Consequently, there is significant benefit to be derived from a case by case evaluation of the ferrite-carbon trade-off at these two locations.

In order to characterize the first welded layer carbon content for these weld overlays, a dilution rate for the dilution of the first welded layer by the base metal was determined, based upon physical examination and chemical analysis of the diluted first layer of welded coupons made using the same welding procedures as were used in weld overlay application. This led to a predicted dilution rate of 32.5 %. Using this dilution rate, the first layer of each of the applied weld overlays was calculated to have carbon content as shown in Table 3-3. In all cases, the diluted carbon level in the first layer is less than 0.035 wt%. These carbon contents meet the NUREG-0313 criterion for conforming IGSCC-resistant austenitic stainless steel base metal, even if no ferrite is present. The first layer weld material is also predicted to be IGSCC resistant by the results illustrated in Figure 3-1 from Reference 6 even with 5 FN delta ferrite, which is the lowest delta ferrite allowed by NUREG-0313, Revision 2 for conforming austenitic stainless steel weld metal.

Figure 3-1 includes data points representative of each of the five stainless steel weld overlay locations. These data have been superimposed on the Reference 6 curve and data. These weld overlay data points reflect the as-diluted first layer carbon content, and the lowest measured delta ferrite point reported for each weld. This illustrates that the lowest measured delta ferrite which could be justified for acceptance of the first welded layer (5 FN), is limited by the NUREG criteria (discussed below) rather than by the data in Figure 3-1.

Although the above results support the position that the first layers of all five welds are sufficiently IGSCC resistant by the criteria of Figure 3-1, NUREG-0313, Revision 2 contains a cut-off minimum level of 5 FN which is defined to be IGSCC resistant. Based upon this requirement together with the above considerations, the first layers of the weld overlays on weld 28B-2 and 20B-D-4 are considered as IGSCC resistant and therefore could have been included as a part of the structural reinforcement weld material used in meeting the design thickness. The first layer of the overlay on 28B-2 was conservatively not considered as part of the design thickness however. The first layer of the overlay on weld G4 is acceptable since all measured delta ferrite data are greater than 5 FN. The first layer of the overlay on weld E4 is not acceptable by the 5 FN minimum criterion, nor are the first two layers of the overlay on weld A4. The third layer of the overlay on weld A4 meets this criterion. Additional weld layers were added to the E4 and G4 welds to achieve a weld layer meeting the NUREG criterion. The weld metal considered in meeting the design thickness was only that including and outboard of the conforming layer.

The weld overlay design drawings for these five overlays all contain a note stating that the first layer of the overlay must have delta ferrite greater than 7.5 FN. The intent of this note is that a first welded layer with measured delta ferrite equal to or greater than 7.5 FN is acceptable for inclusion in the design thickness <u>without further evaluation</u> (in accordance with NUREG-0313). As discussed above, lower levels are acceptable following case by case evaluation.

3.4 Comparison of Design and As-Built Weld Overlays

Contingency weld overlay designs for the six overlaid locations were originally presented in [2]. The design for weld 28B-2 was revised to account for the as-measured component wall thickness on the safe-end side of the weld. The as-measured thickness data for the other weld overlays applied during this outage (welds 12-AR-G4, 12-BR-A4, 12-BR-E4, 20B-D-4 and 20-B-D-5) were reviewed and found to have no impact on the designs previously issued in [2]. The designs for the three 12 inch welds and weld 20B-D-5 were modified subsequent to [2] only to illustrate the detail of blending the overlay into the adjacent component transitions. The design thicknesses of these overlays remain the same as in the previously issued revision [2].

3.5 Conclusions Regarding As-Built Overlays

Table 3-1 presents the design and as-built dimensions for the weld overlays applied during the 1991 outage. Thickness measurements (t) only represent layers which met δ-ferrite/carbon criteria as presented in Section 3-3 for stainless steel overlays. These layers were included in meeting the design thickness. Additional layers inboard of these layers may not have met δ-ferrite requirements and were not included in the design thickness. As may be seen from this table, the dimensions of the as-built overlays meet or exceed the design dimensions in all cases. All of these six weld overlays therefore may be considered to meet the requirements of the NUREG-0313, Revision 2 "Standard Weld Overlay" category.

Table 3-1

Comparison of Design and As-Built Weld Overlay Dimensions

Weld	Design t (in)	Design L (in)	Average As-Built t (in)[1, 2]	Average As-Built L (in)
12BR-A-4	0.27	2.0**	0.44/0.43	2.1
12BR-E-4	0.27	2.0**	0.4/0.37	2.1
12AR-G-4	0.26	2.0**	0.31/*	2.2
28B-2	0.52	8.0	0.57/0.69	8.4
20B-D-4	0.36	6.0	0.44/0.44	6.2****
20B-D-5	0.33	***	0.5/0.39	***

* Measurement not meaningful due to transition angle.

** Length on pipe side only; on component side (safe-end, valve), blend into component transition.

*** Upstream, blend into adjacent overlay, downstream, blend into transition.

**** Downstream, blend into adjacent overlay.

Note: 1. All thicknesses are shown on upstream and downstream sides of girth weld centerline.

2. Reported thicknesses are only for layers which met the δ-ferrite/carbon levels of Section 3.3 for stainless steel overlays.

Table 3-2

Measured Delta Ferrite in First Layers

	1st Layer				2nd Layer				3rd Layer			
Weld Number Location	0	90	180	270	0	90	180	270	0	90	180	270
1B31-1RC-28B-2, Safe-End Pipe Weld Wire HT# W.M. %C B.M. %C = 0.055	7.5 6 PB940 0.008	6 6	6.5 5.5	7.5 6.5	8 8 PB940 0.008	7.5 7.5	8 7.5	7.5 8	N/R N/R PB940 0.008	N/R N/R	N/R N/R	N/R N/R
1E11-1RHR-20B-D-4, Downstream Upstream Weld Wire HT# W.M. %C B.M. %C = 0.056	6.5 6 PB940 0.008	6 6	5.5 6	6 6	7.5 6.5 PB940 0.008	7.5 6	7 5	7 5	8.5 6.5 PB940 0.008	9 6	8.5 6.5	9 6
1B31-1RC-12BR-A-4, Safe-End Pipe Weld Wire HT# W.M. %C B.M. %C = 0.075	4 5.5 PB940 0.008	3.5 6	4 5	5 6.5	7.5 5.5 PB940 0.008	3.5 6	6 6	6 7.5	6 6 PB940 0.008	7 7.5	6.5 7	7 7.5
1B31-1RC-12BR-E-4, Safe-End Pipe Weld Wire HT# W.M. %C B.M. %C = 0.047	5 5.5 PB940 0.008	5.5 6.5	4.5 6.5	5.5 5.5	10.5 8.5 S57735 0.014	9.5 8.5	9.5 8.5	10 8.5	N/R N/R	N/R N/R	N/R N/R	N/R N/R
1B31-1RC-12AR-G-4, Safe-End Pipe Weld Wire HT# W.M. %C B.M. %C = 0.075	7.5 8 S57735 0.014	8 9	8 8	6.5 7.5	9.5 9.5 S57735 0.014	10.5 10	8.5 8.5	8.5 9.5	N/R N/R	N/R N/R	N/R N/R	N/R N/R

Weld Wire ER308L, HT# PB940, 0.008%C, 12.2FN (Magna Gage) per CMTR
Weld Wire ER308L, HT# S57735, 0.014%C, 11FN (Fig. NB-2433.1-1) per CMTR

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Table 3-3

Calculated Carbon Content in Diluted Weld Layers

Weld #	Base Carbon %	Weld Carbon %	Diluted Carbon %
28B-2	0.055	0.008	0.0233
20B-D-4	0.056	0.008	0.0236
12BR-A-4	0.075	0.008	0.0298
12BR-E-4	0.047	0.008	0.0207
12AR-G-4	0.075	0.014	0.0338

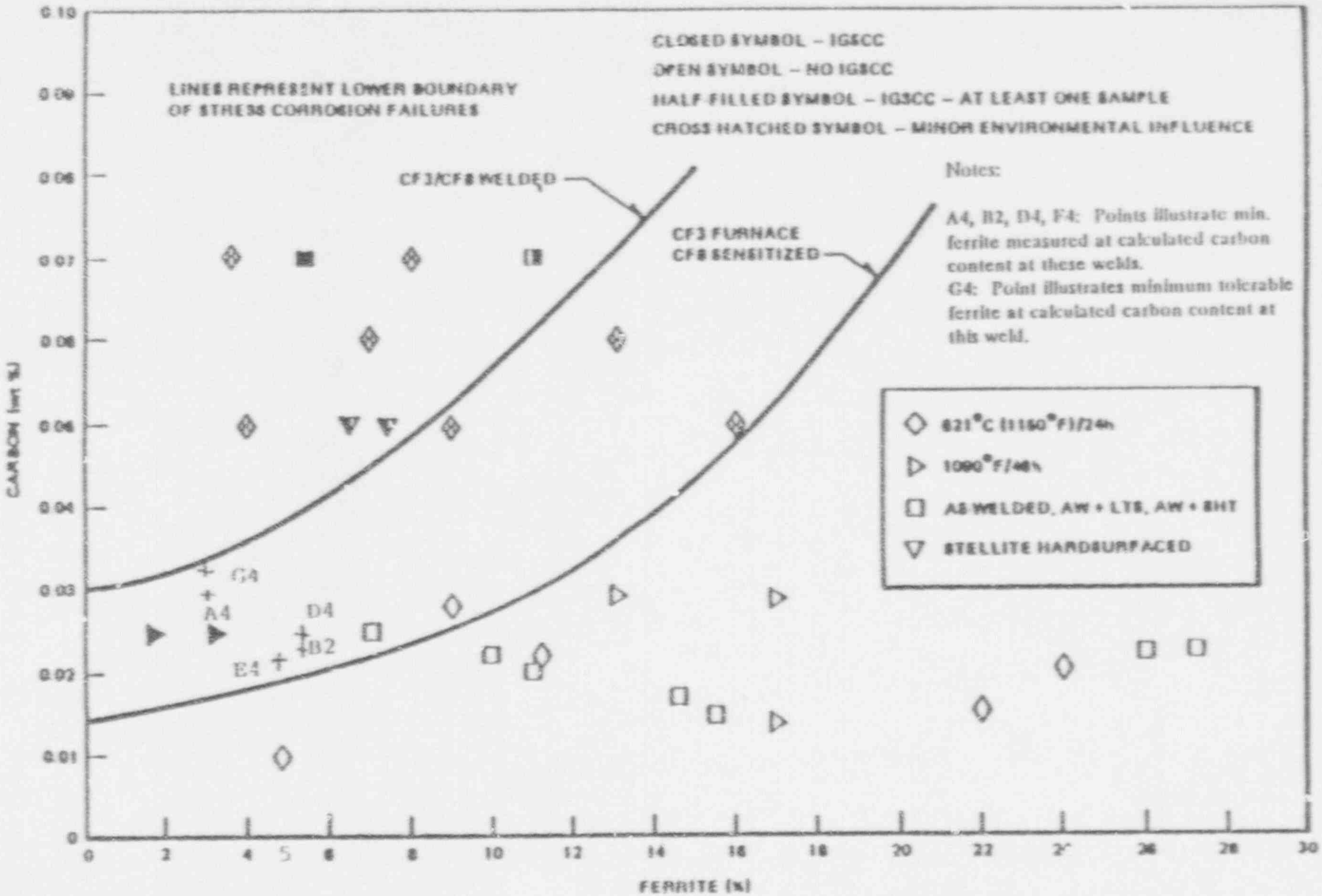


Figure 3-1. IGSCC Resistance Figure from Reference 6, with Worst Case 1991 Hatch Data Points Added

4.0 WELD OVERLAY SHRINKAGE EVALUATION

When weld overlays were completed, measurements of axial shrinkage due to the weld overlay application were made as presented in Table 4-1. SI performed analysis of the weld overlay shrinkage-induced stresses at all locations on the affected piping, considering all weld overlays (1991 and previous). Previous bounding analyses [3] had shown that application of any combination of these overlays would not result in unacceptable shrinkage stress effects in the system.

A finite element model of each loop of the Hatch 1 recirculation system was developed. The as-measured shrinkage resulting from the application of all overlays on the loops, including the overlays applied during the 1991 outage, were imposed on the models. The stresses due to the aggregate shrinkage on each loop were calculated at each unrepaired location.

The shrinkage stress results at each unrepaired location are presented in Table 4-2. These stresses are judged to be generally insignificant with regard to integrity of the piping system, but should be considered in any future flaw evaluations or crack growth calculations on these systems.

4.1 Effects of Shrinkage on Piping Supports and Pipe Whip Restraints

Subsequent to the application of weld overlays, visual inspections of piping supports and whip restraints were performed by GPC. These inspections included verification of spring hanger load settings, snubber pin-to-pin and stroke dimensions, and pipe whip restraint clearances for all piping supports in the recirculation loops. As-built dimensions were documented by ISI personnel, and were evaluated against design requirements. The results of these inspections showed that the as-built condition of piping supports is acceptable, with no impact on plant operation. No adjustments to piping support settings or whip restraint clearances were required.

4.2 Effect of Increase in Deadweight and Stiffness Resulting from Weld Overlays in the Piping Systems

When the mass of the piping system increases due to the number of weld overlays, the dynamic characteristics of the system also change. These changes may have an effect on the seismic stress due to varying the modal response of the system. Therefore, a second analysis was performed to examine the effect of additional weld overlays on the modal frequencies of the recirculation piping system.

The model used for the modal analysis is based on the weld shrinkage finite element model with some modifications to permit it to be used for a dynamic analysis. These modifications include adding the weight of the piping, valves, pump, motor, and weld overlays and the snubber stiffnesses.

Table 4-3 presents the unit weights of the recirculation system using nominal pipe sizes. The unit weights include the pipe, water and insulation. The weight of the pump is 67100 lbs. and the weight of the valves are 10188 lbs. each. The weight of the overlays were calculated assuming the overlay thickness is 0.5 inch and the overlay length is 6 inches. These are nominal overlay sizes, however the analysis results will not be significantly affected due to as-built variations in these values. The resulting overlay weights are 76.16 lbs. for a 28 inch pipe, 60.13 lbs. for a 22 inch pipe and 35.41 lbs. for a 12 inch pipe.

A total of 11 snubbers was included in the recirculation system dynamic model. Two were placed on the suction side (SB7 & SB8). Three were placed on the discharge size (SB12, SB13 and SB14). The rest of the snubbers were used to restrain the pump and motor.

For the SB14 snubber, the stiffness was estimated from load and displacement results of the piping seismic analyses performed by GE. The stiffness was estimated to be about 1.4 x 10^6 lb/in. The stiffness of the remaining snubbers (SB7, SB8, SB12 & SB13) were estimated from other recirculation piping dynamic analysis. These were estimated to be about 0.5 x 10^6 lb/in and were used at the pump location in the piping model to simulate all the snubbers connected to the pump and the motor. All other hangers in the recirculation piping were neglected because of low stiffness. All nozzles in the recirculation piping system were assumed to be fixed. Also, all welds in the recirculation system were assumed to be overlaid. This assumption is consistent with the most added mass to the piping system, and therefore, the most potential impact on the piping system dynamic analysis.

Table 4-4 presents the modal response analysis results. The first mode was found to be about 5.52 hz. for the recirculation system without any overlays. With the overlays, the first mode frequency decreases to about 5.49 hz. for a difference of 0.68%. The biggest difference is about 2.1% for mode 20.

Figures 4-2 and 4-3 present the Hatch Unit 1 response spectra at reactor vessel elevations 146 ft. and 172 ft. They both show a peak response at a frequency range of about 3.5 hz. to 5 hz. With the first mode of 5.52 hz. when there are no overlays, the response is very close to the peak of the spectrum. Even though a decrease in the mode frequency would correspond to an increased response for the given spectrum, the magnitude of the decrease in the first mode frequency is so small that it would not cause a significant change in the response. With only about 50% of the welds overlaid, the change in the first mode frequency would be even smaller. Therefore, it is concluded that the overlays, either in the current or any imagined future configuration, would have a negligible effect on the dynamic analysis of the system.

Table 4-1

Measured Shrinkage Values
1991 Weld Overlays

Weld	Shrinkage (avg) (in)	(Max)
12BR-A-4	0.10	0.14
12BR-E-4	0.20	0.25
12AR-G-4	0.32	0.37
28B-2	0.05	0.1
20B-D-4	0.00	0.00
20B-D-5	0.01	0.06

Table 4-2

Shrinkage Stresses at Unrepaired Welds in Hatch Unit 1 Recirculation System Following 1991 Overlays

Weld	Shrinkage Stress (ksi)
28A-1	0.15
28A-3	0.12
28A-5	0.12
28A-5A	0.25
28A-9	0.25
28A-11	0.11
28A-13	0.19
28A-15	0.42
28A-16	0.46
28A-17	1.35
12AR-F-1	6.77
12AR-F-5	2.89
12AR-G-1	3.09
12AR-G-2	2.26
12AR-G-5	7.32
12AR-H-1	10.43
12AR-H-5	6.83
12AR-J-1	4.66
12AR-J-2	4.31
12AR-J-4	7.20
12AR-J-5	8.58

Table 4-2 (continued)

Shrinkage Stresses at Unrepaired Welds in Hatch Unit 1
Recirculation System Following 1991 Overlays

Weld	Shrinkage Stress (ksi)
12AR-K-1	5.3[illegible]
12AR-K-4	2.8[illegible]
12AR-K-5	3.65
28B-1	0.32
28B-5	0.80
28B-6	0.93
28B-7	0.41
28B-12	0.38
28B-17	0.55
28B-18	1.59
22AM-2	1.94
22AM-3	1.41
22BM-2	1.52
22BM-3	0.89
20B-D-1	0.31
20B-D-2	0.11
12BR-A-1	5.92
12BR-A-2	1.37
12BR-A-3	0.18
12BR-A-5	2.17
12BR-B-1	5.68

Table 4-2 (concluded)

Shrinkage Stresses at Unrepaired Welds in Hatch Unit 1 Recirculation System Following 1991 Overlays

Weld	Shrinkage Stress (ksi)
12AR-K-1	2.19
12AR-K-4	1.59
12AR-K-5	1.57
28B-1	12.93
28B-5	6.02
28B-6	5.51
28B-7	6.33
28B-12	9.42

Table 4-3

Piping System Unit Weights Used in Dynamic Analysis

Unit Weight (lb/ft)				
Item	Pipe	Water	Insulation	Total (lb/in)
28" Pipe Suction	330	208	38	48.00
28" Pipe Disch.	389	208	38	52.92
12" Pipe	91	42	20	12.75
22" Pipe	242	127	31	33.33

Table 4-4

Results of Dynamic Analysis Comparison of Natural Frequencies for First Twenty Modes - With and Without Overlays

	Recirculation Loop				
Mode	w/o overlays (hz)	w/ overlays (hz)	Diff(%)	w/o overlays period (sec)	w/ overlays period (sec)
1	5.5245	5.4867	-0.68%	0.181010	0.182260
2	6.9959	6.9255	-1.01%	0.142940	0.144390
3	7.6848	7.6461	-0.50%	0.130130	0.130790
4	9.6416	9.6114	-0.31%	0.103720	0.104040
5	10.4640	10.3410	-1.18%	0.095567	0.096702
6	12.5700	12.5350	-0.28%	0.079554	0.079777
7	14.4610	14.3010	-1.11%	0.069149	0.069924
8	15.0970	15.0110	-0.57%	0.066237	0.066619
9	16.8210	16.7190	-0.61%	0.059450	0.059811
10	18.1080	17.9230	-1.02%	0.055224	0.055796
11	18.2680	18.0110	-1.41%	0.054740	0.055521
12	19.2290	19.1100	-0.62%	0.052005	0.052327
13	20.6930	20.3850	-1.49%	0.048324	0.049056
14	22.7780	22.4370	-1.50%	0.043901	0.044569
15	26.7640	26.6590	-0.39%	0.037364	0.037511
16	29.3070	29.1600	-0.50%	0.034122	0.034294
17	34.6740	34.4310	-0.70%	0.028840	0.029044
18	36.5010	35.9100	-1.62%	0.027396	0.027847
19	38.2240	37.4960	-1.90%	0.026162	0.026669
20	39.7990	38.9620	-2.10%	0.025126	0.025666

Figure 4-1. Finite Element Models: Loops A and B

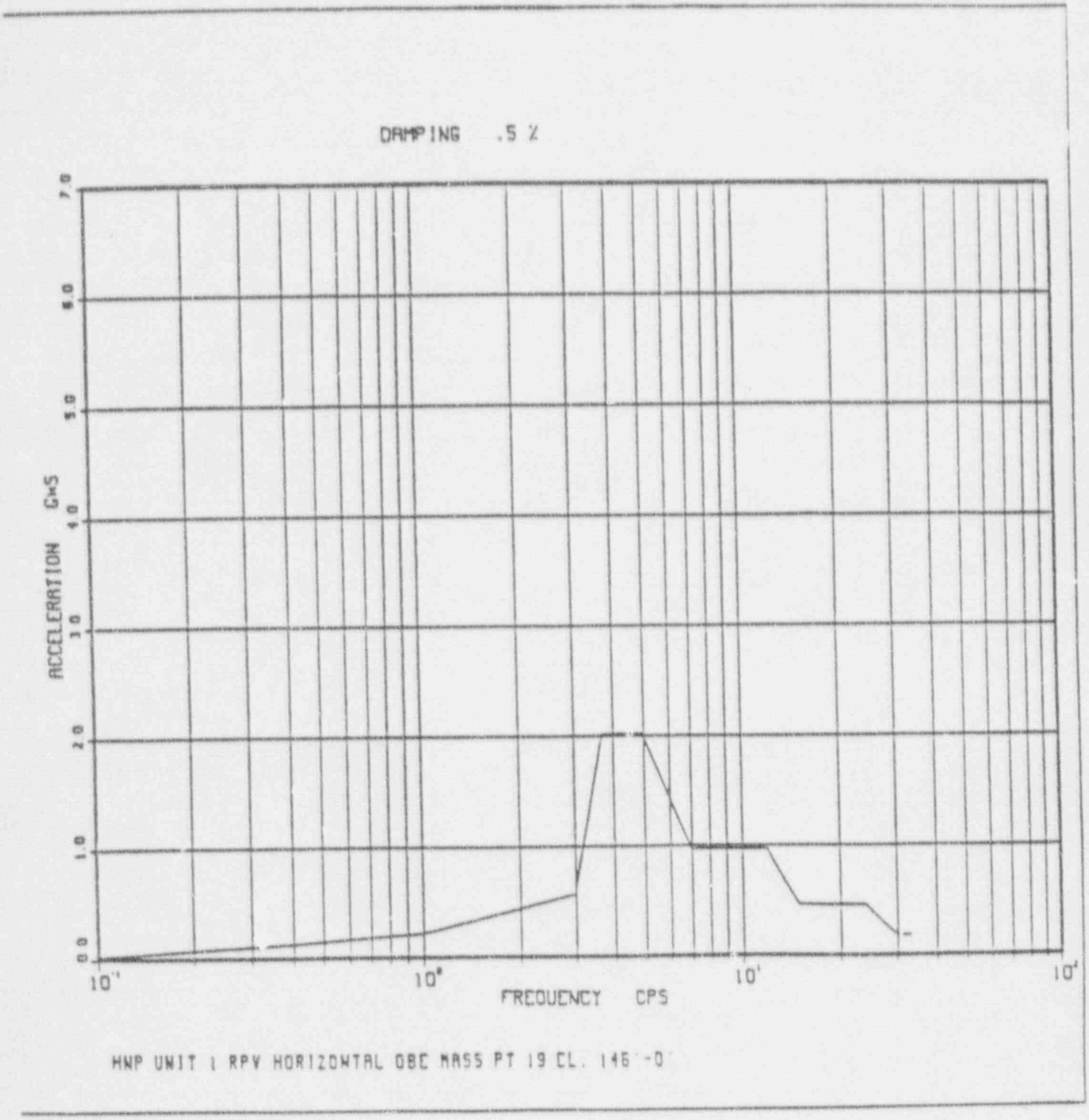


Figure 4-2. Hatch Seismic Response Spectra: Elev. 146 ft.

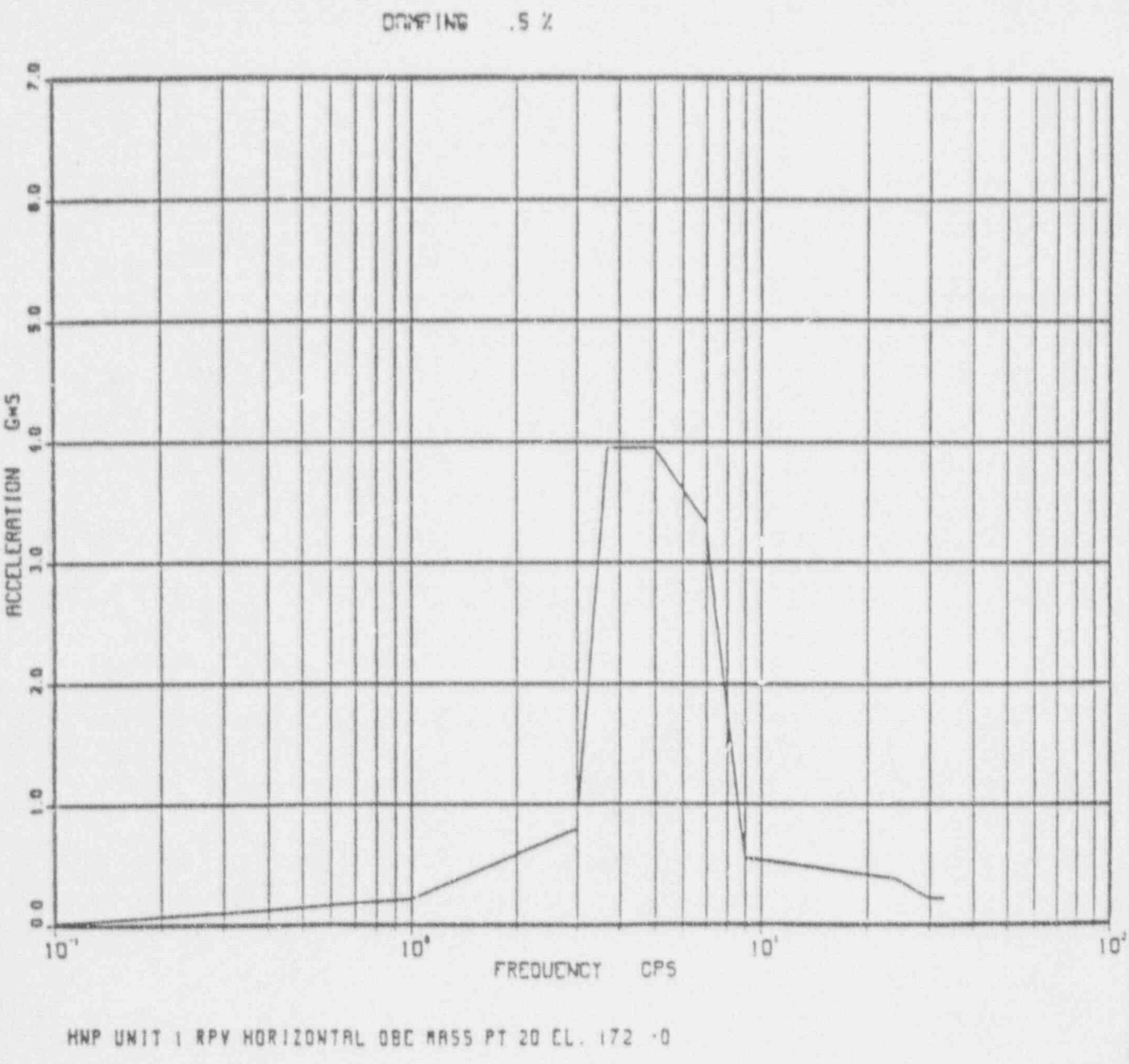


Figure 4-3. Hatch Seismic Response Spectra: Elev. 172 ft.

5.0 EVALUATION OF EMBEDDED INDICATIONS IN WELD OVERLAYS

During the inspection of previously applied weld overlays at Hatch Unit 1, sub-surface flaws that are characteristic in most cases of lack of fusion were identified in several locations. These locations and flaws are summarized in Table 5-1. These indications were documented in Georgia Power Company INFs I91H1015, 1020, 1021, and 1024.

5.1 Disposition of INF I91H1015

This INF documents the flaws observed in the weld overlay on weld 28A-7. These flaws are summarized in Table 5-1. Six of the seven observed flaw indications were previously observed. In addition, a previously unobserved flaw indication (Indication #3) was observed. The new flaw indication (Indication #3) is acceptable without further action or repair. This conclusion is based upon the following considerations:

1. There is a remaining ligament of 0.64 inch outboard of the reported Indication #3. The design overlay thickness for this repair location is 0.49 inches. Therefore, the full design thickness of the overlay is outside of the flaw indication, and the adequacy of the weld overlay is in no way affected by this flaw.

2. The indication is remote from other lack of fusion indications. The nearest of the other fabrication-related defects appears to be Indication #1, which is located approximately 1 inch axially and 6 inches circumferentially from this indication.

3. All other reported lack of fusion indications are located on the other side of the original girth weld.

4. The reported location of the indication appears to be sufficiently far away from the underlying IGSCC flaw indication that there is little potential for connecting with the inside surface of the pipe. There is therefore no recognized mechanism for flaw growth.

5. This flaw indication and the other five indications can all be treated as unconnected to each other for the purpose of evaluation. Each of the reported indications is acceptable by the criteria of IWB-3500 of ASME Section XI [7].

5.2 Disposition of INFs I91H1020, I91H1021 and I91H1024

The indications documented on INF I91H1020 (weld 28B-15, 11/1/91), and INF I91H1024 (weld 24B-R-12, 11/07/91) are summarized in Table 5-1. The indications reported in these INFs are acceptable without further action or repair. This conclusion is based upon the following considerations:

1. There is a remaining ligament outboard of the reported indication in excess of the weld overlay design thickness at each indication location. In other words, the full design thickness of the overlay is outside of the flaw indication depth in all cases, and therefore the adequacy of the weld overlay is in no way affected by these flaws.

2. Each of the reported indications is acceptable by the criteria of IWB-3500 of ASME Section XI, using Table IWB-3514-2 [7].

3. For these embedded flaws, there is no apparent mechanism for continued growth, since there is no detected connection with the inside surface of the pipe.

Table 5-1

Ioentified Embedded Flaws

Weld	Type of Flaws
28A-7	Lack of Fusion (6 Total)
28B-15	Lack of Fusion (1 Total)
24B-R-12	Lack of Fusion (7 Total)

6.0 EFFECTIVENESS OF IHSI AT HATCH UNIT 1

NUREG-0313, Revision 2, Section 4.5 states in part that "Because the effectiveness of the SI [stress improvement] treatment is also related to the applied stress on the weldment, mitigation by SI is not recommended for weldments with service stresses over 1.0 S_m...". In practice, this limitation has been interpreted to mean that no credit may be taken for IHSI or other stress improvement methods at weld locations where the sustained stresses (pressure, deadweight, thermal expansion, and weld overlay induced shrinkage stresses) total more than 1.0 S_m.

Tables 6-1 and 6-2 summarizes the sustained stresses at all locations in the Hatch recirculation system which have not received weld overlays. None of these locations have identified unrepaired flaws. As can be seen from these tables, several locations in 12-inch pipe have combined sustained stresses greater than 1.0 S_m, while no locations in larger pipe have sustained stresses greater than 1.0 S_m. If future inspection results indicate that any of these highly stressed locations in 12-inch pipe have flaws requiring evaluation in accordance with the NUREG, the as-welded residual stress distribution will be used in any crack growth calculations, rather than the more favorable post-IHSI residual stress distribution. At other locations in the recirculation system, credit for IHSI may be taken consistent with the requirements in Section 4.5 of the NUREG.

As stated above, NUREG-0313 Revision 2 does not consider stress improvement treatments to be effective for weldments with service stresses over 1.0 S_m, due to the concern that the stress improvement might be reduced by an overload or stress relaxation condition. Laboratory data has illustrated that, for unflawed weldments, IHSI is an effective mitigation measure against IGSCC for loadings well above the engineering yield strength at temperature, i. e. 1.2 σ_y, [8]. When flaws exist in the structure, the mitigation measure may not be effective even at loads of S_m. The EPRI-GE Degraded Pipe Test Program [9] on four inch and twelve inch schedule 80 pipes observed that: "The IHSI treatment of welded piping will provide crack arrest where IGSCC cracks are approximately 17% of wall thickness or less, provided loading higher than the primary membrane stress (S_m) is avoided....... At higher applied stresses, the compressive residual stress benefit afforded by the IHSI treatment is lost and crack growth occurs".

The flaws in the IGSCC Category F weldments were all sized at greater than 17% through wall and thus would have been expected to exhibit some growth. That is the principal reason that these welds have been subject to inspection during each refueling outage and why Georgia Power Company decided to overlay repair all Category F welds.

The deepest IGSCC indication in weld 28-B2 was located in the same vicinity where root geometry had been called in the past. It is possible that the refined automated P-Scan and GE Smart 2000 detection capability used for inspection during this outage was able to resolve this indication as an IGSCC indication where previously, only a geometry call had been made using the manual inspection techniques. Discussion with the UT level 3 inspector revealed that the capability of the new GE Smart 2000 automated UT system with digital signal data storage produced a significantly increased capability to resolve indications following the inspection. The detailed flaw evaluation can be performed remotely thereby reducing human radiation exposure and allowing for a more precise examination of the component.

Table 6-1

Sustained Stresses in Unrepaired 12 Inch Locations

Weld	Sustained Stress (ksi)[1]
12AR-F-1	18.7
12AR-F-5	15.6
12AR-G-1	15.5
12AR-G-2	9.9
12AR-G-5	15.9
12AR-H-1	27.6
12AR-H-5	21.0
12AR-J-1	17.0
12AR-J-2	12.3
12AR-J-4	20.8
12AR-J-5	22.2
12AR-K-1	16.6
12AR-K-4	13.3
12AR-K-5	14.1
12BR-A-1	18.6
12BR-A-2	9.0
12BR-A-3	7.3
12BR-A-5	13.9
12BR-B-1	18.9

Note: 1. Sustained stresses include pressure, deadweight, thermal, and shrinkage stresses.

Table 6-1 (continued)

Sustained Stresses in Unrepaired 12 Inch Locations

Weld	Sustained Stress (ksi)
12BR-B-2	10.3
12BR-B-4	12.3
12BR-B-5	12.2
12BR-C-1	31.3
12BR-D-1	18.3
12BR-D-4	16.6
12BR-D-5	17.4
12BR-E-1	20.5

Table 6-2

Sustained Stresses in Unrepaired Locations in Large (>12 inch) Pipe

Weld	Sustained Stress (ksi)[1]
28A-1	6.7
28A-3	6.4
28A-5	6.3
28A-5A	6.4
28A-9	6.8
28B-1	7.5
28B-5	7.4
28B-6	7.8
28B-7	7.1
20B-D-1	9.9
20B-D-2	8.1
28A-11	5.8
28A-13	5.8
28A-15	6.9
28A-16	6.8
28B-12	5.9
28B-17	7.7

Note: 1. Sustained stresses include pressure, deadweight, thermal, and shrinkage stresses.

7.0 EFFECTIVENESS OF HYDROGEN WATER CHEMISTRY AT HATCH UNIT 1

The hydrogen water chemistry mitigation measure is an extremely effective IGSCC mitigation measure in sensitized austenitic stainless steels if the electrochemical potential (ECP) of stainless steel in the BWR environment is reduced to a level below the protection potential of -230 mv SHE at the BWR operating temperature. It has been demonstrated in laboratory programs that a factor of improvement of more than 10 can be expected in reduction in crack growth rates in the protective HWC environment. When combined with excellent water quality, this mitigation measure is extremely effective in reducing or eliminating IGSCC in the BWR environment.

During the past few years, the hydrogen water chemistry system has been installed at Hatch and has operated during power operation. Prior to this operating cycle, cycle 13, the hydrogen system was unable to consistently reduce the electrochemical potential to below the protection potential for stainless steel. During the prior refueling outage, the condenser was changed from a copper based condenser to a titanium condenser in part to assist in reducing the electrochemical potential to below the protection potential. During this operating cycle, the hydrogen injection system was consistently able to reduce the electrochemical potential to below the protection potential.

The water chemistry records at Hatch Unit 1 were reviewed to determine the water quality during operating cycle 13 as well as the effectiveness of the hydrogen injection system. The ECP was obtained in the crack arrest verification system (CAVS) autoclave. The CAVS results revealed that the HWC system was on and produced full protection for approximately 41% of the time at power. During the remaining 59% of the time the system was either partially protective or not protective. The total time in which no protection was observed was approximately 47% of the time at temperature and pressure. No investigation was performed to ascertain why the system was providing no protection during this period of time during the cycle. However, it is noteworthy that for approximately 4500 hours during this latest cycle, the HWC system was not providing effective protection to the recirculation system piping. Clearly, that quantity of time is adequate for additional IGSCC or crevice corrosion to occur in the oxidizing BWR environment. This additional crack initiation or growth is consistent with that observed during the IGSCC inspections following cycle 13. Additional detailed discussion of the operation of the HWC system during cycle 13 is presented in Appendix B to this report, prepared by the General Electric Company.

8.0 EVALUATION OF OBSERVED CRACK GROWTH IN FLAWED WELDS

During the 1991 inspection, several locations yielded inspection results indicative of flaw growth. Inspections prior to 1991 were performed manually, while the 1991 inspections were performed using automated P-Scan. The difference in inspection technique could be responsible in part for the recorded changes in indications. A comparison of prior and 1991 inspection results is presented in Table 8-1.

Two of the four existing Category F welds had identified flaw characteristics slightly different from previous inspection results. Weld 12BR-A4 had observed flaw depth of 26% as compared to the previous result of 17-22%. Weld 12BR-E4 had observed flaw depth of 32%, as compared with the previous result of 21-25%. These differences are considered to be within the bounds of the accuracy of the inspection technique, and are not indicative of significant crack growth. Both of these locations, as well as the other two Category F welds (12AR-G4 and 20B-D-4), were repaired during the 1991 outage using weld overlay designs qualifying as NUREG-0313 "Standard Weld Overlay" repairs. These welds therefore are reclassified as Category E locations for future inspections.

In addition to the above Category F welds, three locations with existing weld overlays had recorded inspection results which are indicative of flaw growth under the overlays. These three locations are welds 12-AR-H3, 12-AR-J3, and 24B-R-13. The new flaw characterizations for these locations show a maximum flaw depth within the outer 25% of the original base material. In no case was propagation into the weld overlay material observed. The reported remaining ligament outside of the crack depth for each of these three locations is summarized in Table 8-2.

Flaw growth calculations for these flaws, to determine if such growth is in line with predictions made in accordance with the methods of NUREG-0313 are not meaningful in these cases, since the starting depth of the underlying flaws is not known.

The weld overlays for these locations were applied in 1984. At that time, the reported flaw lengths on the two 12 inch weld locations (360° intermittent) were such that a repair was required regardless of flaw depth. It was determined that the weld overlay design would not be affected by flaw depth, and so the decision was made to minimize radiation exposure to the inspection personnel by not requiring detailed depth sizing. Consequently, an accurate starting depth for use in flaw growth calculations is not available.

The flaw on weld 24B-R-13 was reported in 1984 as axially oriented and 47% deep. The recent inspection reported axial flaws with depths nearly through original pipe wall. This is not inconsistent with the fact that sizing of axial flaws was imprecise at best in 1984, and is still difficult today, especially through a weld overlay. The 1991 reported depth of the axial flaws in this weld may be indicative of either inspection variations or flaw growth, or a combination of both. In any case, the observed flaws do not reduce design margins in the weld overlay.

Table 8-1

Comparison of Flaw Characterizations with Previous Inspection Results

WELD OVERLAY LOCATIONS:

12AR-H3: OVERLAY 1984: 360 X 20-30%

1991: CIRC. 3.8" X TO OVERLAY INTERFACE

CIRC. 1.3" X 0.06 BELOW OVERLAY

12AR-J3: OVERLAY 1984: 360 X 20-30%

1991: CIRC. 1.3" X 0.12" BELOW OVERLAY

24B-R-13: OVERLAY 1984: AXIAL X 47%

1991: MULTIPLE AXIALS DEEPEST TO 0.4" OF OD

CATEGORY F:

12BR-A4: PREVIOUS: 17-22%, PRESENT: 26%

12BR-E4: PREVIOUS: 21-25%, PRESENT: 32%

12AR-G4: PREVIOUS: 13-19%, PRESENT: UNABLE TO SIZE DUE TO CONFIGURATION

20B-D-4: PREVIOUS: 16% AXIAL, PRESENT: 10-15% AXIAL

Table 8-2

Weld Overlays: Design Thickness and Remaining Ligament
(Observed Flaws under Weld Overlay in Outer 25% of Base Metal)

Weld	Min. Remaining Ligament	Design Overlay Thickness
24B-R-13	0.4 "	0.20"
12AR-H-3	0.46"	0.25"
12AR-J-3	0.5 "	0.26"

9.0 CONCLUSIONS

The inspection and repair activities at Hatch Unit 1 during the Fall 1991 outage were performed in accordance with the requirements of NUREG-0313, Revision 2. The inspections, design, and weld overlay activities are discussed in detail in this report. Based upon the above discussion, several conclusions can be drawn regarding IGSCC mitigation activities at Hatch. These are:

1. Weld overlays are effective in repairing IGSCC susceptible locations, and in arresting existing IGSCC. Weld overlays have been in service at Hatch 1 since early 1983, and UT examinations of portions of the base metal under the overlays show only minor changes in flaw character. Such changes may be due, in part, to improvements in inspection techniques.

2. All weld overlays applied during 1991 (six total) meet or exceeded the design requirements. and therefore all qualify as NUREG-0313 "Standard Weld Overlay" repairs.

3. Weld overlay shrinkage stresses may be sufficiently high in 12 inch welds that, combined with other sustained stresses, total sustained stresses may exceed the 1.0 S_m criterion of NUREG-0313 for effectiveness of stress improvement processes. If future flaw evaluations need to be performed for 12 inch locations, no residual stress benefit due to IHSI may be assumed for such highly stressed locations. No evaluated locations in piping larger than 12 inch diameter exhibited combined sustained stresses greater than 1.0 S_m, so IHSI may still be considered effective for these locations.

4. The cumulative effect of all overlays applied to the recirculation and associated systems at Hatch is insignificant with regard to the design piping analysis and the operability of supports and pipe whip restraints.

5. Embedded flaws identified in some overlays are acceptable for continued operation without repair, based upon evaluation in accordance with ASME Section XI, IWB-3500.

6. The hydrogen water chemistry system at Hatch is effective in eliminating IGSCC growth when the system is operating. Even normal water chemistry was favorable during the past cycle, since excellent chemistry was achieved.

7. Although inspection results yielded some flaw characterizations which were different from those previously reported, the differences are generally not considered to be significant. Apparent growth may be due in fact to improved inspection techniques, including the use of automated techniques, rather than actual flaw growth.

10.0 REFERENCES

1. NUREG-0313, Revision 2, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping" Revision 2, January 1988.

2. Structural Integrity Associates Report, "Contingency Weld Overlay Designs for Hatch Unit 1" SIR-91-039, Revision 0, June. 1991.

3. Structural Integrity Associates Report, "Contingency Study Regarding the Effects of Additional Weld Overlays at E. I. Hatch Unit 1", SIR-90-044, Revision 0, July 11, 1990.

4. GE Stress Report, "Plant Piping Analysis Design Memo 170-113", September 26, 1984.

5. Structural Integrity Associates, pc-CRACK, Version 2.0, August, 1989.

6. ASTM Special Technical Publication 756 "Stainless Steel Castings", November 1980. Page 43.

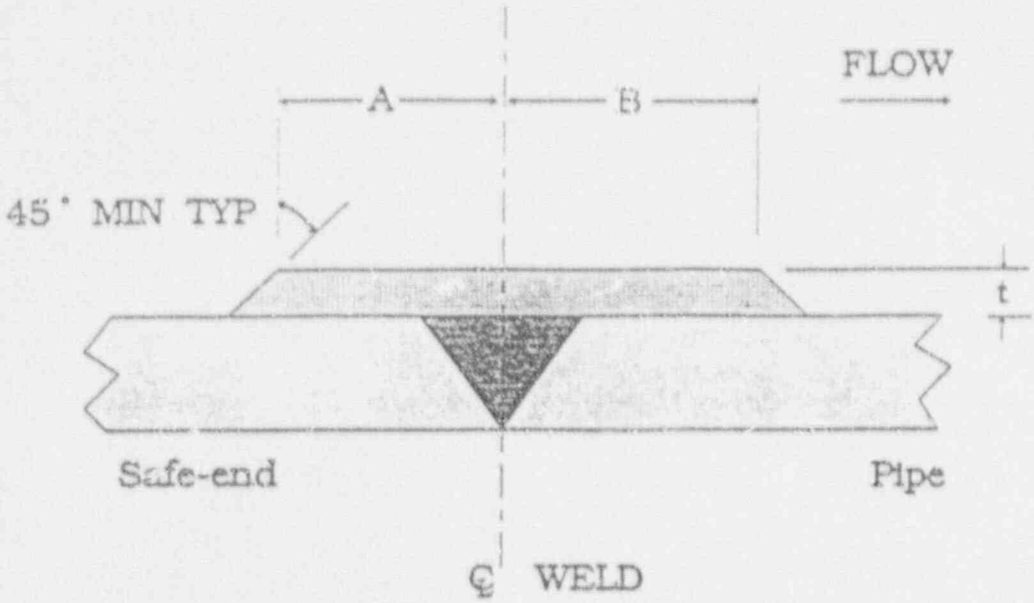
7. ASME Section XI, IWB-3500. 1986 Edition.

8. EPRI "Induction Heating Stress Improvement", EPRI NP-3375, November 1983.

9. EPRI, "Assessment of Remedies for Degraded Piping", EPRI NP-5881-LD, June 1988

APPENDIX A

Weld Overlay Design Drawings



Not to Scale

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-2	Assumed 360° Circ. 100% throughwall flaw	0.52"	4.0"	4.0"	Overlay Thickness revised.

Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS
1	GAM 10/22/91	NGC 10/22/91	HLD 10/22/91	Overlay dimensions based on as-built thickness.
0	HLD 6/18/91	[illegible] 6/18/91	[illegible] 6/18/91	

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-07	Title: Standard Weld Overlay Design	Sheet 1 of 2

NOTES

1. Weld wire material is to be type ER308L, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

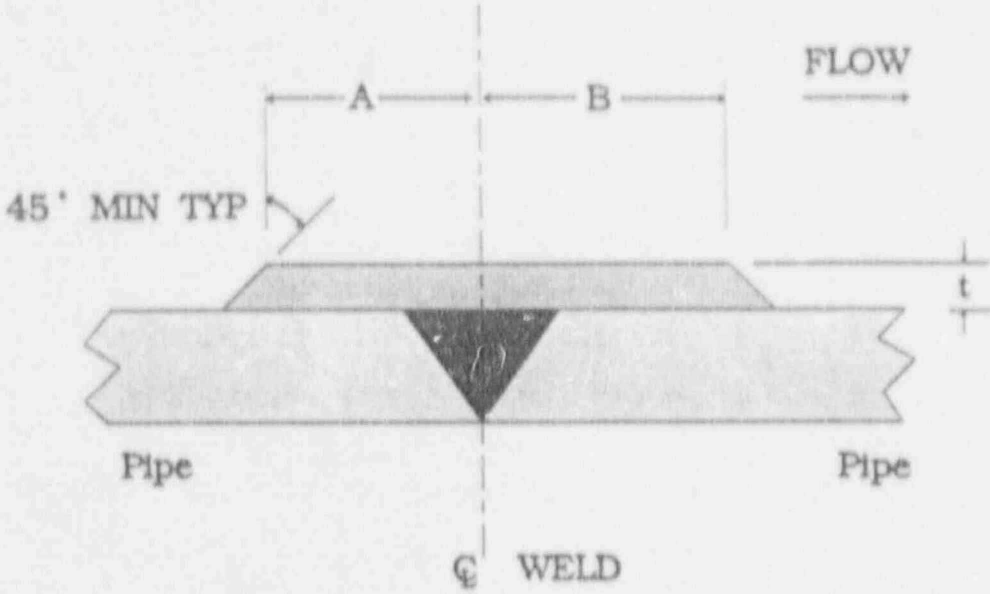
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN. This requirement does not apply to the final weld layer.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-07	Title: Standard Weld Overlay Design	Sheet 2 of 2



Not to Scale

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1E11-1RHR-20B-D-4	Ass .ned 360 ' Circ. 100% throughwall flaw	0.36"	3.0"	3.0"	

0	[illegible] 6/18/91	[illegible] 6/18/91	[illegible] 6/18/91	
Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-13	Title: Stand.rd Weld Overlay Design	Sheet 1 of 2

NOTES

1. Weld wire material is to be type ER308L, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

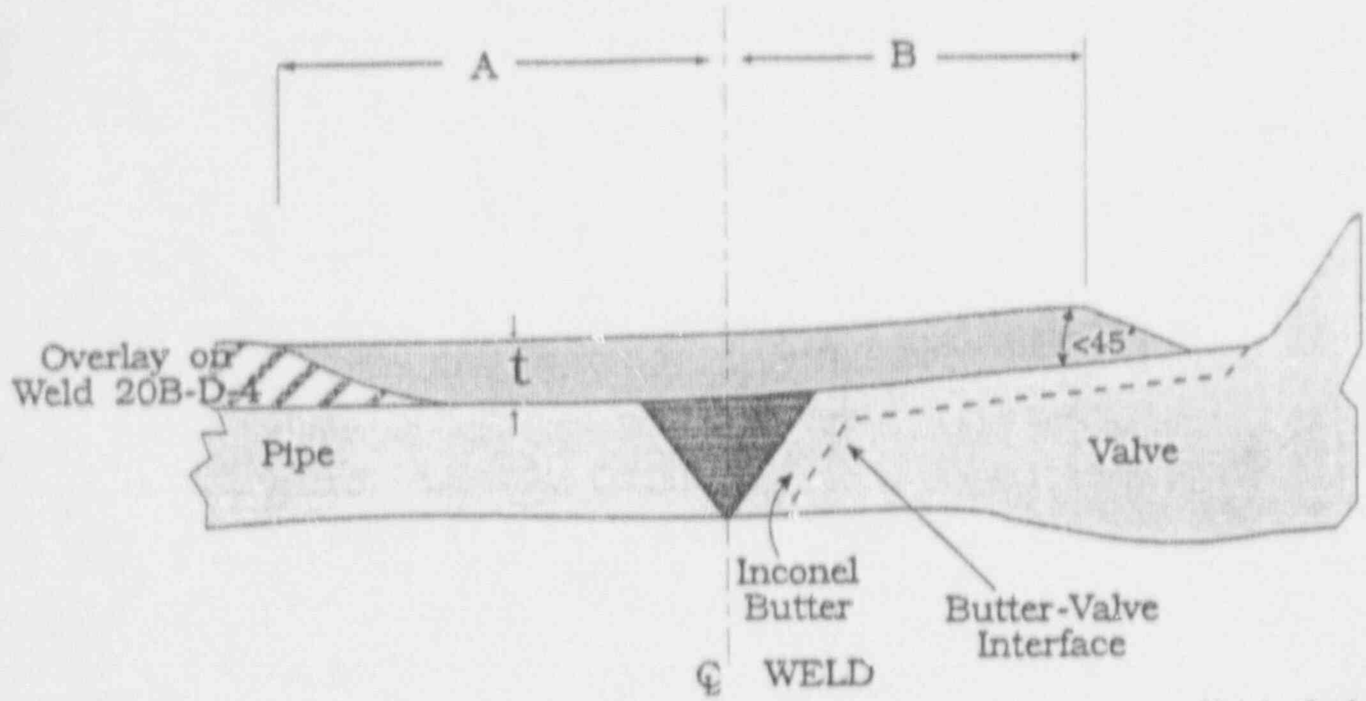
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN. This requirement does not apply to the final weld layer.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-13	Title: Standard Weld Overlay Design	Sheet 2 of 2



Not to Scale

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1E11-1RHR-20B-D-5	Assumed 360° Circ. 100% throughwall flaw	0.33"	Note 1	3"	

Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS
3	HLD 2/17/92	CJB 2/17/92	CJB 2/17/92	Revised to show Inconel butter on valve body transition
2	HLD 11/4/91	CJB 11/4/91	CJB 11/4/91	Revised to show inspection requirements
1	HLD 11/1/91	CJB 11/1/91	CJB 11/1/91	Revised to show weld transition detail
0	HLD 6/18/91	[illegible] 6/18/91	[illegible] 6/18/91	

Job No: GPCO-20Q	Plant/Unit: Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401	92108r0	
Drawing No: GPCO-20Q-14	Title: Standard Weld Overlay Design	Sheet 1 of 2

NOTES

1. Blend repair into adjacent repair on weld 20B-D-4. Follow contour of transition with all weld layers. Repair should blend into valve body transition at an angle of 45 degrees or less with the component surface.

2. Weld overlay material is to be type ERNiCr-3.

3. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

4. In the event that the original component surface does not pass the note 3 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

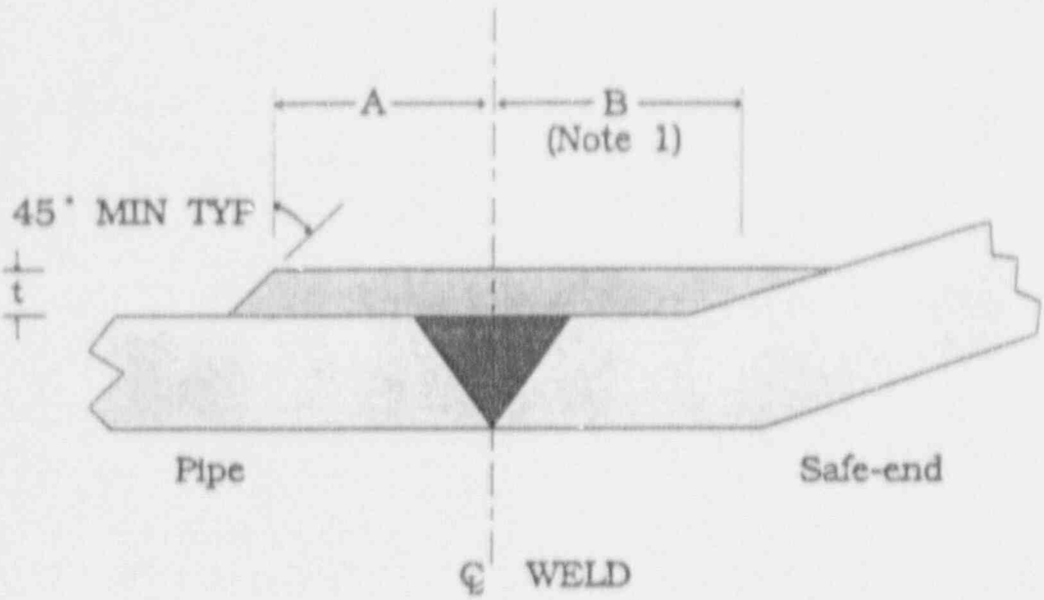
5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

7. On the valve side of the weld, the inspection volume shall include the outer 25% of the girth weld and the Inconel butter, and shall extend approx. 1" beyond the carbon steel valve - Inconel butter interface.

8. Final structural evaluation and disposition shall be performed using as-built weld overlay dimensions. Pre- and post- overlay contours are to be provided for use in evaluation and disposition.

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-14	Title: Standard Weld Overlay Design	Sheet 2 of 2



Not to Scale

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-12AR-G4	Assumed 360 ° Circ. 100% throughwall flaw	0.26"	2.0"	NA	

Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS
1	HLD 10/23/91	AJG 10/23/91	AJG 10/23/91	Revised to show safe-end transition
0	HLD 6/18/91	[illegible] 6/18/91	[illegible] 6/18/91	

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-28	Title: Standard Weld Overlay Design	Sheet 1 of 2

NOTES

1. Blend repair into transition.

2. Weld overlay wire is to be type ER308L, with as-deposited delta ferrite content greater than 7.5 FN.

3. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

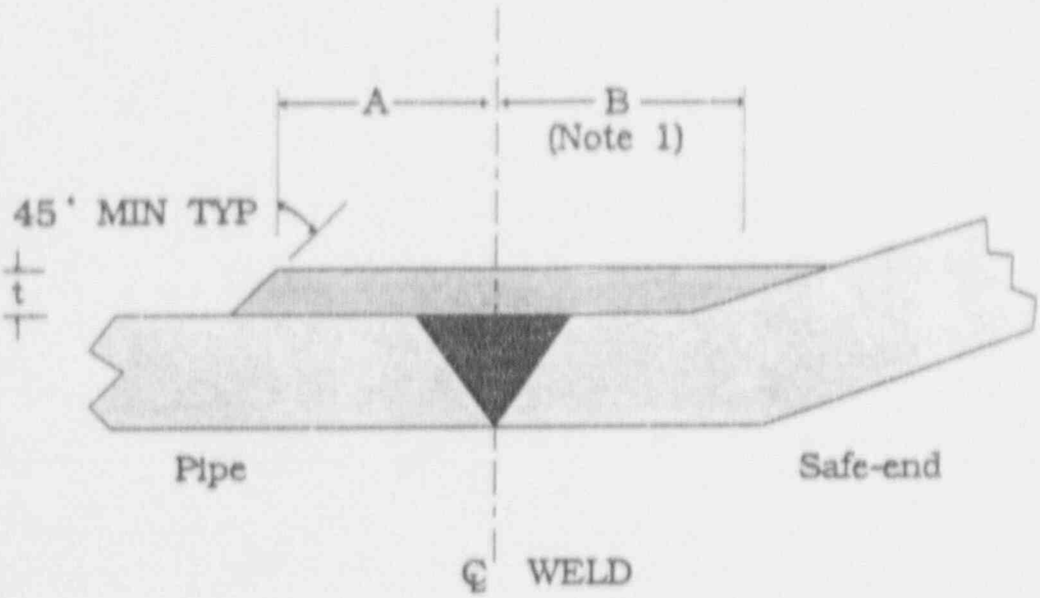
4. In the event that the original component surface does not pass the note 3 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

5. First weld layer is to have a measured delta ferrite content greater than 7.5 FN. This requirement does not apply to the final layer.

6. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

7. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-28	Title: Standard Weld Overlay Design	Sheet 2 of 2



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WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-12BR-E4	Assumed 360° Circ. 100% throughwall flaw	0.27"	2.0"	NA	

Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS
1	HLD 10/23/91	CJS 10/23/91	CJS 10/23/91	Revised to show safe-end transition
0	HLD 6/18/91	[illegible] 6/18/91	[illegible] 6/18/91	

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-33	Title: Standard Weld Overlay Design	Sheet 1 of 2

NOTES

1. Blend repair into transition.

2. Weld overlay wire is to be type ER308L, with as-deposited delta ferrite content greater than 7.5 FN.

3. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

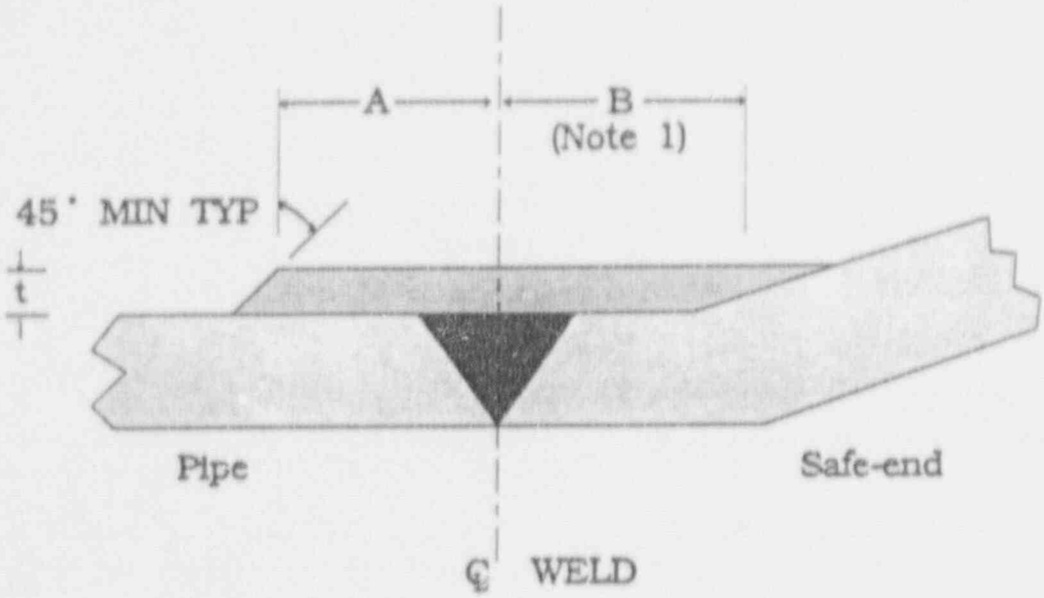
4. In the event that the original component surface does not pass the note 3 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

5. First weld layer is to have a measured delta ferrite content greater than 7.5 FN. This requirement does not apply to the final layer.

6. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

7. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-33	Title: Standard Weld Overlay Design	Sheet 2 of 2



Not to Scale

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-12BR-A4	Assumed 360° Circ. 100% throughwall flaw	0.27"	2.0"	NA	

Revision	Prepared by/ Date	Checked by/ Date	Approved by/ Date	COMMENTS
1	HLD 10/23/91	[signature] 10/23/91	[signature] 10/23/91	Revised to show safe-end transition
0	HLD 6/18/91	[signature] 6/18/91	[signature] 6/18/91	

Job No: GPCO-20Q	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
File No: GPCO-20Q-401		
Drawing No: GPCO-20Q-42	Title: Standard Weld Overlay Design	Sheet 1 of 2

NOTES

1. Blend repair into transition.

2. Weld overlay wire is to be type ER308L, with as-deposited delta ferrite content greater than 7.5 FN.

3. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

4. In the event that the original component surface does not pass the note 3 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

5. First weld layer is to have a measured delta ferrite content greater than 7.5 FN. This requirement does not apply to the final layer.

6. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

7. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

Job No: GPCO-20Q File No: GPCO-20Q-401	Plant/Unit Georgia Power Company Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.
Drawing No: GPCO-20Q-42	Title: Standard Weld Overlay Design	Sheet 2 of 2

APPENDIX B

General Electric Plant Hatch Unit 1
Crack Arrest Verification (CAV) System

SASR-523-147-1291
DRF 137-0100
December 1991

PLANT HATCH UNIT 1
CRACK ARREST VERIFICATION (CAV)
SYSTEM

SUMMARY REPORT
FUEL CYCLE 13

Report period:

June 1990 to September 1991

Prepared by: Don Hale 12/12/91
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Verified by: Kevin P. Dias 12/12/91
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S.Ranganath, Manager
Materials Monitoring & Structural Analysis Services

HATREP03.WP1.0

1.0 INTRODUCTION

A Crack Arrest Verification (CAV) system was installed at Plant Hatch Unit 1 in 1988/89. The system contains three crack growth specimens, has electrochemical potential (ECP) measurement capability and accommodates inputs from Plant Hatch water chemistry instrumentation. The system is connected to an existing recirc water chemistry sample line with flow being returned to the RWCU system.

A separate autoclave is provided in the CAV for ECP measurements. Copper/Copper Oxide, Silver/Silver Chloride, and Platinum reference electrodes and Type 304 and 316NG working electrodes are installed in this autoclave. In addition, the ECP autoclave itself (Type 316 stainless steel) is used as a working electrode.

The CAV system also accepts inputs from the existing Plant Hatch Dissolved Oxygen Monitor and Conductivity Monitor to allow these primary system water chemistry parameters to be included in the CAV data base.

The CAV system began operation on November 16, 1989. Information covering this initial period of operation was summarized in a previous report (1). The present report covers operation of the CAV system during fuel cycle 13 only.

2.0 RESULTS

2.1 General

Pertinent parameters for the three specimens included in the CAV system are summarized in table 1.

Table 1. Crack Growth Test Specimen Details

Specimen	Material	Condition	Stress Intensity
SS-144	T-304 Stainless Steel	Sensitized (1200F, 16 hrs)	20 ksi$\sqrt{in}$
SS-126	T-316NG Stainless Steel	Simulated Weld Sensitization (1200F, 1 hour)	20 ksi$\sqrt{in}$
INC-76	Alloy 182		25 ksi$\sqrt{in}$

2.2 Crack Growth

The Crack Length versus Elapsed Time data for the three crack growth specimens are shown in Figures 1, 2 and 3. Each of these three figures is divided into regions representing normal water chemistry (NWC) and hydrogen water chemistry (HWC) operation periods. Note that the key operating parameters changed many times over fuel cycle 13, these different operational regions are identified in Appendix A.

2.3 Water Chemistry/ECP

The electrochemical potential (ECP) data are summarized in Figure 4. The solid line in Figure 4 represents the data from the Type 304 stainless steel working electrode. The other symbols represent the data from the ECP autoclave itself. It should be noted that this vessel is made from Type 316 stainless steel and is grounded to the Plant Hatch primary piping compared to the Type 304 working electrode which is isolated from the plant piping.

Figure 5 summarizes the hydrogen injection rate into the Plant Hatch Unit 1 primary system, these values represent corrected values which take into account calibration shifts observed by plant personnel and the subsequent corrections made in the plant data base.

The reactor recirc water dissolved oxygen and conductivity data for this time period are shown in Figures 6 and 7, respectively. Note that these signals are provided to the CAV system from existing Plant Hatch Unit 1 instruments.

3. DISCUSSION

3.1 Effect of Hydrogen Water Chemistry on Crack Growth.

The crack growth data from the welding alloy 182 specimen (Figure 1) show a clear effect of hydrogen injection on crack growth. Figure 8 is an expanded view of the data from Figure 1 which shows the distinct change in slope which occurs shortly after the start of hydrogen injection in August 1990 (T = 799 hours). The steady state crack growth rate* drops a factor of ≈20 beginning shortly after the start of hydrogen injection.

*The range on growth rate shown in all figures represents a ± 3 sigma interval about the mean value. In statistical terms this means that there is a ≈99.9% confidence that the actual value falls within this interval.

Figure 9 shows the data from the two stainless steel specimens covering this same time period. Here there is no distinct difference between the NWC (i.e. 200 part/billion oxygenated water) and HWC (Hydrogen Water Chemistry) periods.

However, the growth rate, even in the NWC environment is very low in both stainless steels and is, in fact, near the limits of detectability of the potential drop technology. For example, the growth rates represented in Figure 9 correspond to less than 1 mil of measured crack extension over the 800 hour duration of the initial NWC region (i.e. 1 mil in 800 hours is ≈11 mil/year). Existing SCC models (GENE PLEDGE) would predict a growth rate of about 32 mil/year depending on the value of conductivity assumed. It is, therefore, somewhat unexpected to see growth rates this low for these two materials.

Figure 10 is an expanded view of another region of the data from Figure 1 covering a time period ≈2400 hours later when hydrogen injection is stopped. While interruptions in hydrogen injection have occurred, the specimens at this point in time have accumulated over 1700 hours of HWC exposure. The nominal growth rate for this alloy 182 material under HWC conditions has now dropped another factor of ≈10 to a nominal 2 mil/year value. This suggests that for this material, while there is an immediate decrease in SCC growth rate as soon as HWC begins, additional decreases occur the longer HWC is maintained.

The data from the two stainless specimens in this same time region was examined and found to be inconclusive in terms of any detectable differences in crack growth rates due to the HWC-to-NWC transition.

An example of another HWC/NWC transition is shown in Figures 11, 12 and 13. Here the response of the three materials is seen in the March/June 91 time frame where the plant operated under NWC conditions for over a month. HWC resumed for about one week, was suspended for ≈2 weeks and then reestablished again for 6 weeks.

Once again, the alloy 182 crack growth (Figure 11) tracks the changes in water chemistry almost immediately. Distinct decreases in slope are seen each time HWC is initiated. The growth rates observed under long term NWC are still less that those observed during initial NWC exposure suggesting that there is some lingering benefit of exposure to HWC.

Extensive GENE laboratory experience with alloy 182 crack growth specimens has shown that the potential drop technique tends to underpredict crack growth, in some cases by as much as a factor of 2. This is due to the interdendritic nature of the alloy 182 fracture surface and the inherently uneven, multiplanar geometry. This geometry leaves patches of unbroken material behind the primary crack front which evidently continue to conduct current thereby producing a potential drop reading normally associated with a shorter crack. Therefore, it is likely that the true NWC growth rates in the alloy 182 are even greater than those calculated in these figures. If this is the case, then the absolute amount of crack growth mitigated by HWC is likely to be even greater than the values calculated in the present figures would suggest.

The Type 304 and 316NG stainless steel data (Figure 12 and 13) are still exhibiting very low growth rates both in NWC and HWC. However, there now appears to be a slope difference between the NWC and HWC regions, but once again the rates are very low and the variance on the slopes very large.

ECP Considerations.

Electrochemical Potential (ECP) is the primary criterion used to assess the degree to which HWC protection is maintained. The EPRI guidelines specify that the ECP be maintained at -250 mv SHE or lower for full HWC protection. The Plant Hatch Unit 1 CAV system uses a Type 304 stainless steel working electrode and a copper oxide reference electrode as the primary means for making this measurement. Also included in the CAV ECP electrode complement is a platinum reference electrode which allows the ECP to be independently checked. The ECP vessel itself is also used as a working electrode to allow an ECP measurement to be made which represents the grounded recirc piping system itself.

Table 2 is a summary of CAV ECP measurements made over Fuel Cycle 13. The 304 stainless steel/platinum values were calculated based upon an assumed value in the recirc system of 100 part/billion hydrogen. This value is not actually measured at Plant Hatch but a 100 ppb value is reasonable based upon experience at other BWRs. Also shown in table 1 is the vessel ECP referenced to the copper oxide electrode and the hydrogen injection rate associated with the individual readings.

Table 2. Plant Hatch Unit 1, Fuel Cycle 13, ECP Results (all values mvSHE**)

Test Hours	T304/Cu	T304/Pt*	Vessel/Cu	Hydrogen Injection (scfm)
500	+78	N/A	+71	0(NWC)
900	-175	-202	-208	16
1200	-371	-402	-401	22
1700	-477	-491	-424	16
6100	-466	-397	-409	16
8750	-191	-298	-312	16
Replaced copper oxide ref @ 9049				
9550	-310	-312	-251	16
10000	-213	-262	-123	12
10251	-291	-317	-195	16

* Calculated for an assumed 100 ppb hydrogen level.
** SHE = Standard Hydrogen Electrode

These results, and the more comprehensive plot of these data in Figure 4, indicate that full protection was achieved at 16 scfm until late in the fuel cycle when the vessel (i.e. ground) reading drifted out of protection. This is consistent with previous experience at other BWRs which indicates that late in the fuel cycle, more hydrogen must be injected to maintain the ECP levels previously achieved earlier in the cycle at lower levels.

Table 3 represents a summary of the entire fuel cycle in terms of CAV availability and amount of time on HWC.

Table 3. Plant Hatch Unit 1, Fuel Cycle 13, CAV/HWC Operating Summary.

Total duration, fuel cycle 13 (June 1, 1990 to September 18, 1991)	11376 hours
Total time CAV on line	8866 hours
Total time CAV&HWC on line	4691 hours
HWC Availability 4691 / 11376 = 41%	

4.0 SUMMARY

The CAV system at Plant Hatch Unit 1 has provided data which support the following conclusions:

1. Implementation of hydrogen water chemistry (HWC) has resulted in significant decreases in stress corrosion crack growth in alloy 182 from rates as high as 138 mil/year prior to HWC to very low growth rates after long periods of time on HWC.

2. When HWC is suspended, the alloy 182 growth rates increase again, although not to their former pre-HWC values. These new values are on the order of 19 mil/year.

3. Over the last several thousand hours of the fuel cycle, the alloy 182 post-HWC growth rates are much lower than those seen in the pre-HWC period. However, they do appear to be increasing with time. This may be an indication of a residual benefit to the long exposure period to HWC conditions.

4. The growth rates measured in either the sensitized Type 304 stainless steel or the simulated weld sensitized Type 316 NG stainless steel were very low and ,therefore, displayed significant variability. It was not possible to detect significant differences in growth rate between the HWC and normal water chemistry (NWC) conditions. This may be due to the excellent water chemistry control (low water conductivity) seen during the current fuel cycle.

5. The ECP levels measured during the current fuel cycle, at hydrogen injection levels of 16 scfm or greater, were sufficient to achieve full protection until late in the fuel cycle. This was true for the isolated Type 304 stainless steel electrode as well as the grounded Type 316 stainless steel ECP vessel.

6. Although the HWC system was on line 41% of the time, the alloy 182 crack growth data, showed significant reductions in crack growth. This suggests that a substantial amount of crack propogation was avoided even though HWC was only on line for part of the operating time.

5.0 REFERENCES

1. D.Hale, "Plant Hatch Unit 1, CAV Progress Report #1", GENE Report SASR-91-04, January 1991.

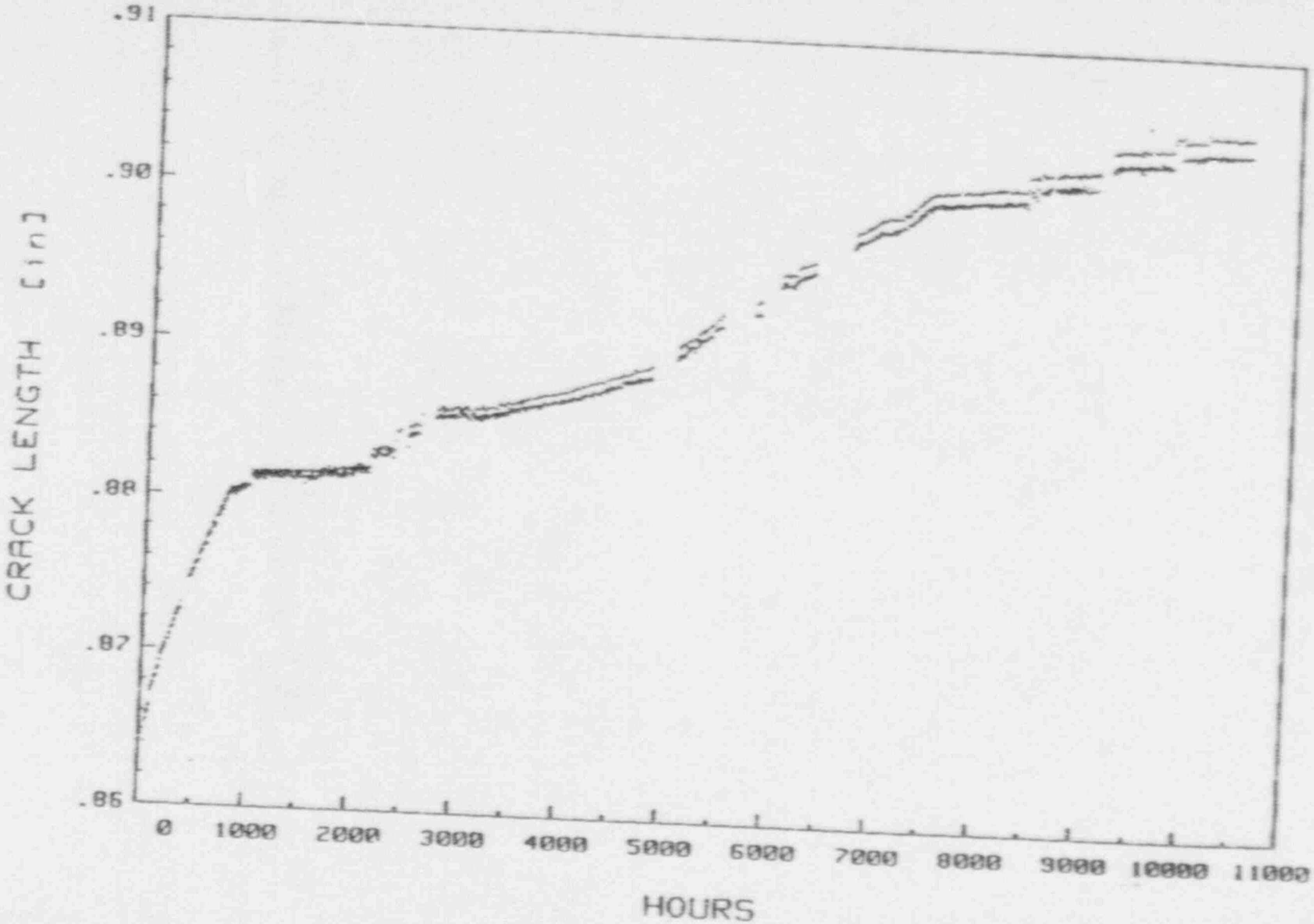

Figure 1. Plant Hatch Unit 1 CAV, Crack Length Versus Time Data, Fuel Cycle 13, Alloy 182, Specimen IHC-76, Stress Intensity 25 ksi√in.

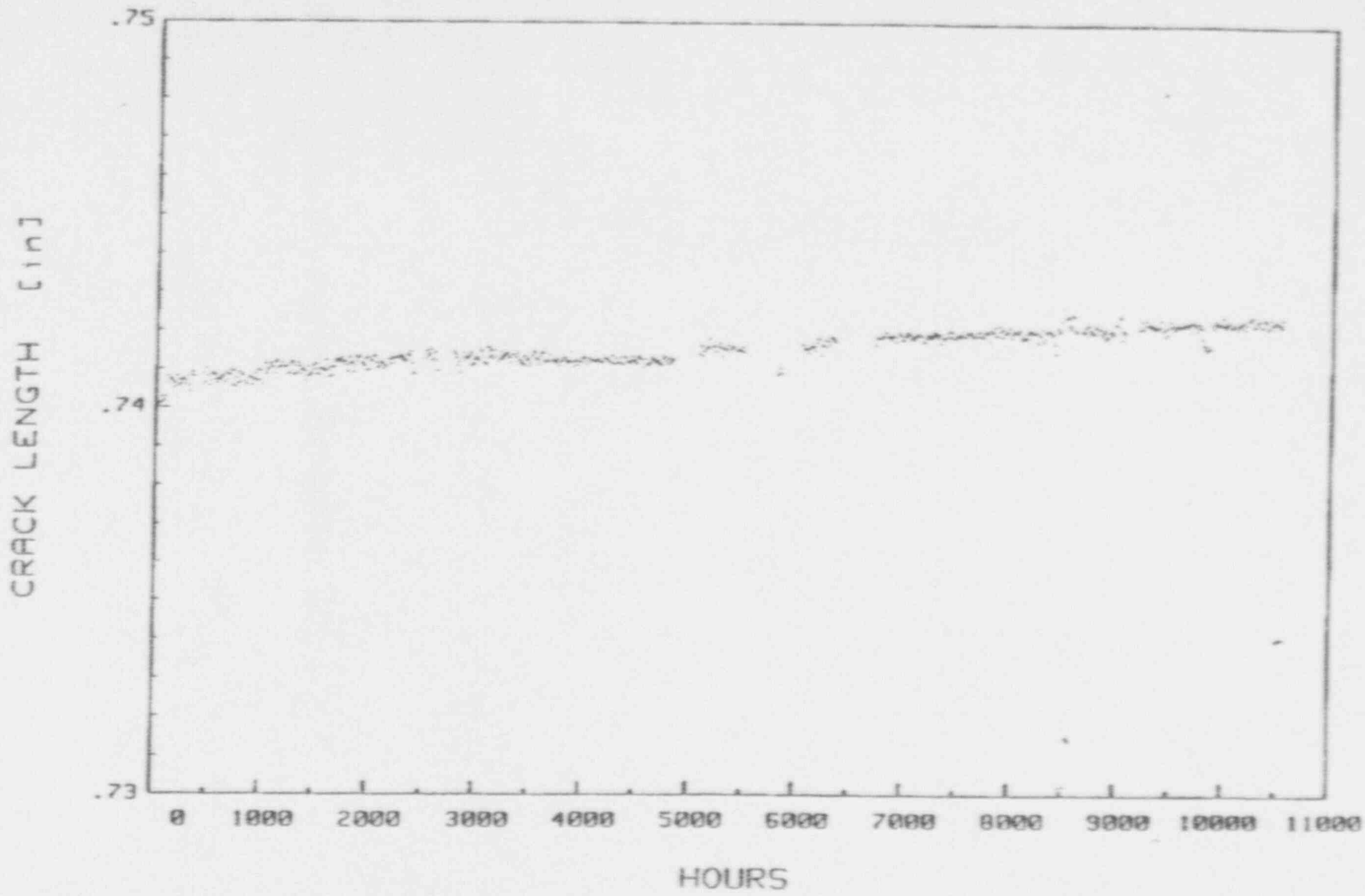

Figure 2. Plant Hatch Unit 1 CAV, Crack Length Versus Time Data, Fuel Cycle 13, Type 304 Stainless Steel (sensitized), Specimen SS-144, Stress Intensity 20 ksi/in.

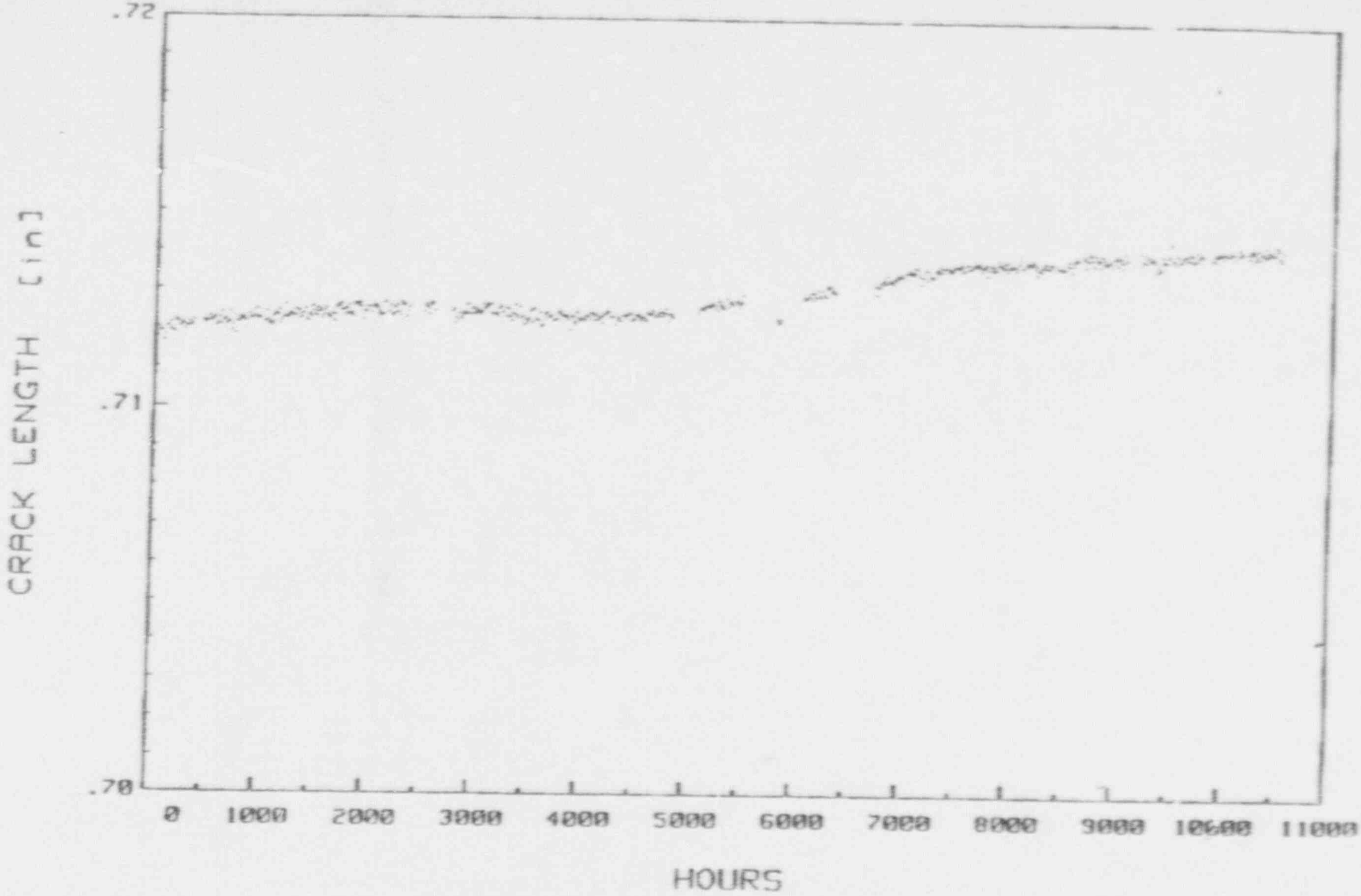

Figure 3. Plant Hatch Unit 1 CAV, Crack Length Versus Time Data, Fuel Cycle 13, Type 316NG Stainless Steel, Specimen SS-126, Stress Intensity 20 ksi/in.

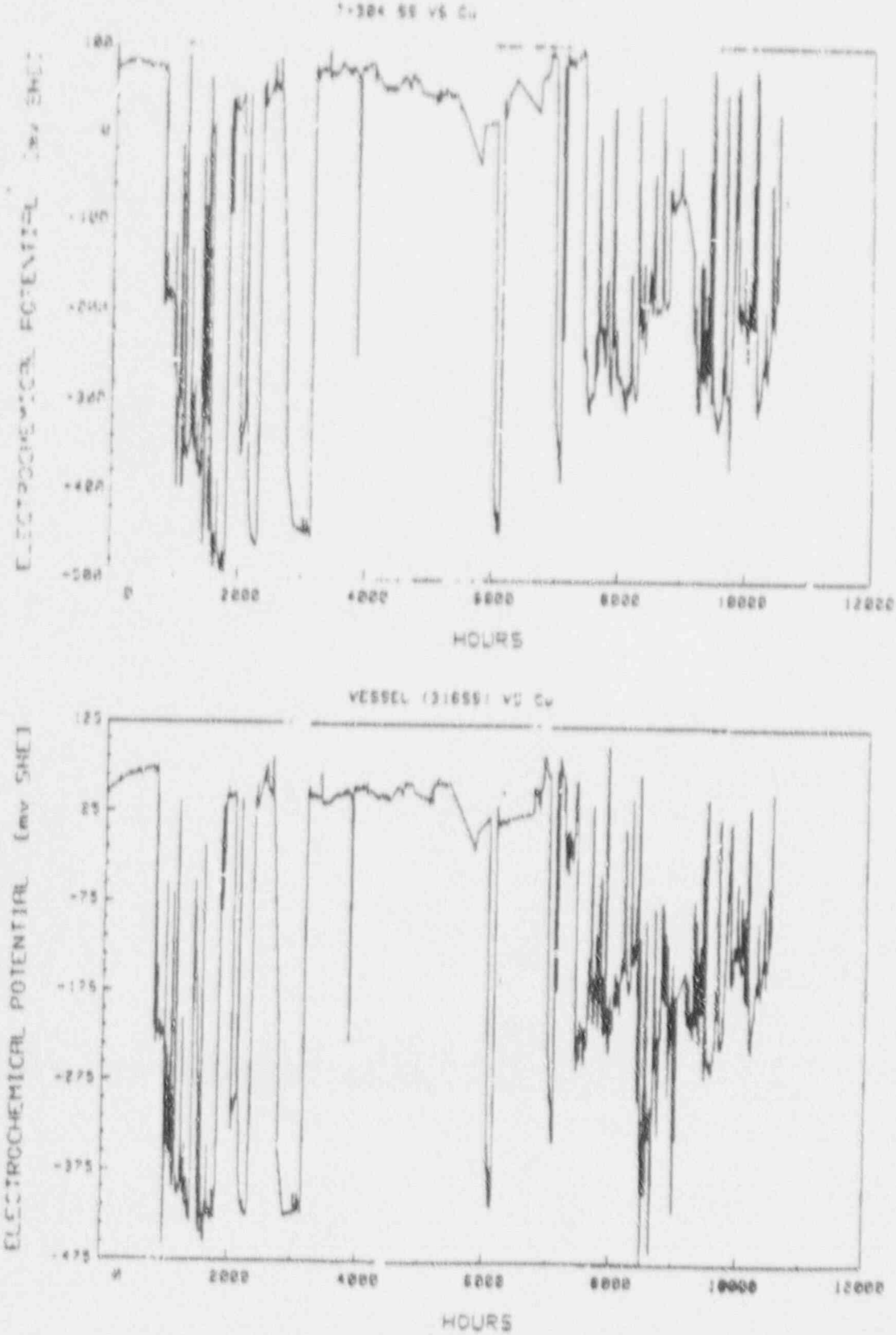

Figure 4. Plant Hatch Unit 1 CAV, Electrochemical Potential (ECP) Data, Fuel Cycle 13.

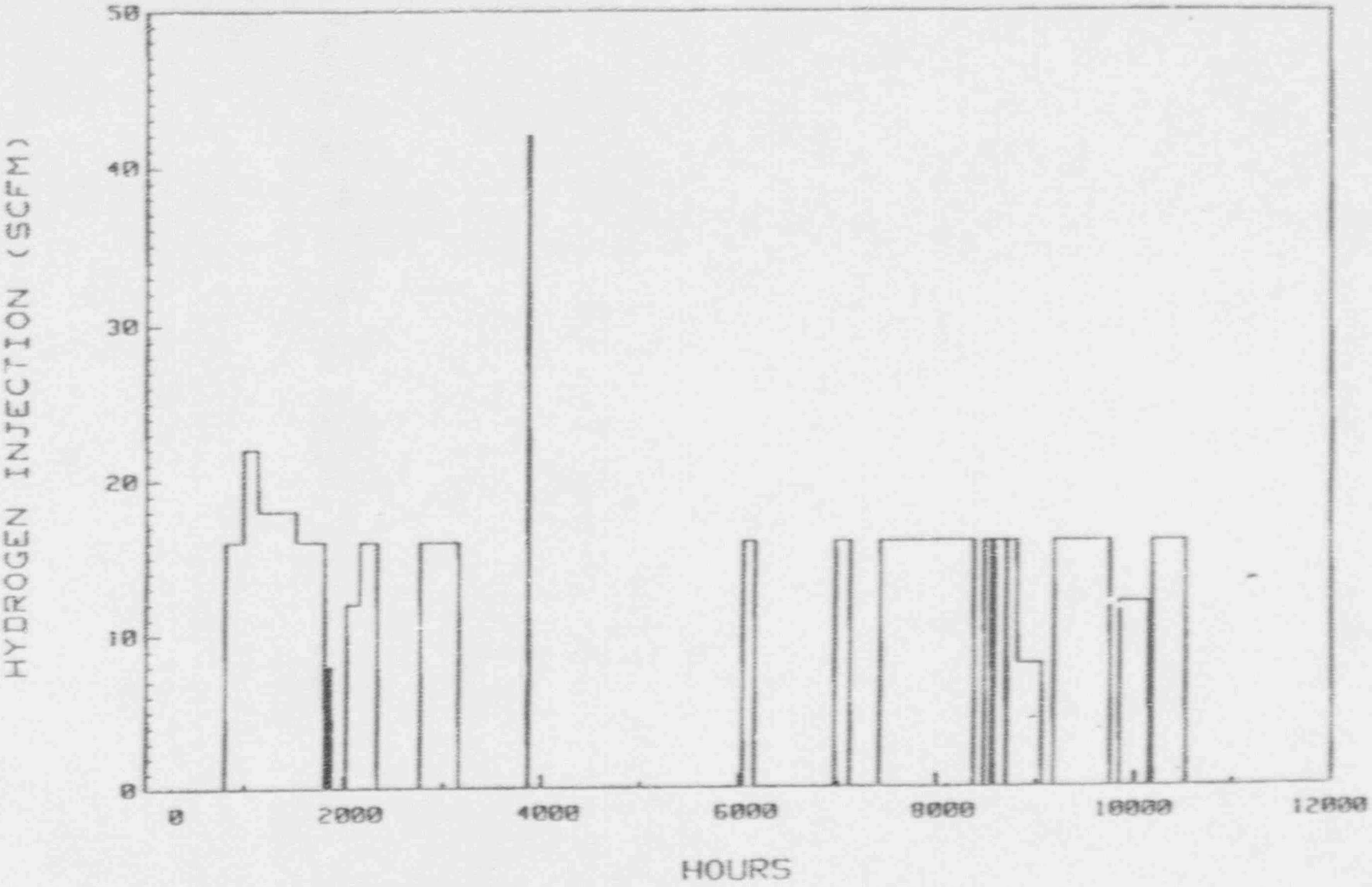

Figure 5. Plant Hatch Unit 1, Hydrogen Addition Rates, Fuel Cycle 13.

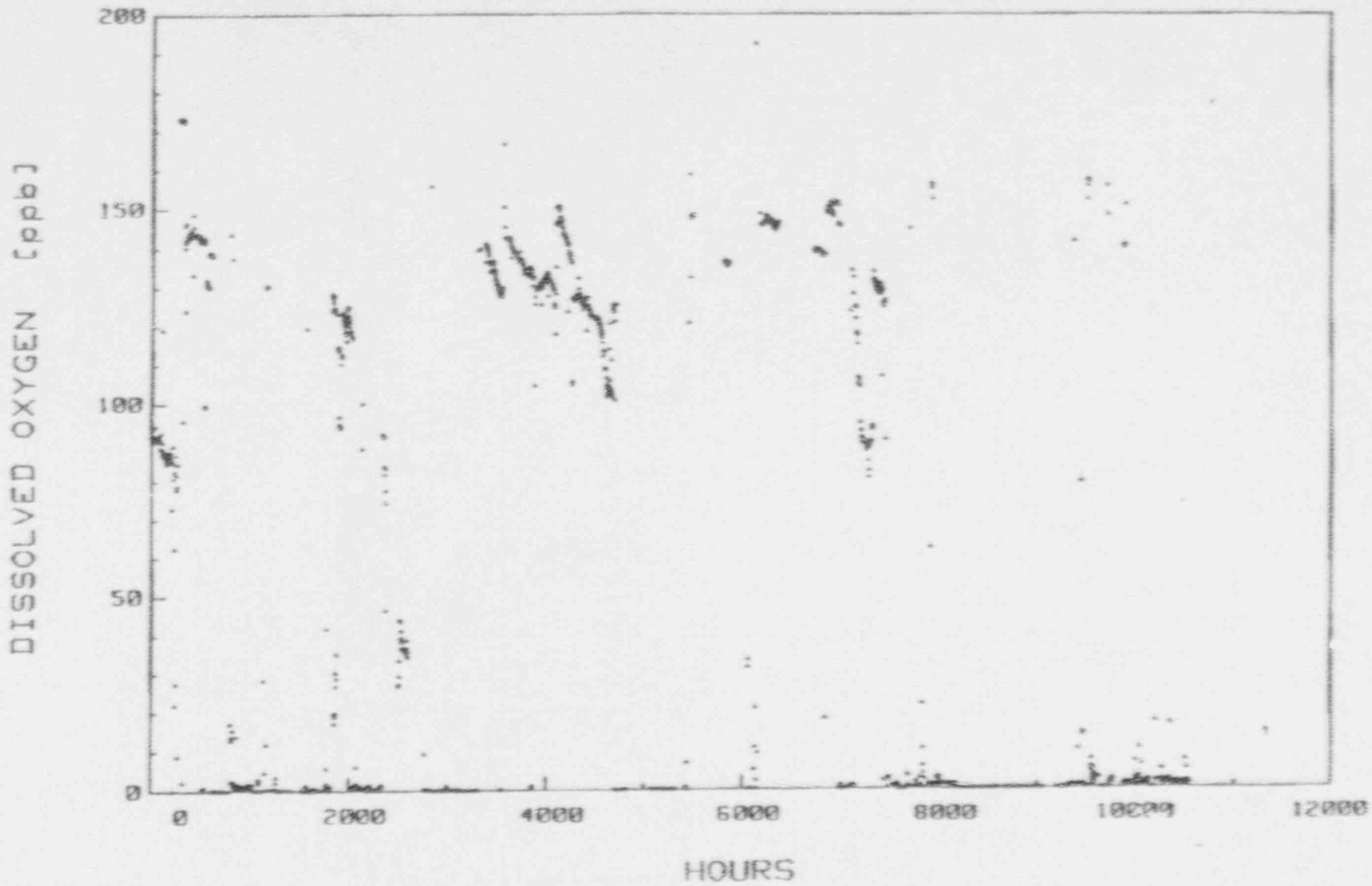

Figure 6. Plant Hatch Unit 1 CAV, Dissolved Oxygen Data, Fuel Cycle 13

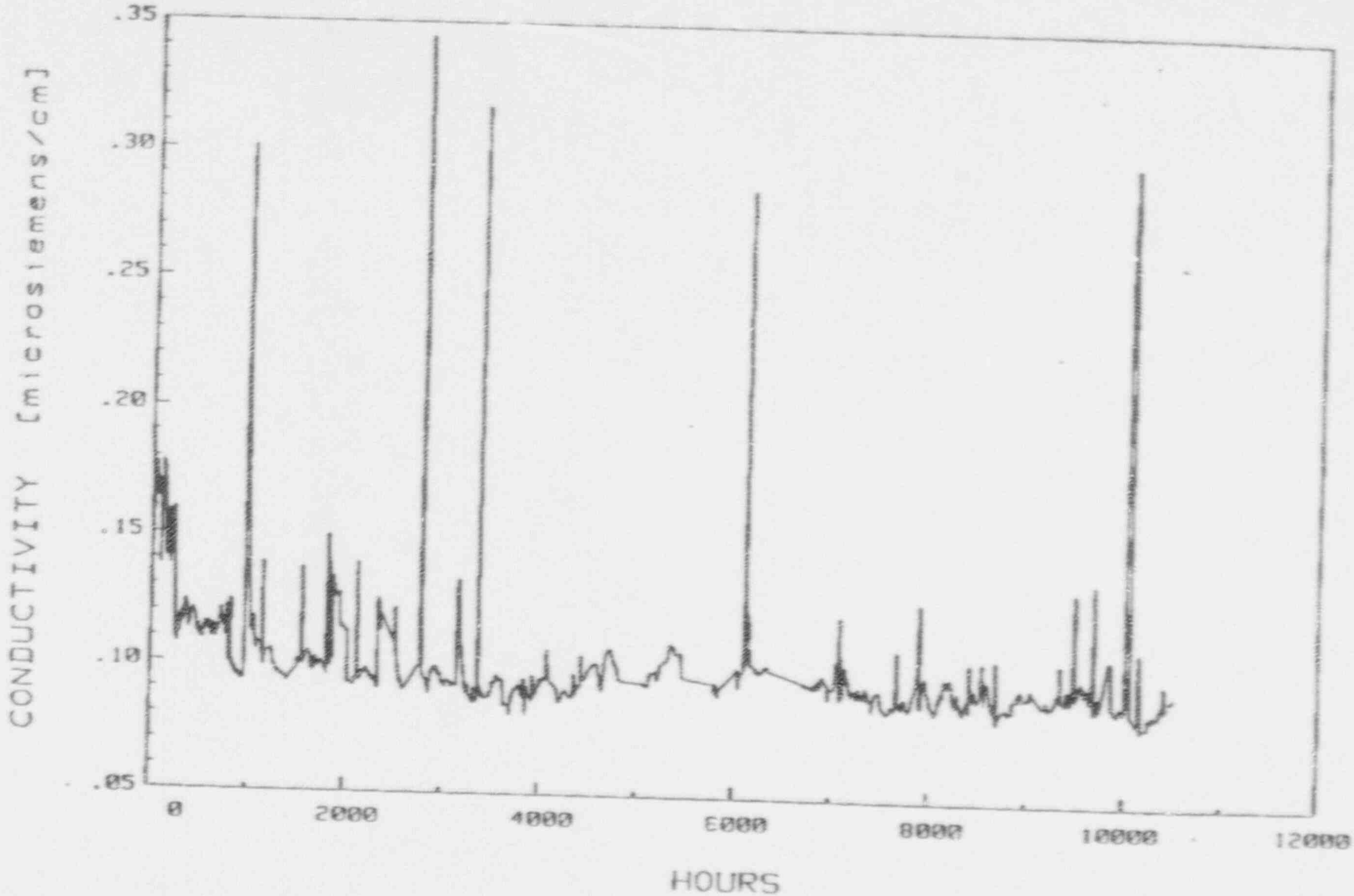

Figure 7. Plant Hatch Unit 1 CAV, Conductivity Data, Fuel Cycle 13.

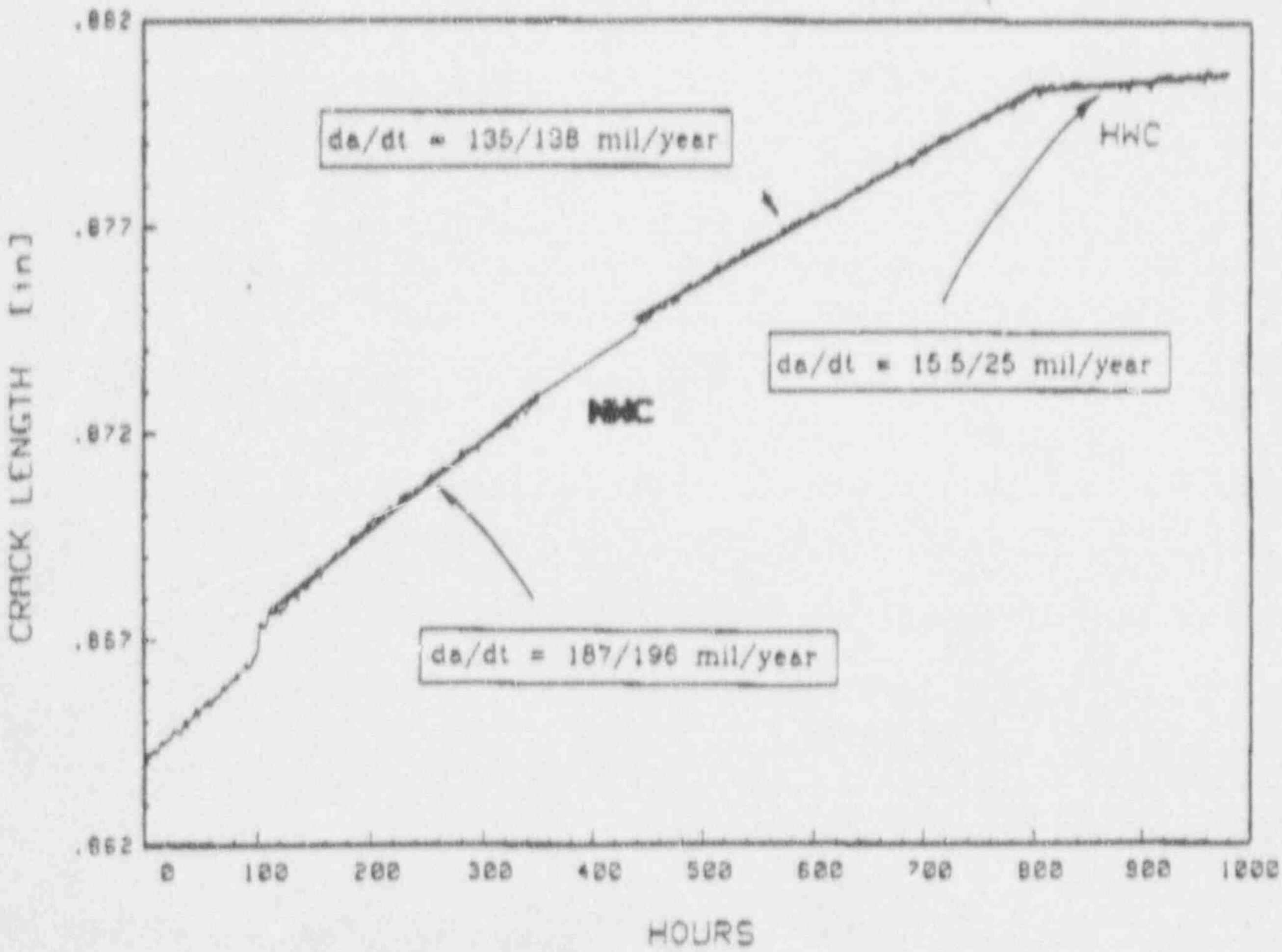

Figure 8. Plant Hatch Unit 1 CAV, Expanded View of Alloy 182 Crack Length Versus Time Data For Initial Application of Hydrogen Water Chemistry.

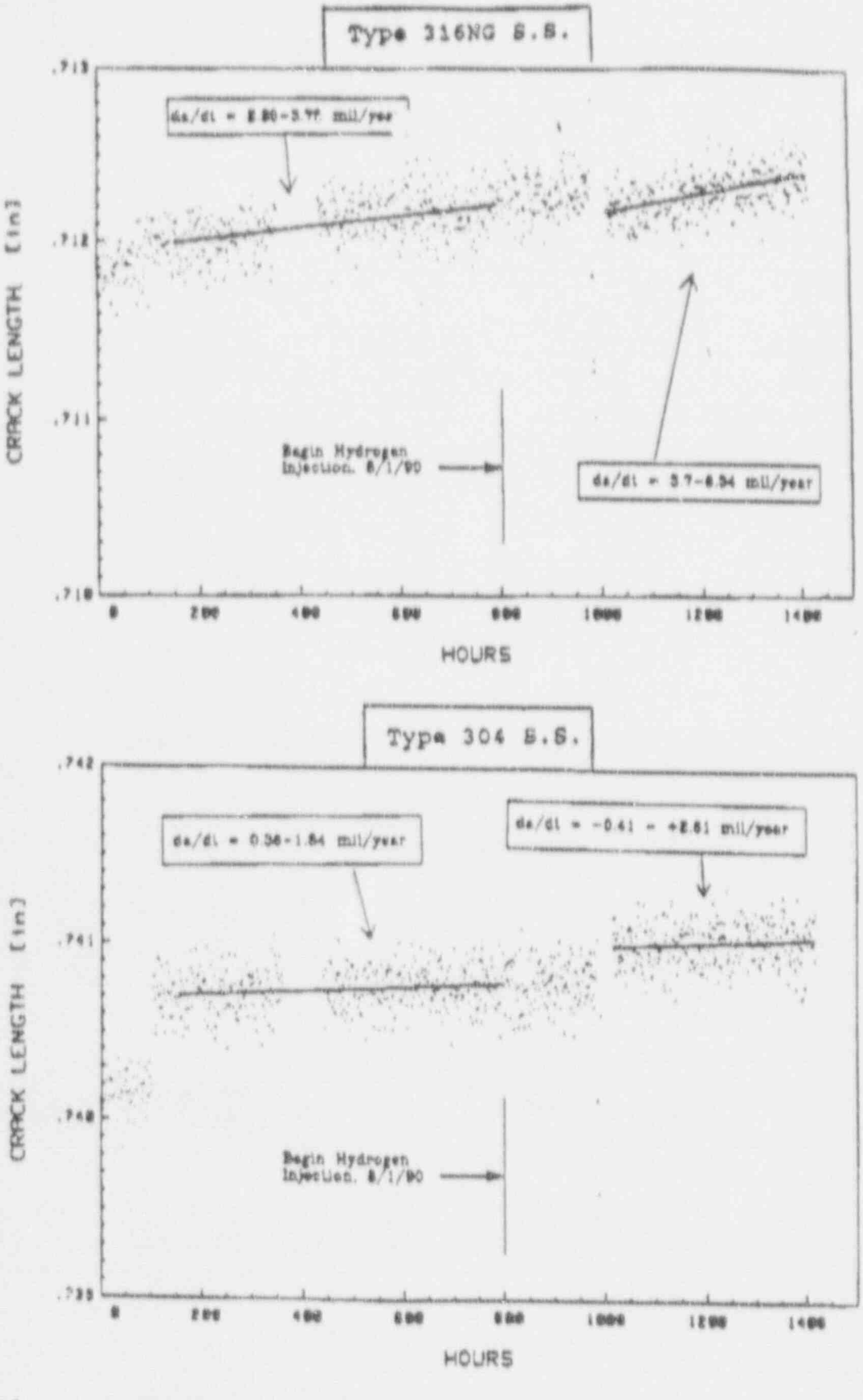

Figure 9. Plant Hatch Unit 1 CAV, Expanded View of Type 304 and 316NG Stainless Steel Crack Length Versus Time Data For Initial Application of Hydrogen Water Chemistry.

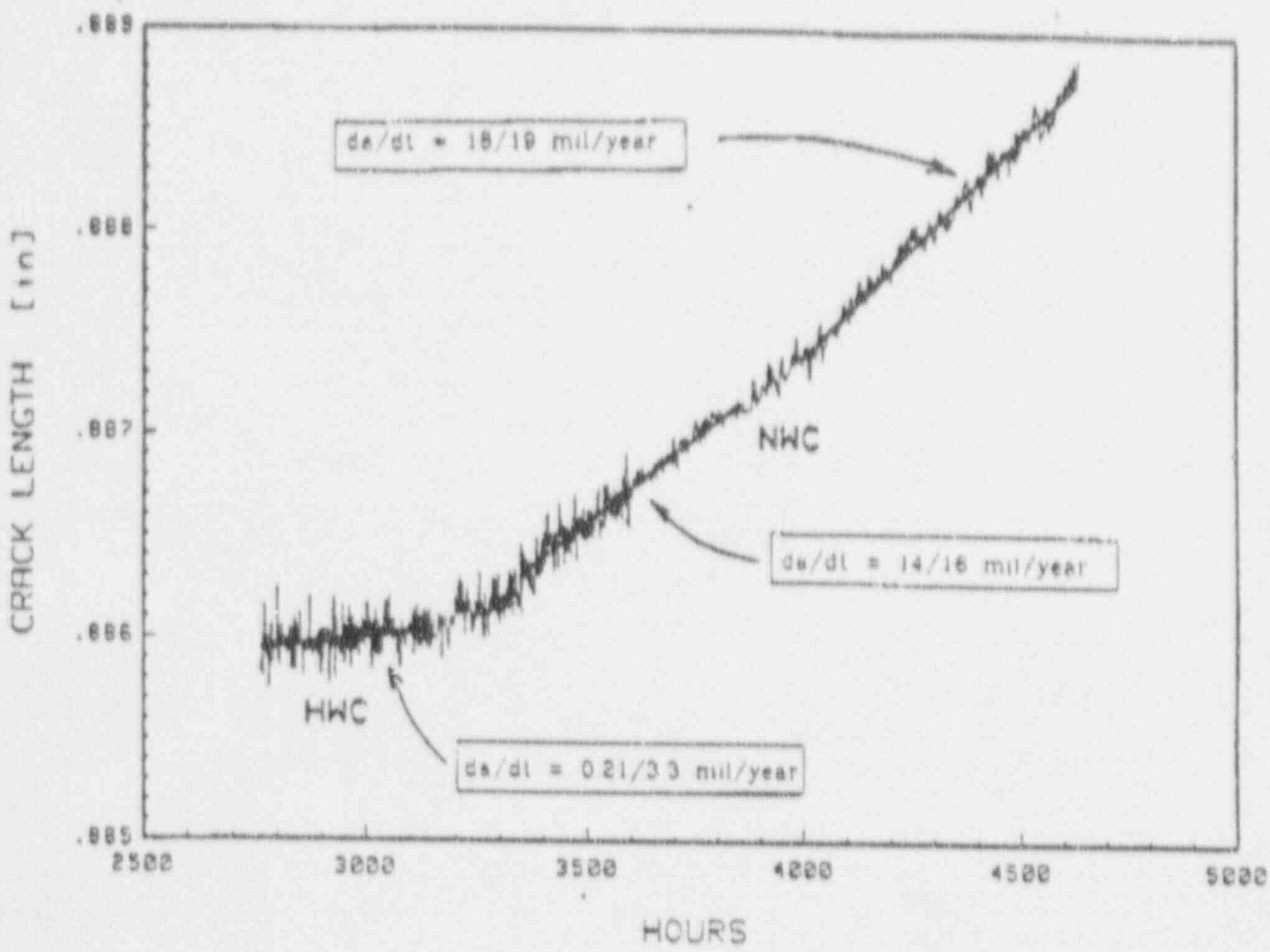

Figure 10. Plant Hatch Unit 1 CAV, Expanded View of Alloy 182 Crack Length Versus Time Data For Time Period After Resumption of Normal Water Chemistry, October/November 1990.

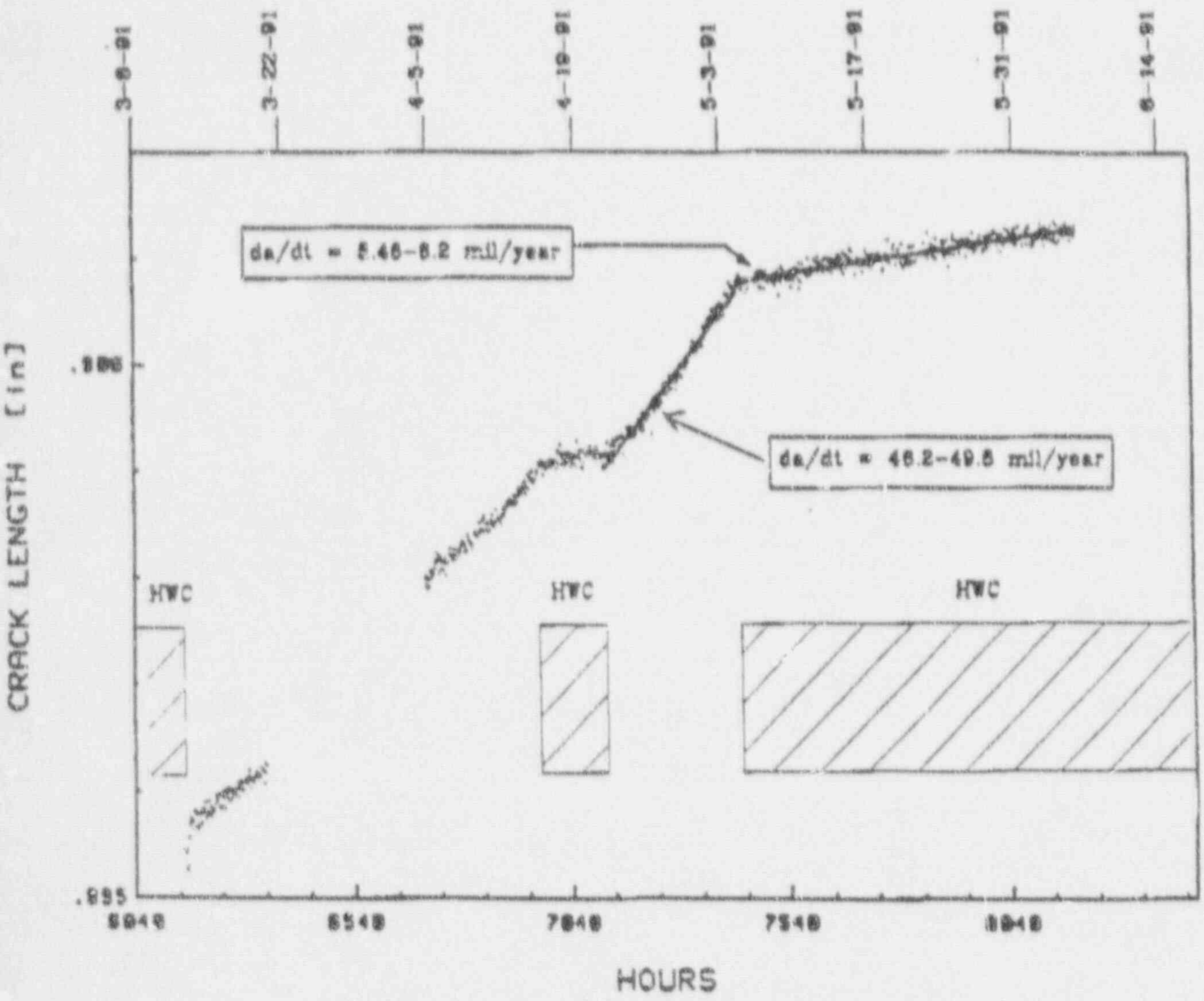

Figure 11. Plant Hatch Unit 1 CAV, Expanded View of Alloy 182 Crack Length Versus Time Data For Time Period After Resumption of Normal Water Chemistry, March/June 1991.

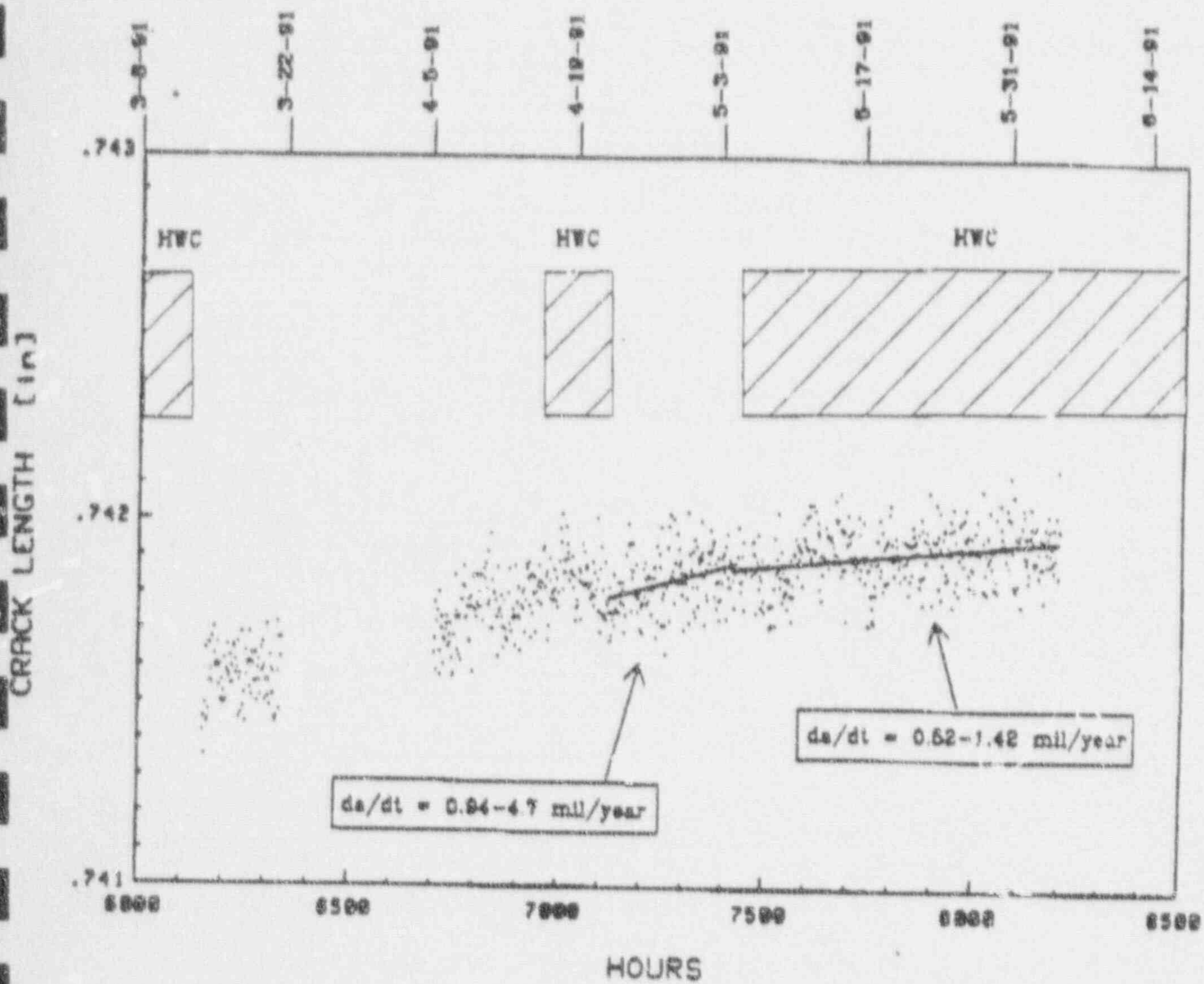

Figure 12. Plant Hatch Unit 1 CAV, Expanded View of Type 304 Stainless Steel Crack Length Versus Time Data For Time Period After Resumption of Normal Water Chemistry, March/June 1991.

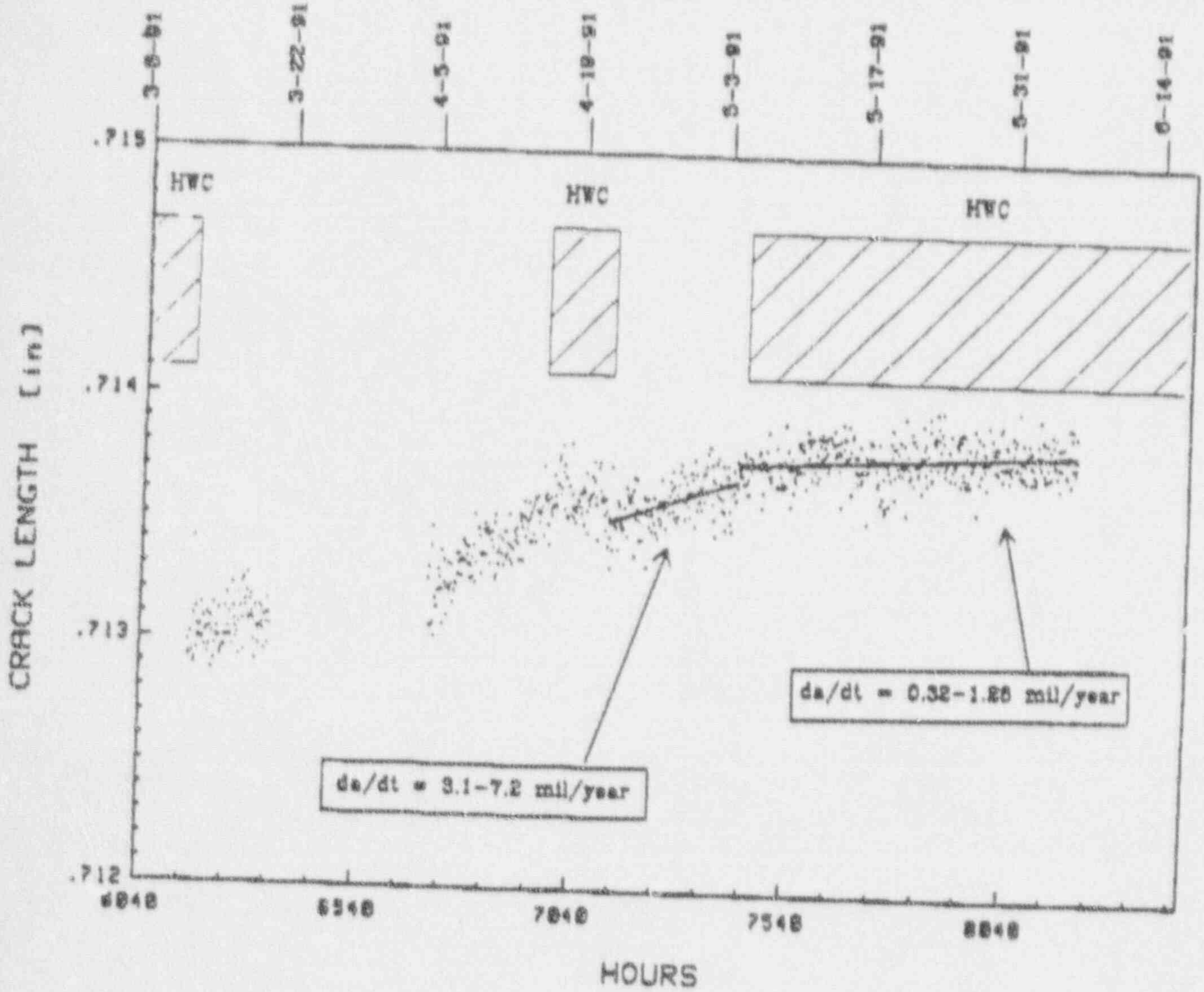

Figure 13. Plant Hatch Unit 1 CAV, Expanded View of Type 316NG Stainless Steel Crack Length Versus Time Data For Time Period After Resumption of Normal Water Chemistry, March/June 1991.

Appendix A, Fuel Cycle 13, Operating History.

Region	Start (Test Hours)	Stop (Test Hours)	Remarks
N/A	6/1/90	6/29/90	Plant startup to begin Fuel Cycle 13, Normal Water Chemistry (NWC) operation
1	6/29/90 (0)	8/1/90 (798)	Start CAV system, operation on NWC
2	8/1/90 (799)	8/9/90 (984)	Started hydrogen addition @ 16 SCFM.
3	8/9/90 (985)	8/15/90 (1128)	Started Zinc addition, hydrogen increased to 22 SCFM
4	8/15/90 (1129)	8/27/90 (1418)	Continued Zinc, hydrogen to 18 SCFM
5	8/27/90 (1419)	8/31/90 (1516)	Isolated ECP vessel to replace reference electrode
6	8/31/90 (1517)	9/12/90 (1812)	Continued Zinc, hydrogen dropped to 16 SCFM
7	9/12/90 (1813)	9/14/90 (1844)	Continued Zinc, returned to NWC
8	9/14/90 (1845)	9/15/90 (1869)	Continued Zinc, addition of hydrogen resumed @ 8 SCFM
9	9/15/90 (1870)	9/21/90 (2023)	Continued Zinc, returned to NWC
10	9/21/90 (2024)	9/27/90 (2160)	Continued Zinc, addition of hydrogen resumed @ 12 SCFM
11	9/27/90 (2161)	10/4/90 (2332)	Continued Zinc, addition of hydrogen increased to 16 SCFM

Appendix A, (continued)

12	10/4/90 (2333)	10/22/90 (2762)	Continued Zinc, returned to NWC, two startups during interval
13	10/22/90 (2763)	11/7/90 (3149)	Continued Zinc, addition of hydrogen resumed @ 16 SCFM
14	11/7/90 (3150)	12/6/90 (3852)	Continued Zinc, returned to NWC
14a	12/6/90 (3853)	12/7/90 (3864)	Special 14 hour hydrogen injection test
15	12/7/90 (3865)	1/16/91 (4823)	Resumed NWC operation
16	1/16/91 (4824)	1/26/91 (5058)	CAV Out Of Service
17	1/26/91 (5059)	2/12/91 (5473)	Continued NWC operation
18	2/12/91 (5474)	2/25/91 (5791)	CAV Out Of Service
19	2/25/91 (5792)	2/27/91 (5836)	Continued NWC operation
20	2/27/91 (5837)	3/7/91 (6025)	CAV Out Of Service
21	3/7/91 (6026)	3/12/91 (6149)	Resumed addition of hydrogen @ 16 SCFM
22	3/12/91 (6150)	3/20/91 (6340)	Resumed NWC operation
23	3/20/91 (6341)	4/4/91 (6703)	CAV Out Of Service
24	4/4/91 (6704)	4/15/91 (6963)	Resumed NWC operation
25	4/15/91 (6964)	4/21/91 (7116)	Resumed addition of hydrogen @ 16 SCFM

Appendix A, (continued)

26	4/21/91 (7117)	5/4/91 (7416)	Resumed NWC operation
27	5/4/91 (7417)	6/12/91 (8364)	Resumed addition of hydrogen @ 16 SCFM
28	6/12/91 (8365)	6/14/91 (8400)	Plant shutdown
29	6/14/91 (8401)	6/17/91 (8466)	Resumed NWC operation
30	6/17/91 (8467)	6/20/91 (8539)	Resumed addition of hydrogen @ 16 SCFM
31	6/20/91 (8540)	6/21/91 (8565)	Resumed NWC operation
32	6/21/91 (8566)	6/26/91 (8682)	Resumed addition of hydrogen @ 16 SCFM
33	6/26/91 (8683)	6/26/91 (8692)	Resumed NWC operation
34	6/26/91 (8693)	7/1/91 (8799)	Resumed addition of hydrogen @ 16 SCFM
35	7/1/91 (8800)	7/11/91 (9049)	Resumed addition of hydrogen @ 8 SCFM
36	7/11/91 (9050)	7/16/91 (9174)	CAV out of service
37	7/16/91 (9175)	8/9/91 (9750)	Resumed addition of hydrogen @ 16 SCFM
38	8/9/91 (9751)	8/13/91 (9845)	Plant shutdown
39	8/13/91 (9846)	8/26/91 (10143)	Resumed addition of hydrogen @ 12 SCFM
40	8/26/91 (10144)	8/27/91 (10167)	Resumed NWC operation

Appendix A, (continued)

41	8/27/91 (10168)	9/10/91 (10517)	Resumed addition of hydrogen @ 16 SCFM
42	9/10/91 (10518)	9/18/91 (10696)	CAV out of service
43	9/18/91 (10696)		Plant shutdown to begin refuel outage