Iowa Electric Light and Power Company

May 28, 1993
NG-93-2162

JOHN F. FRANZ, JR.
VICE PRESIDENT, NUCLEAR

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Mail Station P1-137
Washington, DC 20555

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
Request for Reduction in Certain GL 88-01 Inspection Frequencies due to the Use of Hydrogen Water Chemistry

References:
1) NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping (Generic Letter 88-01), dated January 25, 1988
2) NG-88-0973, W. Rothert (IE) to Dr. T. Murley (NRC), dated July 27, 1988

File: A-101b, A-286a, B-31c, B-31f

Dear Dr. Murley:

Generic Letter (GL) 88-01 (Reference 1) was issued on January 25, 1988. This generic letter delineated the Staff's positions on Intergranular Stress Corrosion Cracking (IGSCC), including the Staff's position on the use of Hydrogen Water Chemistry (HWC). It provided for reductions in piping inspection frequencies for certain categories of weldments based on the use of HWC on a case-by-case basis.

Our response to this generic letter stated our intention to request relief from the inspection requirements, if appropriate, based on sufficient HWC system operational data. We have subsequently obtained and reviewed the necessary data. As a result, we are hereby submitting our request for relief.

Iowa Electric is a member of the Boiling Water Reactor Owners' Group (BWROG) Improved Water Chemistry Inspection Relief Committee which has submitted Licensing Topical Report NEDC-31951P to the NRC for review. Our relief request is consistent

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with the technical conclusions in that report.

Should you have any additional questions or concerns regarding this submittal, please contact this office.

Very truly yours,

John F. Franz
Vice President, Nuclear

JFF/CJR/pjv

Attachment

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EXECUTIVE SUMMARY

Introduction

On January 25, 1988 the Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 88-01. This GL provided the Staff's position on Intergranular Stress Corrosion Cracking (IGSCC) in BWR austenitic stainless steel piping, including weld examination frequencies. It also specified methods for applying for reduced examination frequencies when Hydrogen Water Chemistry (HWC) is in use. The Duane Arnold Energy Center (DAEC) has implemented a HWC Program since 1987 with successful results. This document requests reduced frequencies for the weld examinations and provides the justification for this request.

Discussion

A total of 248 welds (178 safety related, 70 non-safety related) are included in the DAEC GL 88-01 Examination Program. The number of safety related welds and the categories as defined in GL 88-01 are as follows:

Materials/Mitigation Process	IGSCC Category	Inspection Extent & Schedule	Number of safety-related welds
Resistant Material	A	25% every 10 years (at least 12% in 6 years)	3
Non-resistant Matls (Stress Improving (SI)) within 2 yrs. of operation	B	50% every 10 years (at least 25% in 6 years)	0
Non-resistant Matls SI after 2 yrs of operation	C	All within the next 2 refueling cycles, then all every 10 yrs (at least 50% in 6 yrs)	91
Non-resistant Matls with No SI	D	All every 2 refueling cycles	75
Cracked Reinforced by weld overlay or mitigated by SI	E	50% next refueling outage, then all every 2 refueling cycles	9
Cracked Inadequate or no repair	F	All every refueling outage	0
Non-resistant not inspected	G	All next refueling outage	0

These welds are found in the Residual Heat Removal (RHR), Recirculation (RC), Core Spray (CS), and Reactor Water Cleanup (RWCU) Systems. All the welds have been examined at least once, while 147 (59%) have been examined two or more times. In 433 examinations over a period of 4 refueling outages, no new indications associated with IGSCC have been detected.

HWC operation at the DAEC began in July, 1987. Since that time, the HWC System has been operating (hydrogen injecting) more than 90% of the time that the reactor has been at greater than 20% power. A Crack Arrest Verification System (CAVS) was installed at the DAEC and has been in use since Refueling Cycle 9 (1987). This system consists of external autoclaves containing crack growth specimens and electrochemical potential (ECP) electrodes that provide crack growth data and ECP data online. The ECP is measured approximately 100% of the time hydrogen is injected, using the external autoclaves. The CAVS ECP data is used in the HWC Program to maintain, by hydrogen injection, the ECP levels below -230 millivolt on the standard hydrogen electrode (mV SHE) during reactor power operation greater than 20%. Furthermore, a limited amount of testing with direct ECP measurements in the recirculation piping has been performed that confirms the CAVS ECP data accurately reflects the ECP in the recirculation piping.

During reactor coastdown, it has been found necessary to increase hydrogen injection rates to maintain the -230 mV SHE potential. During most of the fuel cycles and with nominal injection rates, the potential can be easily maintained below -400 mV SHE.

Crack growth rates monitored during operating cycles 9, 10, and 11 have shown that Type 304 stainless steel crack growth rates have never exceeded 5.8 mils for any cycle and that the cycle 9, 10, 11 average is 3.015 mils/cycle (2.375 mils/yr) during HWC injection. The crack growth rates for Inconel 600 and Inconel 182 are also low. The ECP is maintained less than -230 mV SHE more than 90% of the time HWC is available (i.e., greater than 20% power). Additionally, ECP is maintained less than -230 mV SHE on an average greater than 85% of the time. This includes data taken at less than 20% power. Therefore, it is shown that HWC at the DAEC is effective and reliable.

Conditions in the Reactor Recirculation System have been compared with those in the Reactor-Water Cleanup System using conductivity detectors. Although this data indicates that water in the systems is nearly identical, there are times that differences in chemistry are evident. As no ECP measurements are available on RWCU, the affect of this small difference cannot be fully assessed. There is no ECP or conductivity data for the RHR and Core Spray Systems. Therefore, requests for relief on RWCU, RHR, and CS welds are not included. In addition, this relief request does not change the Technical Specification leakage monitoring program that meets Generic Letter 88-01.

We have estimated the benefits anticipated during Refueling Outages (RFOs) 12 and 13 if the relief from examinations is granted. Based on past exposure histories, savings of 18 man-Rem would be realized during RFO 12 if the relief is granted prior to this outage. Sixteen man-Rem would be saved in RFO 13. Dose relief for the weld overlays (Category E) would be about 2 man-Rem per overlay.

This relief request affects welds in the Recirculation System only. In accordance with GL 88-01, a reduction in the inspection frequency by a factor of 2 for the recirculation welds is requested based on the use of HWC at the DAEC. A summary of the number of recirculation welds and proposed modified inspection frequency is as follows:

Materials/Mitigation Process	IGSCC Category	Inspection Extent & Schedule	Number of recirculation welds
Resistant Material	A	25% every 10 years (at least 12% in 6 years)	0
Non-resistant Matls (Stress Improving (SI)) within 2 yrs. of operation	B	25% every 10 years (at least 12% in 6 years)	0
Non-resistant Matls SI after 2 yrs of operation	C	50% every 10 years (at least 25% in 6 years)	86
Non-resistant Matls with No SI	D	All every 4 refueling cycles.	35
Cracked Reinforced by weld overlay or mitigated by SI	E	All every 4 refueling cycles	8
Cracked Inadequate or no repair	F	All every refueling outage	0
Non-resistant not inspected	G	All next refueling outage	0

Summary and Conclusions

The objective of this report is to document the proactive approach that the DAEC has taken in the implementation of the examination program as set forth in Generic Letter 88-01. The DAEC has a very aggressive program that meets the requirements of this generic letter. The DAEC has performed 433 examinations since the implementation of the program and has not found any new indications associated with IGSCC. This is attributed to the excellent performance of the Hydrogen Water Chemistry System that was put into place during RFO 08. This system is effective and reliable. Recognizing the importance of reducing the dose received during refueling outages, the DAEC has calculated an 18 man-Rem savings for RFO 12 and a 16 man-Rem savings for RFO 13 if a reduction in the frequency of weld examination can be obtained based on the HWC system and examination results over the past 4 refueling cycles.

The reduction in examination frequency will only apply to welds in the Recirculation System and will be based on the availability of hydrogen injection during the cycle prior to the refueling outage. That availability shall be set at 90% of the time that reactor power is greater than 20%. If this availability is not maintained, contingency examinations will be scheduled for that particular outage. An engineering evaluation will be used to justify a revised examination schedule in the unlikely event that system availability is less than 90%.

The DAEC has HWC and CAV systems in place to control and monitor the Reactor Recirculation piping ECP levels below -230 mV SHE which is defined as the threshold for IGSCC mitigation. In addition, and more importantly, the examination results over the last 4 refueling outages reveal that there have been no new IGSCC indications detected since the implementation of HWC.

The technical content of this report concerning the DAEC experience dealing with HWC is consistent with the BWROG's Report on revised piping inspection schedules (NEDC-31951P) which has been submitted and reviewed by the NRC. Based on this report and the generic topical report submitted by the BWROG, a relief from the examination requirements, as stated in Table I of Generic Letter 88-01, is warranted.

TABLE OF CONTENTS

This relief request consists of the following sections.

1) Iowa Electric's original response to Generic Letter 88-01

   This section discusses the correspondence between Iowa Electric and the NRC which established the examination program that is implemented to meet the requirements of GL 88-01.

2) Summary of Examinations per Generic Letter 88-01

   A very important aspect to establish in receiving a relief from the examination requirements of GL 88-01 is to show the history of the weld examinations. This section includes all of the examination results from Refueling Outage 8 up to and including Refueling Outage 11. A synopsis of the results shows that a total of 248 welds are in the program. All the welds have been examined at least once, while 147 (59%) have been examined two or more times. In 433 examinations over a period of 4 refueling outages, no new indications associated with IGSCC have been detected.

3) HWC History

   This section gives a history of hydrogen water chemistry (HWC) at the Duane Arnold Energy Center. An HWC mini-test was performed in April 1986. HWC operation was begun in July 1987. Since 1987, hydrogen has been injected more than 90% of the time that the DAEC is above 20% power. Electrochemical potential (ECP) is measured approximately 100% of the time hydrogen is injected, using the external autoclaves. The ECP is maintained less than -230 mv SHE greater than 85% of the time (including periods of operation less than 20% power).

   In addition to the HWC history, a short history of the Crack Arrest Verification System (CAVS) is provided.

4) HWC Benefit

   This section describes the injection of hydrogen into the feedwater system and the measurement of ECP at the external autoclaves. A comparison of Recirculation ECP and autoclave ECP verified that the two measurements are very consistent. Full credit for HWC can be taken for the Recirculation System. Conditions in the Reactor Recirculation System are compared with the Reactor Water Cleanup (RWCU) System using a conductivity detector.

Although this data indicates that Reactor Recirculation and Reactor Water Cleanup water are nearly identical, there are times that differences in chemistry are seen. As no ECP measurements are available on RWCU, the effect of this small difference cannot be fully assessed. A request for relief on RWCU welds is not included.

5) Dose Savings

This section gives an estimated dose savings if the relief from examinations is granted. A savings for Refueling Outage (RFO) 12 and RFO13 is calculated based on past exposure histories. A savings of eighteen (18) man-Rem would be realized for RFO12 if the relief is granted prior to the outage. Sixteen (16) man-Rem would be saved in RFO13. This equates to approximately $170,000 ($10,000 per man-Rem) for each of the next 2 RFO's.

6) Iowa Electric's Response to Generic Letter 88-01 with the Inclusion of Hydrogen Water Chemistry

This section includes the inspection frequencies using the benefits of HWC.

Iowa Electric's Original Response to Generic Letter 88-01

Iowa Electric's original response and current augmented inspection program to meet the requirements of Generic Letter 88-01 (dated January 25, 1988) were documented in two letters: NG-88-0973 and NG-88-1207, both dated July 27, 1988.

The NRC's review of these letters resulted in a request for additional information. Iowa Electric provided their response under letter NG-89-0373. This response included a complete review of the previous submittals (including a review of all non-safety related welds (Reactor Water Cleanup-RWCU)) which resulted in the following number of welds in the augmented inspection program.

IGSCC CATEGORY	DESCRIPTION	NUMBER OF SAFETY RELATED WELDS	NUMBER OF NON-SAFETY RELATED WELDS
A	RESISTENT MATERIAL	3	11
B	NON-RESISTENT MATERIAL, SI WITHIN 2 YEARS OF OPERATION	0	0
C	NON-RESISTENT MATERIAL, SI AFTER 2 YEARS OF OPERATION	91	0
D	NON-RESISTENT MATERIALS, NO SI	75	0
E	CRACKED, REINFORCED BY WELD OVERLAY OR MITIGATED BY SI	9	0
F	CRACKED, INADEQUATE OR NO REPAIR	0	0
G	NON-RESISTENT MATERIALS NOT INSPECTED	0	81
TOTALS		178	92

This augmented inspection program was accepted by the NRC by letter dated December 15, 1988.

The non-safety related welds were later examined/replaced (except the 28 interconnecting piping welds on the RWCU Heat Exchangers) during RFO10 under DCP 1464. (The subsequent hydrostatic test revealed a through wall indication on weld 1E-214 Interc-11, which was replaced. An analysis showed this indication was not related to IGSCC.) This reduced the total number of non-safety related welds from 92 to 70 of which 41 are category A and 29 are category D.

Iowa Electric's augmented inspection program is very aggressive. The safety related Category A welds (3 each) would be examined twice by the end of the current inspection interval (10/31/95). The safety related Category C welds (91 each) would be examined at least twice with some welds (nozzle-safeend welds) examined four times by the end of the interval. The safety related Category D welds (75 each) would be examined every other outage as required by Generic Letter 88-01. The safety related Category E welds (9 each) would be examined every outage (up to RFO12 and 50% each outage thereafter) rather than every other outage as required by Generic Letter 88-01.

SUMMARY OF EXAMINATIONS PER GENERIC LETTER 88-01

SAFETY RELATED WELDS

CATEGORY A: A total of 3 Category A welds are in the program. All were examined in Refuel Outage (RFO) 09. There were no indications detected that were associated with Intergranular Stress Corrosion Cracking (IGSCC). One of the welds was examined again in RFO11 with no indications associated with IGSCC recorded.

Currently the remaining two welds are scheduled before the end of our current interval, one in RFO12 and the other in RFO13.

CATEGORY C: A total of 91 Category C welds are in the program. 89 welds (98%) were examined in RFO08. There were no indications associated with IGSCC detected. 19 welds (20% of the total Category C welds) were examined in RFO09. Of the 19 welds, 17 had been examined in RFO08 and 2 were examined for the first time after Induction Stress Improvement (IHSI). 29 welds (31% of the total Category C welds) were examined in RFO10. Of the 29 welds, all were previously examined in RFO08. There were no indications associated with IGSCC detected. 17 welds were examined in RFO11. Of the 17 welds, all were previously examined in RFO08. There were no indications associated with IGSCC detected. 19 welds are scheduled for RFO12 and 18 welds are scheduled for RFO13. This means that all welds (100%) would be examined at least twice with 19 welds (21%) being examined 3 times.

To date 61 welds (67%) have been examined twice, 1 weld (1%) has been examined 3 times. The remaining 29 welds (32%) have been examined once.

CATEGORY D: A total of 75 Category D welds are in the program. 33 welds (44%) were examined in RFO08. There were no IGSCC indications recorded. 60 welds (80%) were examined in RFO09 with no IGSCC indications recorded. Of the 60 welds, 18 welds (30% of the total Category D welds) were previously examined in RFO08. No IGSCC indications were detected. 36 welds (48%) were examined in RFO10. Of the 36 welds, 9 welds (12% of the total Category D welds) had been previously examined twice and the remaining 27 welds (36% of the total Category D welds) had been examined once previously. 39 welds (52%) were examined in RFO11. There were no indications associated with IGSCC detected.

All 75 welds are scheduled to be examined prior to the end of the current interval (36 in RFO12 and 39 in RFO13).

CATEGORY E: A total of 9 overlays are in the program. The nine overlays cover a total of 16 welds of which 11 welds had IGSCC indications. All 9 welds have been examined each outage (RFO08, RFO09, RFO10, and RFO11). One new IGSCC indication was identified during RFO11, which upon review of previous reports revealed that the indication had existed and was previously reported as root geometry. The examination technique used during RFO11 was a more sensitive exam and better able to maintain contact on the rough overlay surface. Therefore, this is not considered a new indication and has been mitigated by the existing overlay.

NON-SAFETY RELATED WELDS

CATEGORY A: There are 41 Category A welds in the program. 41 welds (100%) were examined during RFO10. There were no IGSCC indications detected. Currently there are 3 welds (7%) scheduled for RFO12.

CATEGORY D: There are 29 Category D welds in the program. 29 welds (100%) were examined during RFO10. There were no IGSCC indications detected. Currently there are 3 welds (as per GL 88-01, Supplement 1) scheduled for RFO12.

SUMMARY

There are a total of 248 welds in the program. All welds have been examined at least once, while 147 (59%) have been examined two or more times. There have been 433 examinations since IHSI and 271 examinations since Hydrogen Water Chemistry (HWC) implementation. There have been no new indications associated with IGSCC detected in the examinations discussed above.

HWC HISTORY

Reference: ECP MONITORING EXPERIENCES AT DUANE ARNOLD ENERGY CENTER

By
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April 1986 Conducted "Mini-test"

Iowa Electric Light and Power Company started operating with hydrogen water chemistry (HWC) at the Duane Arnold Energy Center (DAEC) in 1985. In April of 1986, General Electric conducted a "mini-test" at the plant to determine how much hydrogen needed to be injected in order to lower the electrochemical corrosion potential (ECP) in the recirculation pipes to less than -230 mv.[1] Only 5.4 cfm was needed to be injected at 100 percent power to reach the desired potential. A consequence of this low injection rate was that the expected increase in radiation fields due to nitrogen -16 was small. The main steam line radiation monitor readings increased by only 10 percent, and the rest of the normally accessible areas showed little or no change. An unexpected observation was that the reactor water conductivity showed a significant decrease when hydrogen was injected.

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[1] -230 mv is the value established to protect against IGSCC. Ref: EPRI Report NP-4947-SR (12/88).

July 1987 Started First Cycle With HWC

Since the results of the mini-test showed that a large amount of hydrogen would not be needed at Duane Arnold, the injection system was designed using tube trailers to provide the needed supply. General Electric's Crack Arrest Verification (CAV) system was installed to measure crack growth rates and to monitor the ECP of the recirculating pipes via external autoclaves. The ECP of the 304SS was measured using a Cu-CuO electrode referenced to the standard hydrogen electrode. The autoclave also contained additional Pt and Ag-AgCl reference electrodes.

In July 1987, DAEC started its first cycle on HWC. Injection was started at about 20 percent power. The ECP quickly dropped to less than -230 mv and remained steady. Reactor water conductivity decreased to about 0.065 uS/cm, and recirculating water oxygen to 0.3 ppb. It was noted that any of these three parameters quickly responded to changes in one another. If recirculation oxygen increased above 0.3 ppb, reactor water conductivity would shortly increase, and the ECP would become more positive. This was especially true toward the end of the fuel cycle when the hydrogen injection rate had to be increased to 6.0 cfm in order to maintain the ECP at less than -230 mv. However, once the role of chromate ion in reactor water conductivity was identified, hydrogen injection and ECP monitoring became fairly routine and HWC was available > 90 percent of the time during the fuel cycle with reactor power greater than 20%.

Chromate Ion

During the first HWC cycle at DAEC, it was observed that reactor water conductivity decreased when hydrogen was added and the ECP decreased to less than -230 mv. However, when hydrogen injection was interrupted, the conductivity increased dramatically. G.E. relayed that this had been seen in some Swedish plants and was thought to be due to a chromate ion equilibrium. (Reference Fig. 1) In order to test this theory, hydrogen injection was shut off for a short test. During this time, reactor conductivity, pH and chromate ion were carefully monitored. (Reference Fig. 2) The increase in conductivity is very quick. (Reference Fig. 3) As can be seen, the pH decreases as conductivity increases. Samples of reactor water taken for analysis by ion chromatography showed very large amounts of chromate ion present. The changes in pH behaved as if a strong acid was being added to the reactor, i.e., H_2CrO. The chromate ion is thought to come from the feedwater heaters. When hydrogen injection is resumed, the curves are reversed. During the first cycle on HWC, it was found that reactor conductivity, recirculation oxygen levels, chromate ion concentration, and the ECP of the 304 SS in the recirculation pipe are closely related. (Reference Fig. 4) During normal operation at 100 percent reactor power, the conductivity can be maintained within a narrow band of 0.062–0.068 µS/cm. At the same time recirculation oxygen levels will be at 0.3 +/- 0.1 ppb, the ECP will be less than -230 mv and the concentration of chromate ion will be less than 10 ppb. If the reactor conductivity rises about 0.070 µS/cm, the other parameters will change. Recirculation oxygen will rise above 0.3 ppb and the ECP will become more positive. For cycle 9 (June 28, 1987 - September 29, 1988) total crack growth for 304SS was 5.8 mils, (5.3 mils/yr.). ECP was maintained less than -230 mV for 92% of the cycle. An increase in ECP is seen during the end of cycle coastdown for 304SS. This is due to the need for more hydrogen injection at the end of cycle since increased core flow is needed to maintain the desired power level. It can be seen though that crack growth during this period is insignificant.

January 1989 Started Second Cycle with HWC

In January 1989, after a normal refueling outage, DAEC started its second fuel cycle with HWC. During that outage, additional ECP monitors had been installed. One set of sensors was installed in the recirculation pipe through the decontamination flange. Others were installed in the core via two LPRM strings. Also, another recirculation autoclave was added. (Reference Fig. 5) The purpose of these extra monitors was to conduct a joint DAEC-EPRI study to see if enough hydrogen could be added to protect the reactor internals. In addition, it would provide a comparison between the ECP values measured in the recirculation pipe to those measured via the external autoclave.

April 1989 Increased Hydrogen Feed Test

The test took place in April 1989. It was found that enough hydrogen can be injected at 45 cfm to protect most of the reactor internals. Also, for DAEC, it was found that the ECP measured in the recirculation pipe via the decontamination flange was the same as that measured in the external autoclave. This is an advantage because it is much more convenient to measure the ECP via the external autoclave. In addition, it is possible to replace or repair the electrodes in this system whereas the electrodes in the recirculation pipe are virtually inaccessible.

It was noted during the increased hydrogen feed test that radiation levels rose as expected due to the increased release of nitrogen -16 from the reactor vessel. Additional shielding will be necessary if we are to feed the higher levels of hydrogen in the future.

After the test in April 1989, data was collected from the original autoclave, the in-pipe and in-core sensors until they failed. The last in-core/in-pipe electrode ceased to function near the end of the fuel cycle in June 1990.

For cycle 10 (January 10, 1989 - June 28, 1990) total crack growth for 304SS was 5.4 mils (3.6 mils/yr). ECP was maintained less than -230 mV for 81% of the cycle. During this cyc'e, the plant experienced six scrams, system maintenance and a forced outage. The frequent cycling of the system is the primary reason for ECP to drop below 90%. It is important to note that crack growth for the cycle remained excellent.

September 1990 Started Third Cycle With HWC

In September 1990, DAEC started its third cycle -- fuel cycle 11 -- on HWC. During the refueling outage, the Cu-CuO, the Ag-AgCl, and the 304 SS electrodes were replaced. In addition, the electrometer used to measure the electrode voltages was recalibrated. We are now routinely collecting ECP data as we have for the past four years.

For cycle 11, (September 10, 1990 - February 27, 1992) total crack growth for 304SS was 0.86 mils (0.6 mils/yr). ECP was maintained less than -230 mV for 88% of the cycle. During this cycle, the plant experienced seven scrams and one week of system maintenance. Late in the cycle the CAV System was taken off line to perform an upgrade and perform an hydrogen interruption study. Crack growth for that cycle however, remained excellent.

For cycle 12, (April 26, 1992 - July 29, 1993) total crack growth as of February 1993 is 0 mils (0 mils/yr.). ECP was maintained less than -230 mV for 91% of the cycle. The system was isolated in September due to an offgas premature recombination. Crack growth data to date was taken from Inconel 600 specimen and closely follows 304SS response. Crack growth for the cycle is excellent. Isolation of the CAVS occurred at various points during the cycle (labelled as "thermal cycles" on graph).

Current Status

Hydrogen is now fed virtually 100 percent of the time we are above 20 percent power.

ECP is measured approximately 100 percent of the time hydrogen is fed using the original external autoclave.

Electrodes in the autoclaves last about one fuel cycle. They should all be replaced during each refuel outage.

Today, HWC is very routine at the DAEC. When the plant is started, HWC is put on line at about 20 percent power and will stay on until the plant is shut down. We are now used to the low reactor water conductivity and alarmed if it ever gets up to 0.1 μS/cm. Monitoring the ECP in external autoclaves provides an additional advantage in that repairs can be performed with the plant on line. The entire system seems to work quite well with very few problems.

Currently, Engineering is looking into the possibility of increasing the hydrogen injection rate up to 25 scfm based on the results of the April 1989 test. The increased injection rate will extend protection to some RPV internals. Bechtel recently performed a shielding analysis for DAEC for increased injection which provided information on the radiological and financial impact of increased injection.

The DAEC is currently working with G.E. on the increased hydrogen injection project.

EA23291.167 APS 13 SEP 91 KRIEGE 00:05 EA102

ECP Monitoring Experiences at Duane Arnold Energy Center

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EA23291.168 APS 13 SEP 91 KRIEGE 00:08 EA102

Cr(III) - Cr(VI) Equilibrium

- Conductivity spike due to the following:

$$Cr_2O_3 + 5H_2O \underset{H2\ on}{\overset{H2\ off}{\rightleftharpoons}} 2HCrO_4^- + 8H^+ + 6e^-$$

FIG. 1

Hydrogen Injection Interruption Study August 28, 1987

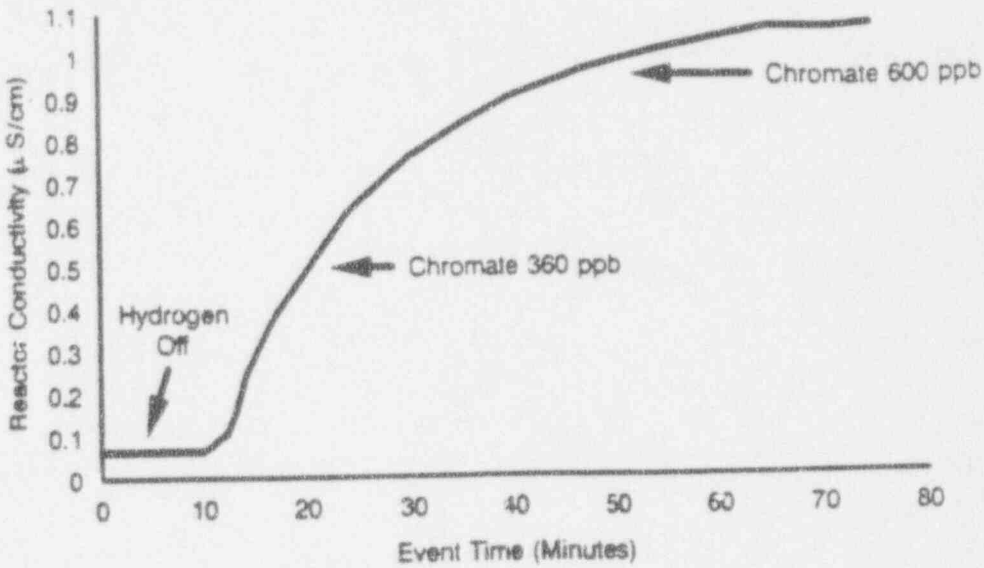


FIG 2

Hydrogen Injection Interruption Study August 28, 1987

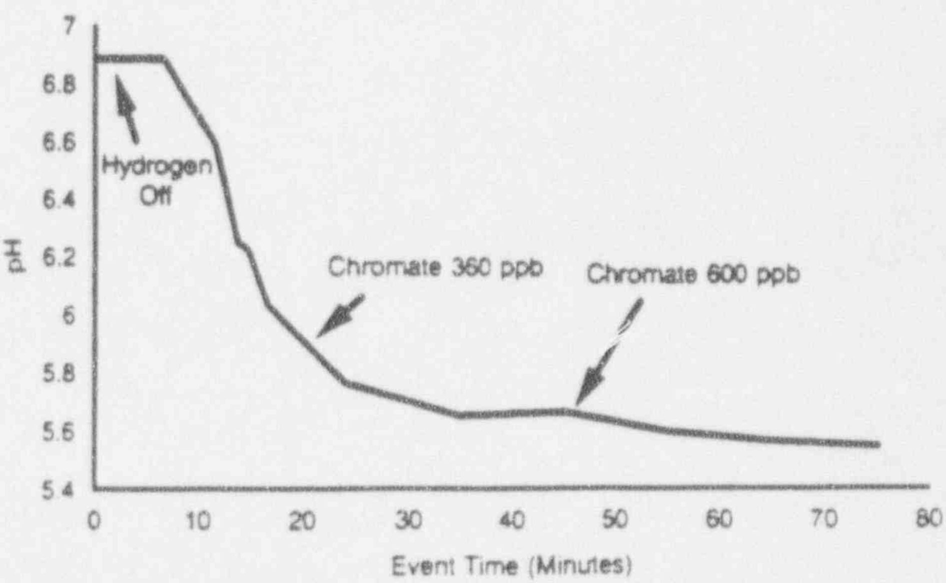


FIG 3

Reactor Conductivity, Recirc Oxygen, and ECP Ranges

- Conductivity 0.062 - 0.068 μS/cm
- Recirc oxygen 0.2 - 0.4 ppb
- ECP <- 230 mv

FIG 4

ECP Monitoring During Increased Hydrogen Feed Test

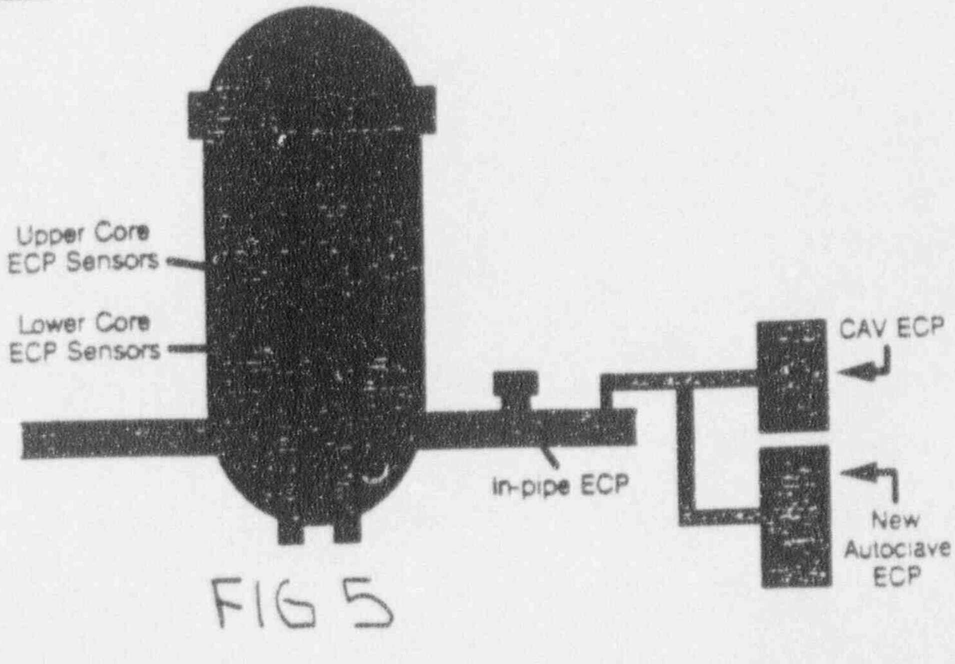


FIG 5

CRACK ARREST VERIFICATION (CAV) SYSTEM HISTORY

A G.E. Crack Arrest Verification (CAV) System was installed at the DAEC during refueling outage 8 in July 1987. The system utilizes two crack-growth autoclaves and two Electro-Chemical Corrosion Potential (ECP) autoclaves to sample recirculation water from the recirculation sample line off of the recirculation riser piping. A reversing DC potential technique is used to monitor pre-existing IGSCC cracks in four compact tension specimens. The materials represented are furnace sensitized Type 304 stainless steel, Inconel Alloy 600 and Inconel Alloy 182.

Additionally, recirculation water chemistry information is also recorded by the CAV System. The ECP measurements of the test materials are recorded by the CAV System and are used to verify that the hydrogen injection system, also in operation since 1987, is effective in protecting recirculation piping. A total sample flow of 5 gallons per minute maintains each autoclave at greater than 500°F. The ½ inch sample line between the recirculation piping and the CAV system is approximately 40 feet long.

During a 1989 EPRI study, the DAEC CAV system was used in conjunction with ECP electrodes mounted in a recirculation pipe decontamination connection, as well as in-core sensors located in an LPRM string. The data collected included a demonstration that ECP readings at the external autoclaves correlate very well with ECP readings at the recirculation piping.

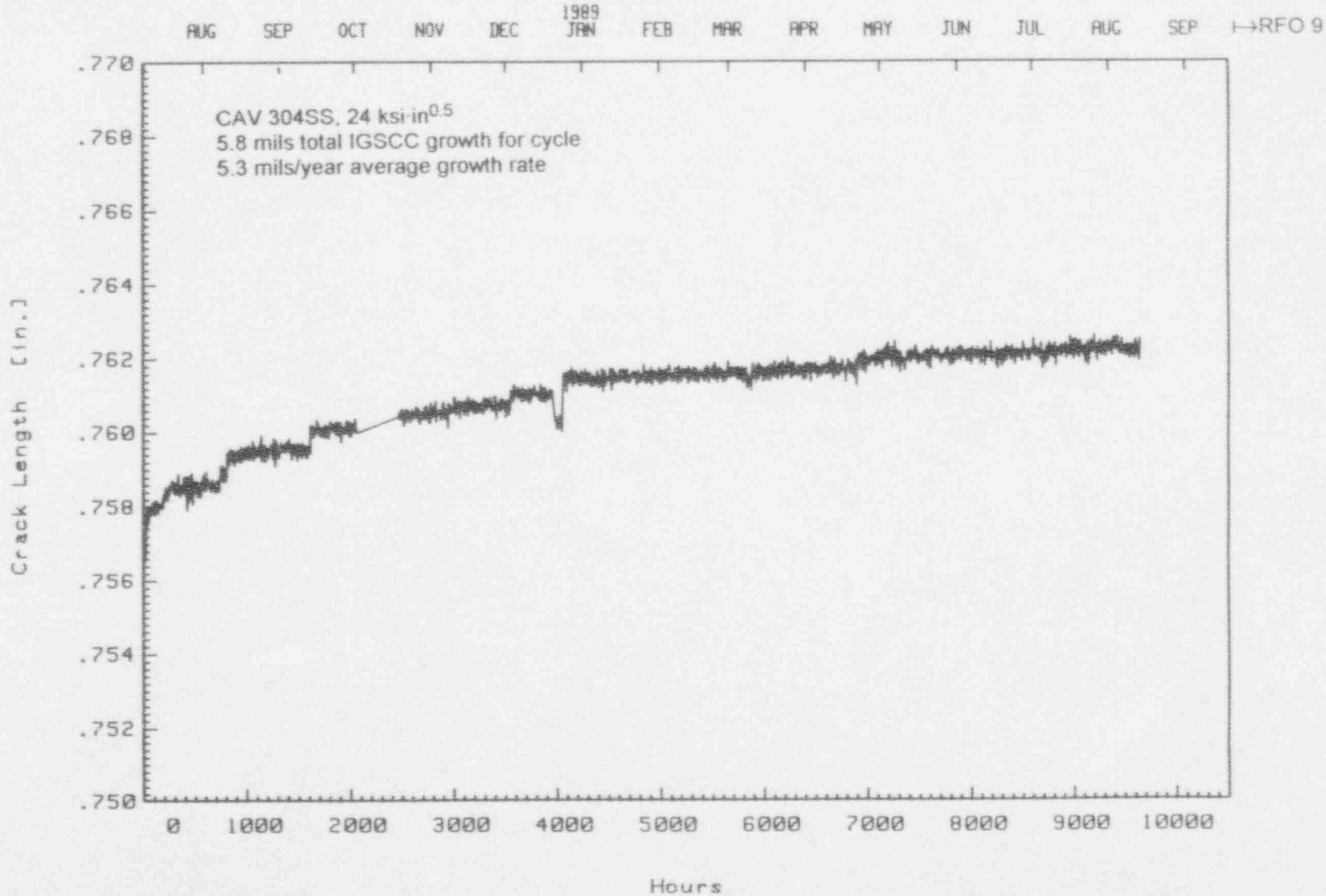
Recently, a plant modification was performed on the HWC System involving the CAV System. The modification involved an "HWC Interruption Study". The test, which began in May 1992, will investigate the "memory-effect" associated with IGSCC protection during hydrogen water chemistry operation. It is possible that the benefits of hydrogen protection remain for some period of time after hydrogen injection has been terminated. At present, little effort has been given to investigating this phenomena. Therefore, the objective of the testing is to determine the effect of periodic interruptions of hydrogen injection. Both the frequency and duration of these interruptions will be varied while Stress Corrosion Cracking (SCC) activity is monitored in each CAV loop. This EPRI test is being performed largely by General Electric.

The test will utilize the modified Crack Arrest Verification (CAV) System, which is comprised of two crack-growth vessels and lever-arm load frames installed on the recirculation system water sample stream. The A CAVS will be used as the control to monitor HWC during operating plant conditions. The B CAVS will be modified to allow oxygenated water to be injected at the vessel influent, thereby simulating a return to normal water chemistry, i.e. 200 ppb O_2. The interruptions scheduled will simulate maintenance intervals of an 8 hr shift or a 2 day weekend.

This information will provide capability for specific materials assessment following unplanned interruptions of the HWC system. This study may also relieve the high radiation and exposure penalty that is encountered with H_2 injection by allowing H_2 reductions or interruptions during planned maintenance activities in high radiation areas.

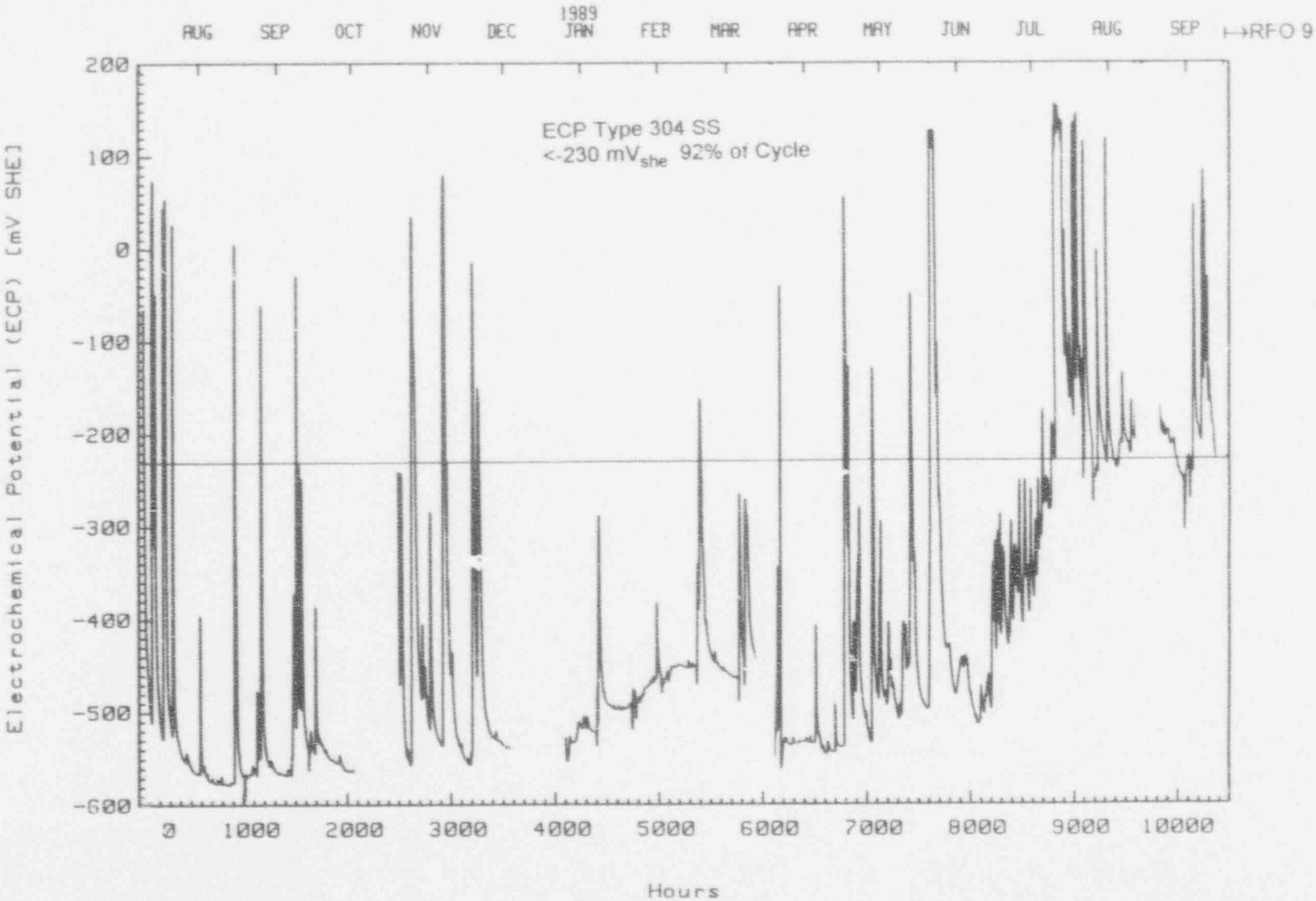
DAEC Fuel Cycle 9

(June 28, 1987–September 29, 1988)



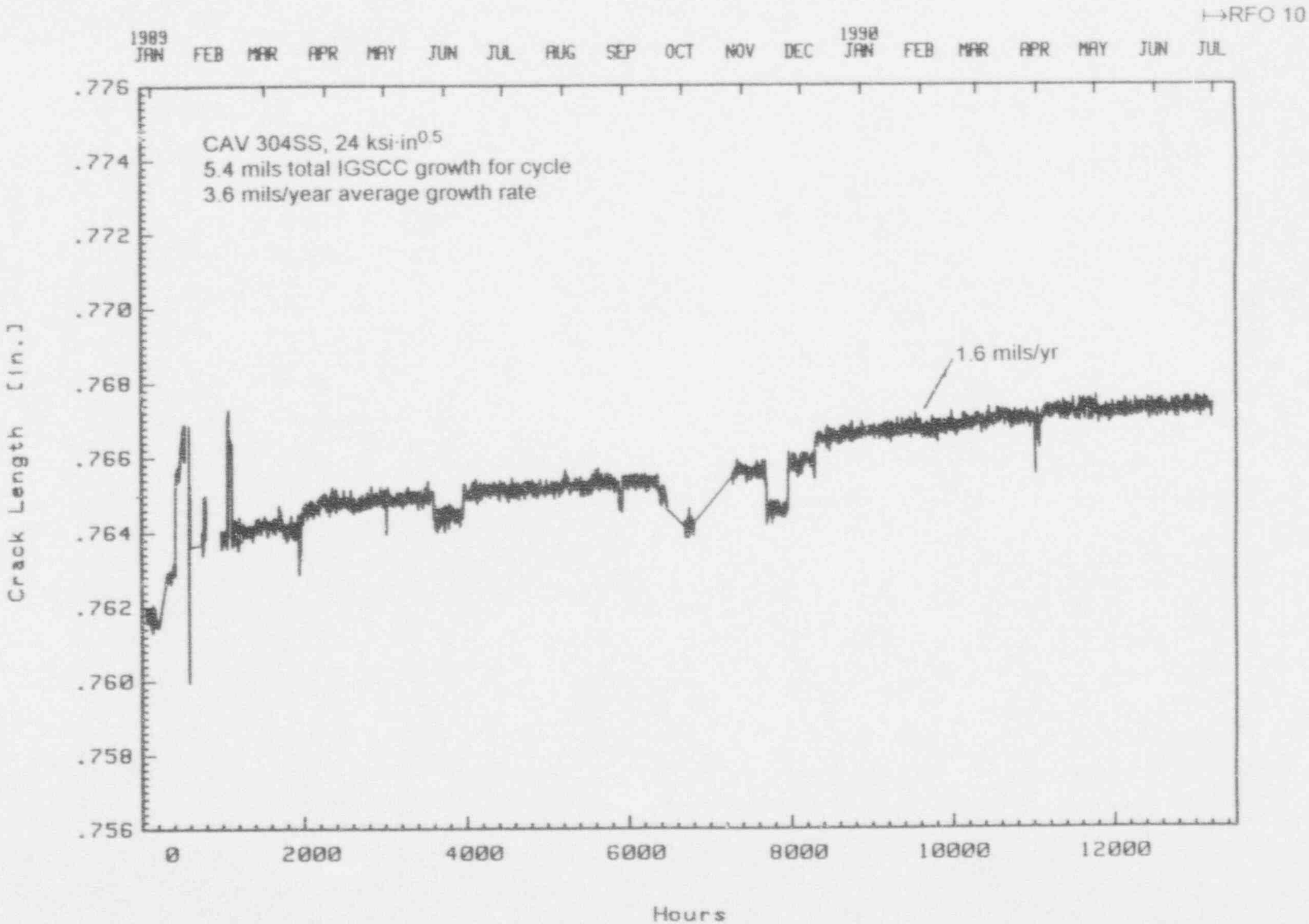
DAEC Fuel Cycle 9

(June 28, 1987–September 29, 1988)



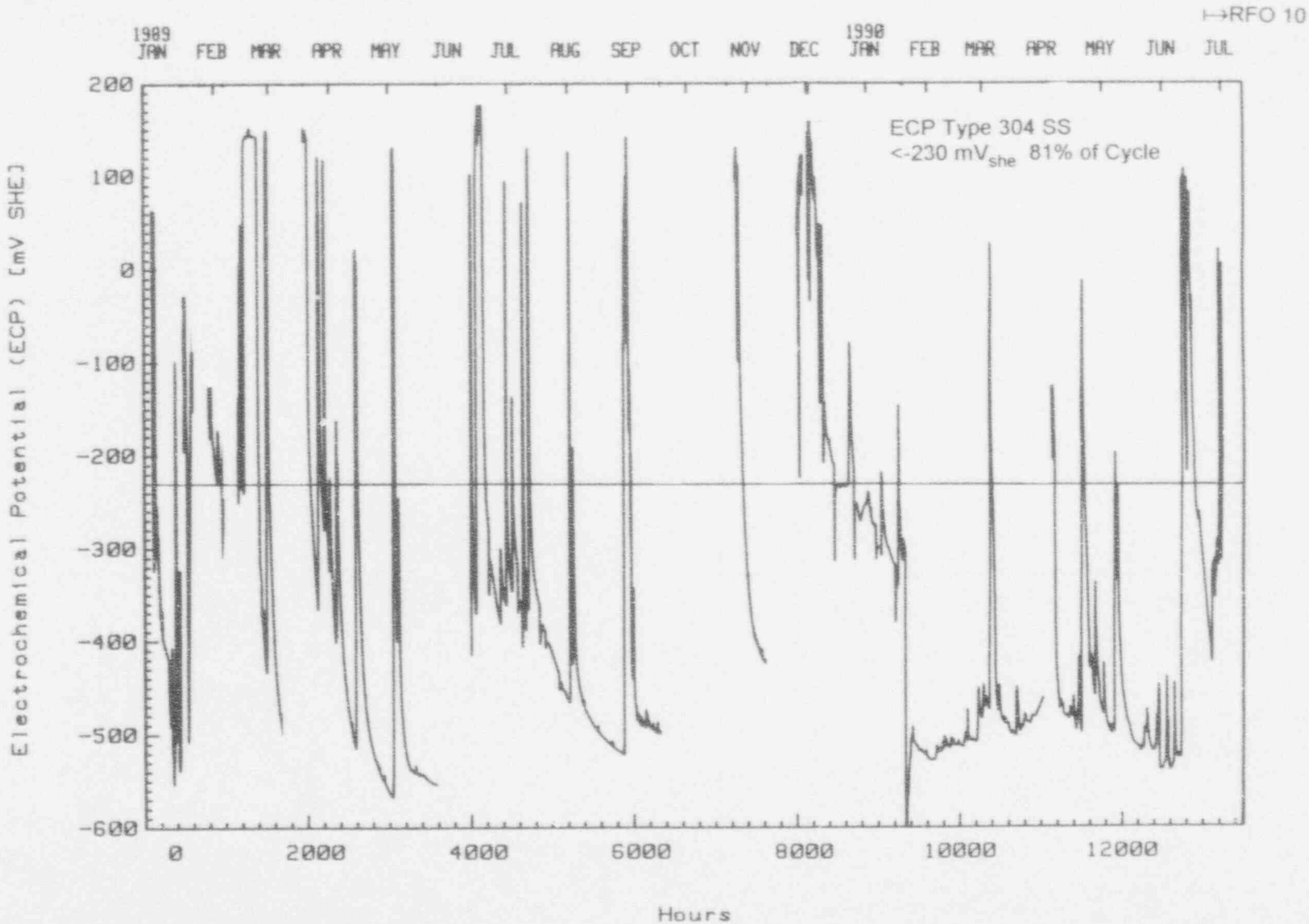
DAEC Fuel Cycle 10

(January 10, 1989–June 28, 1990)



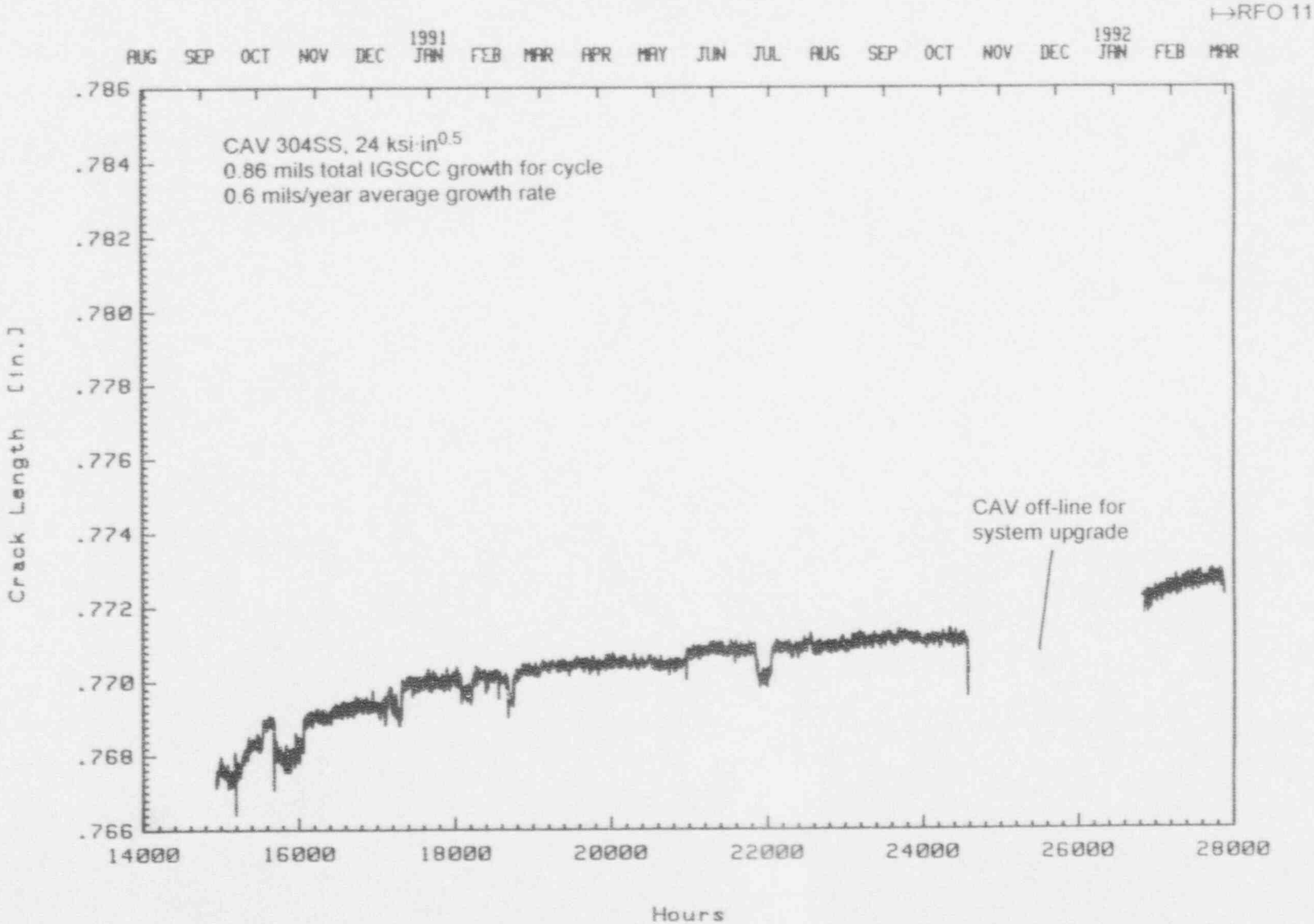
DAEC Fuel Cycle 10

(January 10, 1989–June 28, 1990)



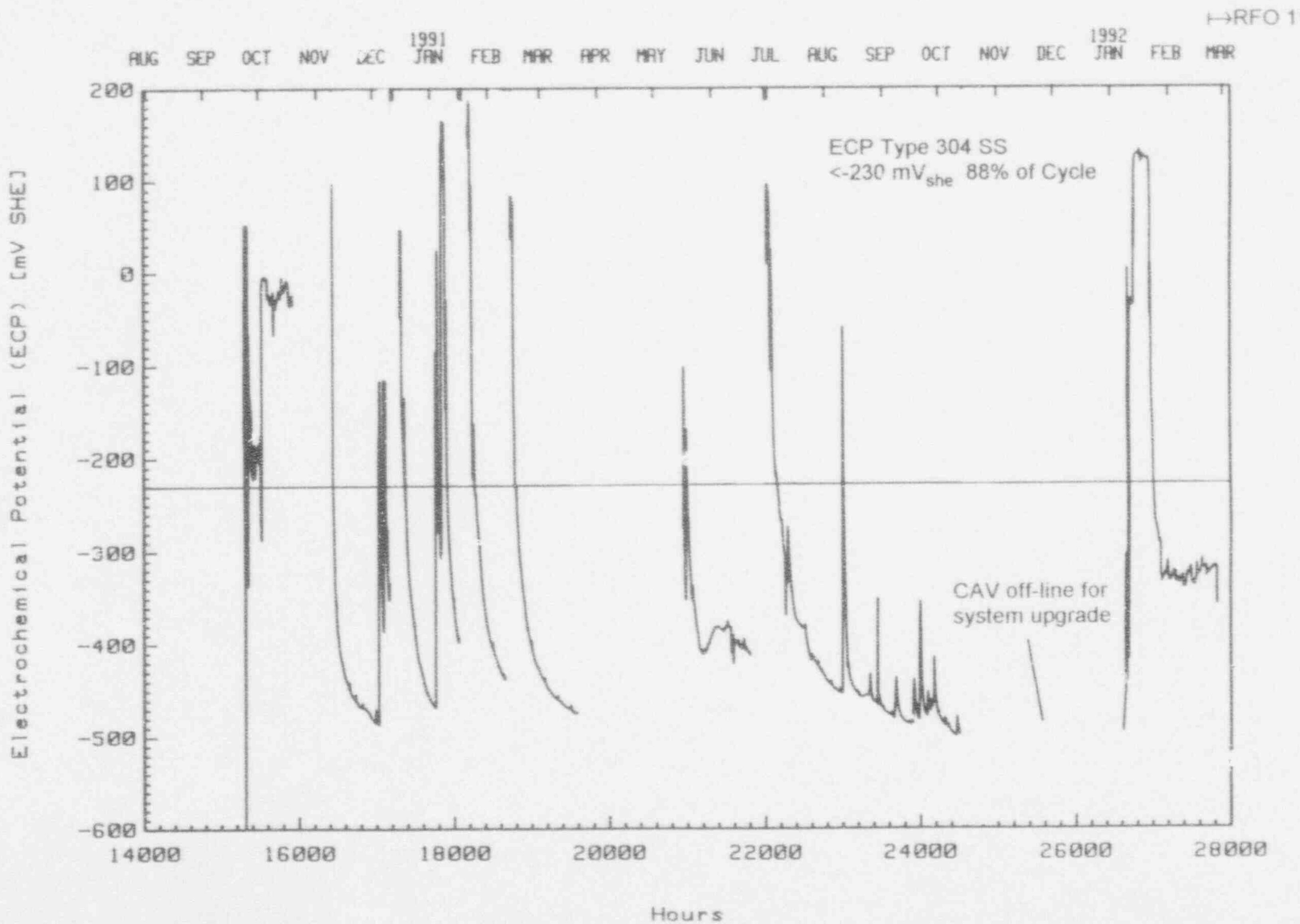
DAEC Fuel Cycle 11

(September 10, 1990–February 27, 1992)



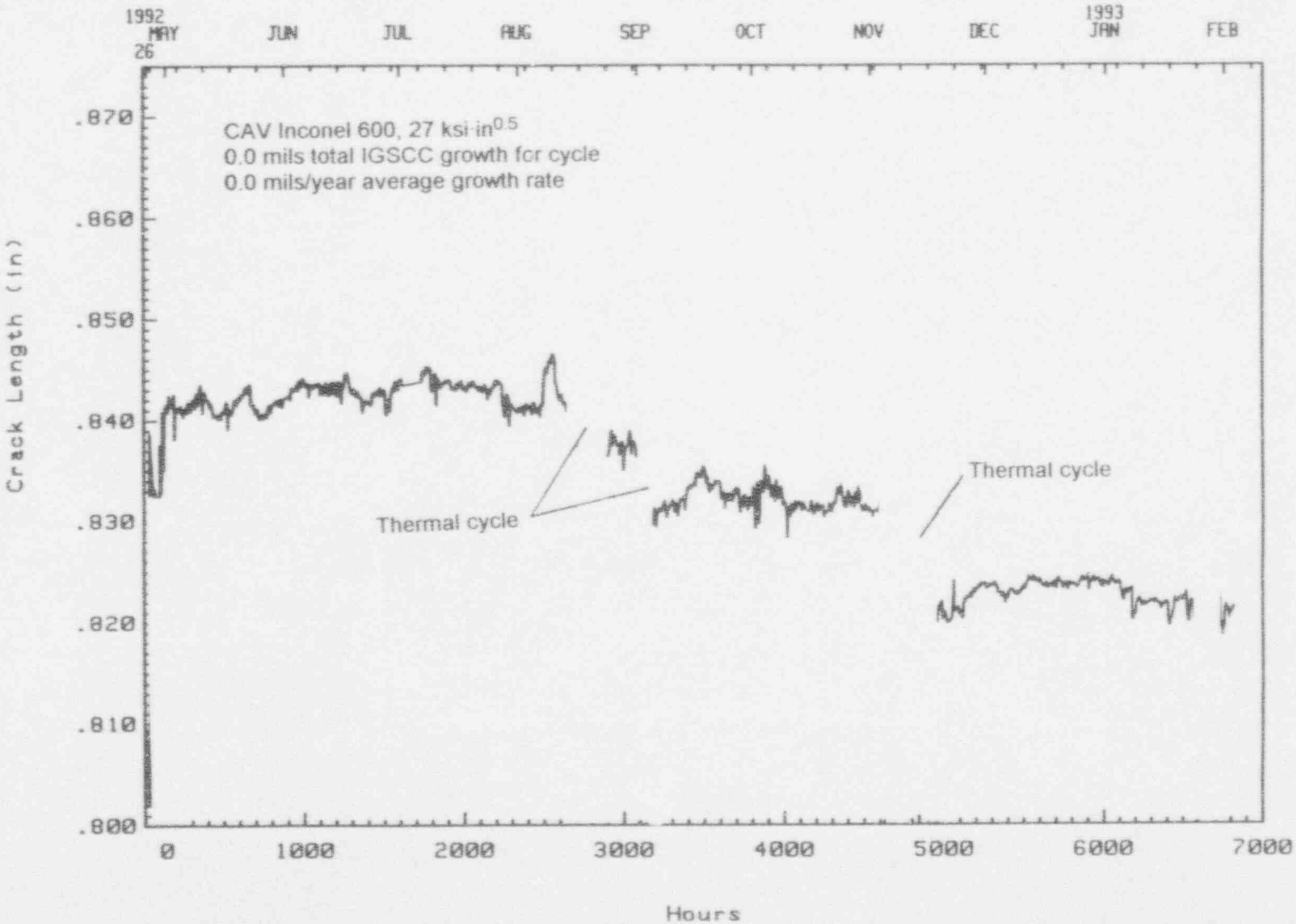
DAEC Fuel Cycle 11

(September 10, 1990–February 27, 1992)



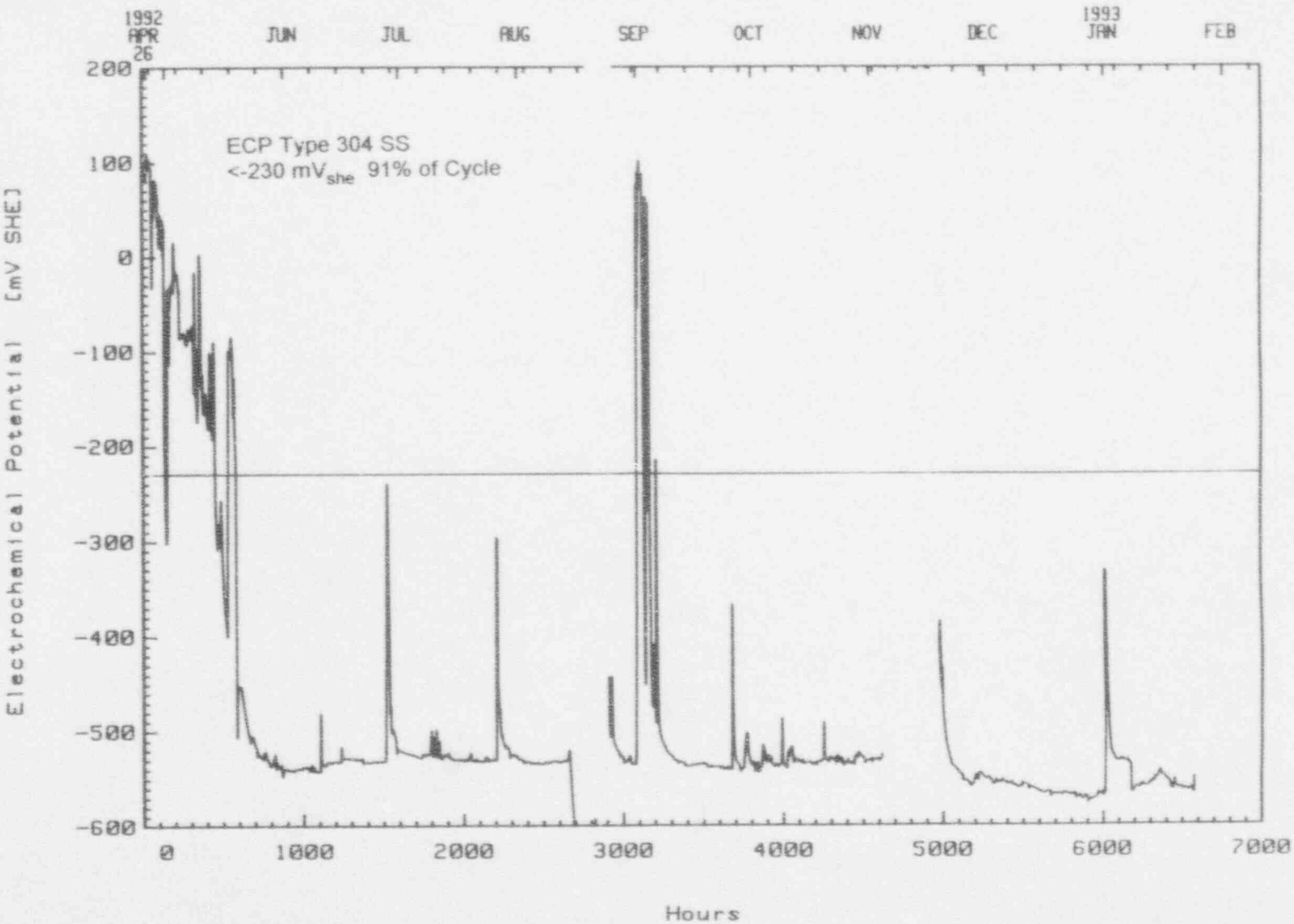
DAEC Fuel Cycle 12

(April 26, 1992–July 29, 1993)



DAEC Fuel Cycle 12

(April 26, 1992–July 29, 1993)



HWC BENEFIT

Hydrogen Water Chemistry was introduced at the DAEC to mitigate intergranular stress corrosion cracking (IGSCC). Control of IGSCC is accomplished by injecting hydrogen water into the suction of each feedwater pump. The additional hydrogen in the feedwater combines with radiolytically produced dissolved oxygen in the reactor downcomer region where gamma flux acts as a catalyst. By reducing the dissolved oxygen concentration of the reactor coolant, hydrogen injection in conjunction with a re-emphasis on water quality control causes a reduction in the electrochemical corrosion potential (ECP) of the coolant.

ECP sensors installed in the recirculation decontamination flange verified that at 6 scfm hydrogen, ECP levels dropped to significantly lower than -230mV SHE (-400 to -500 mV SHE). These values were also verified by the Crack Arrest Verification (CAV) System. Currently, the CAV System continuously monitors the ECP in the recirculation piping. Full credit can be taken for HWC for the entire recirculation system for recirculation weld inspection relief.

The sample point at the Reactor Water Cleanup (RWCU) influent provides the primary continuous indication of reactor water conductivity. The data on the following page records the increase and subsequent decrease in conductivity, as hydrogen feed to the Reactor Recirculation System was stopped and then restarted. The conductivity of RWCU influent (reactor water) and both RWCU effluents recorded the same changes in chemistry. Although ECP monitoring is not available on the RWCU system, the changes in RWCU chemistry directly correlate with changes in ECP monitored from the Reactor Recirculation System.

Water for RWCU comes primarily from the Reactor Recirculation System, with a smaller proportion drawn from the reactor vessel bottom head drain. Although these two locations typically have very similar chemistry, the vessel bottom head water will sometimes have slightly higher conductivity. An example of this was found late in a fuel cycle (December 10, 1991) when RWCU conductivity (including bottom head water) was 0.083 μmho/cm as compared to Reactor Recirculation water conductivity at 0.065 μmho/cm. Higher differences in conductivity as well as increased chromate ion concentration have been measured in RWCU.

Although this data indicates that Reactor Recirculation and Reactor Water Cleanup water are nearly identical, there are times that differences in chemistry are seen. As no ECP measurements are available on RWCU, the affect of this small difference cannot be fully assessed. A request for relief on RWCU welds is not included in this report. However, DAEC is evaluating RWCU piping for future consideration.

Duane Arnold Energy Center
Conductivity Monitoring
August 13,1987

Time	Reactor water/ RWCU influent conductivity CIT2738,umho/cm	'A' RWCU effluent conductivity CIT2737A,umho/cm	'B' RWCU effluent conductivity CIT2737B,umho/cm	Comments
				HWC operation
1230	0.070	0.068	0.068	H2 feed turned off
1242	0.16	0.15	0.16	
1245	0.23	0.26	0.29	
1249	0.29	0.36	0.41	
1253	0.35	0.47	0.52	
1300	0.44	0.60	0.70	
1305	0.50	0.68	0.80	
1315	0.59	0.75	0.95	
1320	0.62	0.75	1.0	
1325	0.65	0.75	1.0	
1333	0.68	0.75	1.0	
1340	0.69	0.71	1.0	H2 feed turned on
1350	0.72	0.52	0.80	
1355	0.56	0.42	0.59	
1401	0.29	0.28	0.42	
1405	0.24	0.24	0.35	
1458	0.175	0.12	0.15	

DOSE SAVINGS

Inservice Inspection is a major contributor to the amount of dose received during each outage at the DAEC. Total dose per outage due to inservice inspections is approximately 75 man-Rem on average. Of the 75 man-Rem, 70 man-Rem is attributed to inspections in the drywell. Of this 70 man-Rem, 50 man-Rem attributed to inspections of the recirculation piping. Inspections of the overlays alone account for 22 to 25 man-Rem per outage. The average contact dose rate on the recirculation piping varies with elevation as shown below:

742' - 225 mr/hr

757' - 917 mr/hr

775' - 310 mr/hr

The DAEC recognizes that Hydrogen Injection causes a redistribution of crud levels and increases the dose rates. The DAEC also recognizes the importance of reducing the dose received during each outage and has for the past two outages performed a chemical decontamination. The chemical decontamination did reduce the dose rates as shown on the attached graphs. The DAEC will continue to pursue techniques to reduce the dose rates irrespective of the HWC relief request. Among the techniques being considered are more chemical decontaminations, water shielding and additional scope reductions.

OUTAGE DOSE REDUCTION DUE TO PROPOSED REDUCED SCOPE BASED ON HYDROGEN WATER CHEMISTRY

RFO12

Present Scope: 55 welds   Reduced Scope: 37 welds

Dose Reduction:

18 welds x 1000 mr/weld = 18 man-Rem

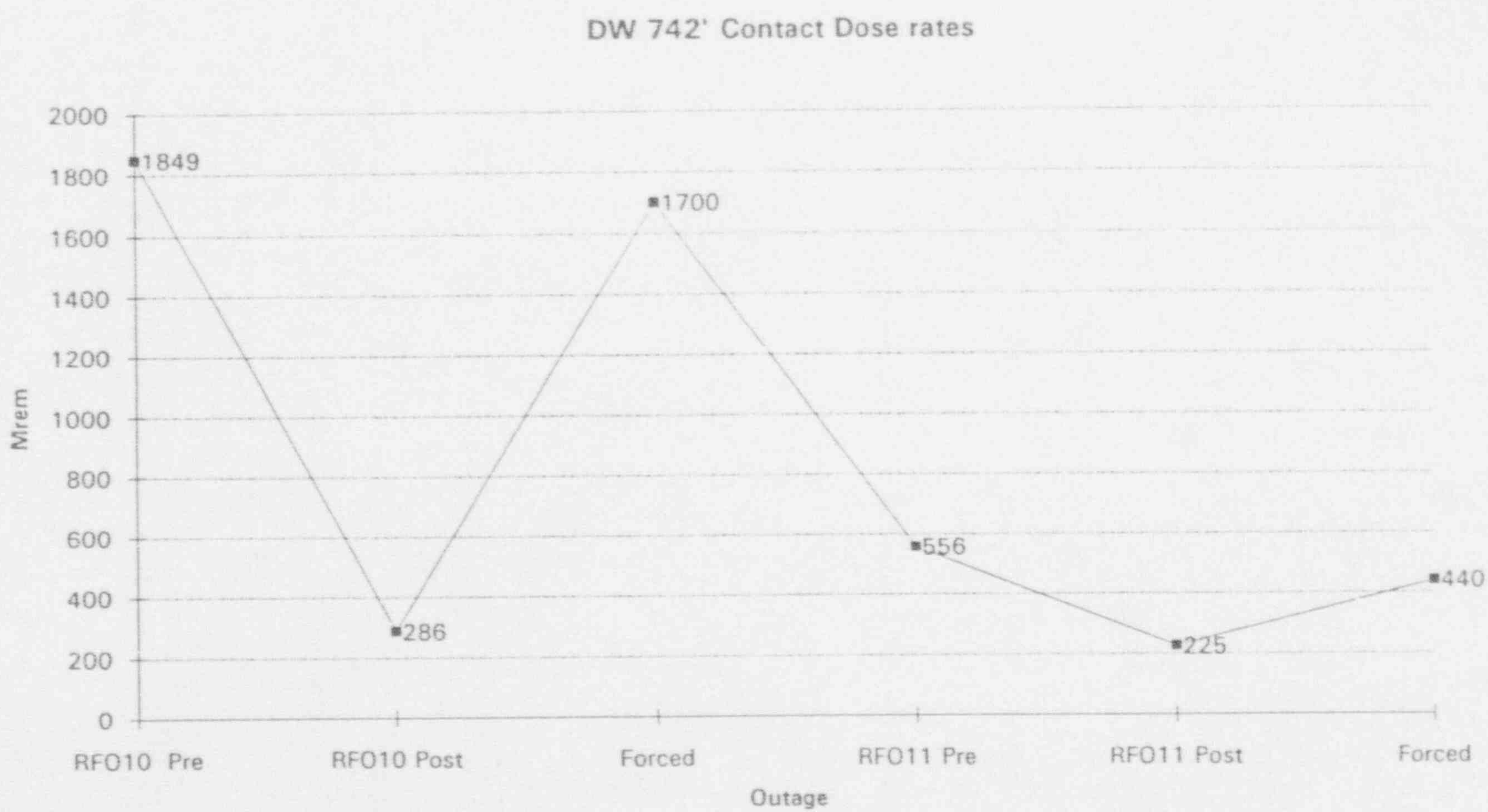
RFO13

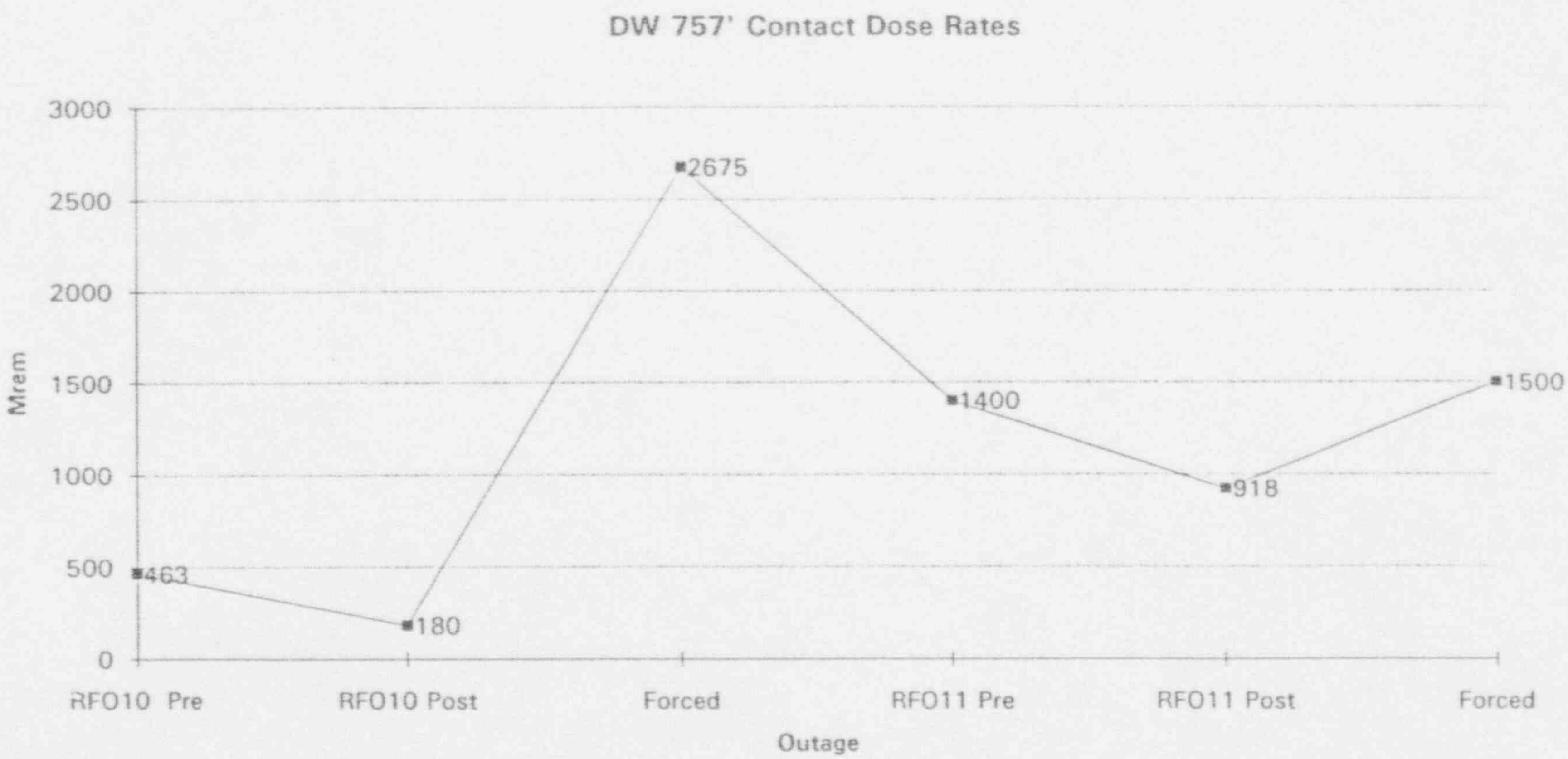
Present Scope: 61 welds   Reduced Scope: 45 welds

Dose Reduction:

16 welds x 1000 mr/weld = 16 man-Rem

This shows an approximate savings of 17 man-Rem per outage or (at $10,000 per man-Rem) $170,000. This would allow us to reach 350 man-Rem outages which puts us in line to achieve a 255 man-Rem three year rolling average as suggested by INPO.


DW 742' Contact Dose rates
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Mrem
1849
286
1700
556
225
440
RFO10 Pre
RFO10 Post
Forced
RFO11 Pre
RFO11 Post
Forced
Outage



DW 757' Contact Dose Rates
3000
2500
2000
1500
1000
500
0
Mrem
2675
1400
1500
918
463
180
RFO10 Pre
RFO10 Post
Forced
RFO11 Pre
RFO11 Post
Forced
Outage

Iowa Electric's Response to Generic Letter 88-01
with the Inclusion of Hydrogen Water Chemistry

The following table summarizes the previous inspection categories and frequencies, and revised categories and frequencies based on HWC.

SUMMARY OF INSPECTION SCHEDULES FOR IGSCC PIPING WELDS

Materials/Mitigation Process	IGSCC Category	Inspection Extent & Schedule	HWC Inspection Extent & Schedule
Resistant Material	A	25% every 10 years (at least 12% in 6 years)	No change
Non-resistant Matls (Stress Improving (SI)) within 2 yrs. of operation	B	50% every 10 years (at least 25% in 6 years)	Same as Category A
Non-resistant Matls SI after 2 yrs of operation	C	All within the next 2 refueling cycles, then all every 10 yrs (at least 50% in 6 yrs)	Same as Category B
Non-resistant Matls with No SI	D	All every 2 refueling cycles	All every 4 refueling outages.
Cracked Reinforced by weld overlay or mitigated by SI	E	50% next refueling outage, then all every 2 refueling cycles	All every 4 refueling outages.
Cracked Inadequate or no repair	F	All every refueling outage	No change
Non-resistant not inspected	G	All next refueling outage	No change

The following is a summary of the changes in the Program as a result of Hydrogen Water Chemistry and the realignment of welds into the new Categories.

CATEGORY	PREVIOUS	REVISED
A	3	3
B	N/A	86
C	91	40
D	75	40
*E	9	9
F	N/A	N/A
G	N/A	N/A

*Eight of the Category E welds are in the Reactor Recirculation System and receive benefit from Hydrogen Water Chemistry. The ninth weld is in the Residual Heat Removal (RHR) System and is not included in the request for reduced frequency examination.

This results in the following reduction in weld examinations for the next two refueling outages (RFO12 and RFO13).

S FETY RELATED WELDS

CATEGORY	PREVIOUS	REVISED	OUTAGE
A	1	1	RFO12
	1	1	RFO13
*B	N/A	5	RFO12
	N/A	7	RFO13
*C	15	11	RFO12
	15	9	RFO13
*D	35	16	RFO12
	40	23	RFO13
E	4	4	RFO12
	5	5	RFO13
F	N/A	N/A	N/A
G	N/A	N/A	N/A

This results in the following reductions of inspections for each outage:

	PREVIOUS	REVISED	% OF REDUCTION
RFO12	55	37	33%
RFO13	61	45	26%

Although the number of inspections is reduced, the safety of the DAEC is not reduced. The welds selected for inspection are a representative sample and if indications are found additional inspections will be performed as required by the original response to Generic Letter 88-01. The reduced schedule was selected based on weld configuration (pipe to fitting, valve, etc.) and obtaining a sample from each system. In addition, the representative sample will be expanded if the HWC requirements are not met.

*The Category B, C, and D welds are reevaluated to include Hydrogen Water Chemistry benefit. The 86 Category B welds were moved from the previous Category C. The Category C welds are the remaining previous Category C welds and the Category D welds that receive Hydrogen Water Chemistry benefit. The Category D welds are the remaining welds from the previous Category D.