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Materials and Fuels Evaluation
Final Report

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Materials and Fuels Evaluation

Final Report

8 September 1994

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Document Control Sheet

The following is a list of the Enrico Fermi 2 Materials and Fuels Evaluation Reports being performed for Detroit Edison Company:

Document No.	Revision No.	Date	Title
NEDC-32320		14 January 1994	Enrico Fermi 2 Materials and Fuels Evaluation - Draft Report
NEDC-32320A	A	4 March 1994	Enrico Fermi 2 Materials and Fuels Evaluation - Interim Report
NEDC-32320B	B	8 April 1994	Enrico Fermi 2 Materials and Fuels Evaluation - Second Interim Report
NEDC-32320C	C	30 June 1994	Enrico Fermi 2 Materials and Fuels Evaluation - Third Interim Report
NEDC-32320D	D	8 September 1994	Enrico Fermi 2 Materials and Fuels Evaluation - Final Report

Acknowledgments

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Executive Summary

This report provides an assessment of the impact of the circulation water intrusion transient on the materials and fuels in the Fermi 2 plant.

The reactor water chemistry data has been incorporated up to August 1994. Present reactor water chemistry is within specification. The maximum reactor water conductivity was 182 μS/cm at a pH of 10.6. The principal ions were chloride (11-12 ppm), sulfate (10-11 ppm), and nitrate (1.2-1.4 ppm). Measurements were continuously being made to monitor the cleanup performance of all impurities. As of 26 August 1994, the reactor water conductivity was 0.82 μS/cm, chloride was <1 ppb, and sulfate was <1 ppb. These levels are less than the EPRI Guidelines Action Level 1 conditions (>2.0 μS/cm conductivity , > 100 ppb chloride, > 100 ppb sulfate) for cold shutdown.

The Fermi 2 circulation water transient was compared to other recorded BWR transients. In terms of conductivity, this transient ranks the highest, with a maximum reactor water conductivity of 182 μS/cm, as compared to the next highest of 95 μS/cm. The Fermi 2 transient was unique in at least two ways:

- Both chloride and sulfate anions were present in the reactor water, whereas other transients have been typically one or the other.
- The reactor water pH was high (basic), whereas most of the other transients have resulted in low pH values (acidic).

Data from materials testing show that both chloride and sulfate anions are contributors to stress corrosion cracking. The effect of high conductivity is to decrease the time before initiation of cracking. Additional data show that a high pH environment could be less severe than a low pH environment. Two intrusions were chosen for comparison to the Fermi 2 circulation water transient. The first (Plant AL) was a chloride intrusion from seawater leakage into condenser tubes (chlorides were higher in comparison to Fermi 2 but conductivity was lower). Most of the LPRMs failed within hours of the transient. Shallow cracking was observed in a few fuel hardware components (nuts, lock tab washers, spacer band dimple). Eight years later, stress corrosion cracking of an unprecedented extent was found in the isolation condenser of this plant. The second intrusion (Plant N) was a sulfate intrusion resulting from the degradation of resin that accidentally entered the vessel. The plant experienced extensive IGSCC in creviced Alloy 600 recirculation safe ends four years after the transient (Appendix 6).

The effects of chlorides on pitting are addressed in this report, as well as the effects of microbiological induced corrosion (MIC). Microbiological samples established that there is a concern for MIC within reactor systems. A recommended RPV corrosion evaluation plan was written to address damage assessment of the RPV to microbiological activity. Inspection of the RPV surfaces by a diver determined that there was no evidence of MIC damage as of 29 June 1994. Since microbes become inactive at temperatures above 200°F, it is not expected that MIC damage will occur to the reactor pressure vessel and internals during startup or operating cycle.

It is recommended that further assessment of operating systems below 200°F be reviewed by DECo, as those systems are most susceptible to potential MIC damage.

A tabulation of the vessel internals, including the control rod drives and in-core sensor materials was made and an evaluation was performed to assess the susceptibility of these components and to identify any immediate impact as a result of this transient. For vessel structural components, no immediate impact was expected and inspection of the most susceptible components to establish a baseline was performed. As there is likely to be some impact in the future on SCC, an evaluation to quantify this effect is presented (Appendix 6). Flushing of stagnant areas in the vessel was performed during RF04, as well as replacement of the jet pump beams.

For the CRDs, inspection was recommended and performed during the already planned maintenance of drives. More corrosion products and pitting were detected on the inspected CRDs than was considered typical for CRDs of this age. Twenty drives were rebuilt during the outage; there are no recommendations to increase the number. Daily flushing and exercising of the CRD mechanisms were performed during the outage to prevent crevice corrosion of the piston tubes. Analysis of a graphitar seal, C-spring, retaining spring, and debris deposits confirmed that flushing of the CRDs was effective and that continued flushing and exercising of the drives was the correct recommendation.

Shroud head bolts (SHBs) were ultrasonically inspected by DECo. It was found that 16 of the 48 SHBs exhibited evidence of cracking. All of the rejected SHBs were replaced and one additional bolt was replaced because of bowing found during the removal and repositioning process. The new, non-crevice design SHBs were placed in a symmetrical pattern. A new seismic/stress analysis was performed and it was determined that only 20 bolts were required to maintain a positive margin.

The majority of the Fermi 2 LPRMs were of the same model that failed during the comparison chloride intrusion; however, only two of the Fermi 2 LPRM detectors failed after the circulation water intrusion. Fermi 2 had some of the newer model LPRM sensors, which have an improved non-crevice design. DECo replaced the older model LPRMs with the improved non-crevice design LPRMs.

All of the IRM/SRM dry tubes installed in Fermi 2 were of the original equipment type, which have experienced stress corrosion cracking failures in other BWR environments. Inspections were made of the susceptible portion of the dry tubes in a manner consistent with the procedure outlined in an existing GE Service Information Letter for inspection (Ref. 25). No rejectable defects were found.

The impact of the circulation water intrusion on the zircaloy components of fuel, including fuel rod cladding, spacers and channels, was insignificant. Visual inspection of the cladding, selected fuel bundle components, and fuel deposits showed that the fuel was unaffected by the transient.

Fermi 2 has 20 control rod blades of the type that have experienced stress corrosion cracking near spot weld regions as a result of high conductivity and irradiation conditions. Two of these type blades were inspected during the RF04 outage and were found to be acceptable. It is recommended that the same two blades be inspected during the RF05 outage.

The G[redacted]model predicts that for Fermi 2, stress corrosion cracks in components wetted by contaminated water as a result of the chemistry transient will propagate at a rat[redacted] that projected for the same components in normal BWR water. Therefore, some augmented inspection of high susceptibility components is prudent.

Fermi 2 is already performing augmented inspections of numerous components and systems to comply with various NRC IE Notices and Regulatory Guides, plus a wide range of GE SILs, RICSILs and other recommendations (Section 4.2). These augmented inspections are judged to be adequate to monitor potential degradation due to stress corrosion. For those components and systems judged to be susceptible to SCC which are not presently included under existing inspection programs, it is recommended that DECo develop criteria for inspection over the next reactor cycle.

Model calculations demonstrate that controlling reactor water conductivity is important in future crack growth considerations. Model calculations also demonstrated the benefit of hydrogen water chemistry in reducing future crack growth concerns.

1.0 Initial Assessment

The purpose of this report is to support Detroit Edison Company (DECo) in evaluating the impact of the water chemistry transient caused by the 25 December 1993 turbine/turbine generator-failure at the Fermi 2 plant. Specifically, the impact on reactor vessel internals, fuel, and primary systems is addressed. This evaluation consists of an assessment of immediate impacts to be addressed prior to plant restart, operational recommendations for inspections, and detailed assessment of the potential long range impacts. This report can also be used to document that the structural integrity is sound in accordance with Tech Spec 3.4.4.

1.1 Description of Event

1.1.1 Event Scenario

Prior to the incident, Fermi 2 was running at 93.4% power; temperature and pressure were 288°C (550°F) and 1030 psig, respectively. Reactor water conductivity was 0.09 µS/cm at a pH of 6.9.

Reactor scram occurred at 1315 EST on 25 December 1993, due to a turbine control valve (TCV) fast closure. The initiating signals for the TCV fast closure were main turbine generator bearing HI vibration and main turbine mechanical overspeed trip. Number 3 low-pressure turbine threw four blades from the 8th Stage. The root cause of the blade separations is still under investigation. One blade punctured the exhaust hood, creating a 30" x 18" hole. The other blades were thrown downward, severing many condenser tubes. This resulted in a massive ingress of untreated circulating water into the hotwells.

Excess water from the condenser hotwells was routed to the condensate storage tank (CST). Because the reactor water level had decreased to a Level 3 condition, the Reactor Core Isolation Cooling (RCIC) System was placed in service to restore level approximately 15 minutes after the scram. The RCIC System was aligned to receive suction from the CST, which by this time had a considerable inventory of circulation water impurities. Shortly thereafter, the standby feedwater pumps, which also take suction from the CST, were placed in service. The CST input to the vessel significantly degraded the quality of the reactor water.

The RCIC System was shut down at 1548 EST, as it was apparent that the water quality of the CST was degrading further. At 1605 EST, the RCIC System was restarted, now taking suction from the torus. The Condensate System was shut down at 1611 EST, and circulation water was isolated from the main condenser at 1626 EST. By 1810 EST, the first chemistry analyses of the reactor water after the transient were available. The reactor water conductivity was 61.4 µS/cm at a pH of 9.8. High concentrations of both chloride and sulfate ions (4-5 parts per million [ppm]) were reported. EPRI BWR Water Chemistry Guideline Action Level 3 (5.0 µS/cm conductivity, >200 ppb chloride or >200 ppb sulfate) suggests that an orderly shutdown be initiated immediately with reduction of coolant temperature to <100°C (212°F) as rapidly as other plant constraints permit. Although the plant scrammed immediately, considerable time was required to reduce the temperature below the recommended value.

Vessel cooldown did not commence until approximately one hour after the scram. A temperature plateau of approximately 171°C (350°F) was obtained at 2100 EST. This temperature was maintained until 1700 EST the following day (26 December 1993). Coincidentally or otherwise, the extremes of the chemistry transient were observed roughly in this time frame. The reactor water conductivity had increased to 182 μS/cm at a pH of 10.6. The principal ions contributing to the conductivity were chloride (11-12 ppm), sulfate (10-11 ppm), and nitrate (1.2-1.4 ppm). Subsequent analyses of calcium (16-20 ppm as $CaCO_3$ or 8 ppm as Ca) and sodium (5-6 ppm) were reported after the transient maxima.

The Residual Heat Removal (RHR) System was placed in the shutdown cooling mode at 2010 EST on 26 December 1993. As a result, the vessel temperature rapidly decreased (Mode 4 cold shutdown at 2251 EST) to a second plateau at 61°C (150°F), achieved at approximately 0100 EST on 27 December 1993. This temperature was maintained for the next 2 ½ days, with a final decrease to 38°C (100°F) on 29 December 1993. A plot of reactor coolant temperature versus time for the seven-day period beginning on 25 December 1993 is shown in Figure 1.1-1. The reactor water conductivity during the same time period is shown in Figure 1.1-2. Since 1 January 1994, the reactor coolant temperature has been maintained between 32°C (90°F) and 43°C (110°F).

The Control Rod Drive (CRD) System tripped approximately 1552 EST on 25 December 1993 and was restarted about an hour later. CRD cooling was continued, even though poor water quality from the CST was entering the drives and reactor, so that cooling could be maintained on the drives. Shortly after reactor temperatures were reduced, as a result of placing the RHR System in the shutdown cooling mode, the CRD Hydraulic System (CRD-HS) was shut down at 2155 EST on 26 December 1993.

Since the peak transient, some reactor water purification was achieved utilizing the Reactor Water Cleanup (RWCU) System; this powdered resin system was not designed, however, to process such large volumes of water with such high conductivity. As a consequence, various temporary plant modifications were initiated to expedite the cleanup of the reactor water by "feed and bleed" techniques through more efficient portable bead resin demineralizer systems. These operations continued until the Radwaste System and associated water treatment systems were restored.

1.1.2 Water Chemistry Concerns

1.1.2.1 Principal Reactor Water Ionic Impurities

Chronological plots of the Fermi 2 reactor water conductivity, pH, and the concentrations of chloride, sulfate, nitrate ions and silica for the period 25 December 1993 until late March are depicted in Figures 1.1-3 through 1.1-8. Conductivity is a reflection on the total quantity of soluble ionic impurities in the water, and includes contributions from both positively and negatively charged species (cations and anions, respectively). At 25 °C, the conductivity of theoretically pure water is 0.055 μS/cm. From 29 December 1993 until 9 January 1994, reactor water conductivity slowly decreased from 120 μS/cm to 90 μS/cm. A very positive downward trend was not established until 10 January with the augmented "feed and bleed" to the Condensate Return Tank. Additional side-stream demineralization through the RWCU System contributed to the purification of the reactor water to more acceptable levels.

A somewhat unique chemistry parameter associated with the Fermi 2 transient was the high reactor water pH. Most of the major chemistry transients that occurred in GE BWRs resulted in pH readings lower than 7. pH values as low as 3 have been observed, which is four orders of magnitude more acidic than neutral solutions. Resin intrusions are usually responsible for these acidic pH transients. From the onset of the Fermi 2 transient until mid January, reactor water pH persisted around a value of 10. The high pH was largely associated with the ingress of the circulating cooling water into the reactor. The "feed and bleed" purification of the reactor water reduced the reactor water pH. By early February, the pH returned to a neutral value of 7 as the purification effort continued.

The Fermi 2 transient was also unique, in that high concentrations of both chloride and sulfate were present in the reactor water. Previous major transients in GE BWRs have been characterized by the ingress of one species or the other, but not both to the magnitude of the Fermi 2 event. Both ions originated from the circulation water that entered the vessel. Chloride ion was present from the chlorination of the circulation water. Sulfate ion, a major constituent of Lake Erie water, was from concentration in the cooling tower circulation water system. This concentrating mechanism was also apparently responsible for the relatively high levels of nitrate ion in the reactor water.

The concentrations of both chloride and sulfate ion were reduced in a parallel fashion with the conductivity since the onset of "feed and bleed" cleanup operations. Chemistry limit values were returned to Technical Specification limits.

1.1.2.2 Material Balances

Comparison of the ratio of the concentration of impurities in the reactor water to the circulation water provides clues as to some chemical changes that may have occurred. Sodium and chloride showed a concentration ratio of about 0.5. This suggests that a factor of two dilution of circulation water resulted from the incident. The lower concentration ratios measured for calcium and sulfate suggests that deposition of these species could have occurred, although there is no physical evidence this occurred.

As shown in Figure 1.1-9, chloride concentration decreased at a moderate rate shortly after reaching its peak value, while sulfate concentrations decreased much more rapidly for the period when elevated temperatures existed. Although calcium analyses were not available during the period, calcium sulfate is known to be less soluble at elevated temperatures.

A conductivity balance was attempted for the two reactor water samples. The results for the 29 December 1993 sample are shown in Table 1.1-2. The results for the 10 January 1994 sample are shown in Table 1.1-3. The major cations contributing to the measured conductivity appear to be sodium, calcium, potassium and magnesium. The latter two elements were not measured in the December sample and are estimated based on the values measured for the January sample.

The major anions contributing to the measured conductivity appear to be chloride, sulfate, nitrate, bicarbonate, and carbonate along with the hydroxyl ion which causes the elevated pH. The total alkalinity was measured in both samples. However, to balance the conductivity/pH for the December sample, a total alkalinity of 20.2 ppm as $CaCO_3$ was estimated as compared to a measured value of 32 ppm. A total alkalinity of 22.75 ppm as $CaCO_3$ was to be estimated for the January sample instead of the 2.04 ppm measured alkalinity.

During the initial phase of the incident, when the reactor was at 227°C (540°F) with cooling being accomplished by steam being released through relief valves to the suppression pool, some carbon dioxide was probably stripped, raising the pH of the coolant. During this process, it is believed that magnesium hydroxide could have partially precipitated in the vessel, along with the calcium sulfate previously mentioned. The single high silica concentration of 1740 ppb measured on 26 December 1993 was followed by a measured concentration of 529 ppb on the next day. This dramatic reduction in silica may suggest that precipitation of calcium and/or magnesium silicate compounds may have occurred.

1.1.2.3 Circulation Water Scale Inhibitor

A scale inhibitor is periodically added to the condenser cooling water. The compound is referred to as Powerline 3461, or Betz 3461. This product is used in concentrations of 1 to 8 ppm (as product). The product has 25% active materials which consist of 80% polyepoxysuccinic acid (PESA), with the remainder polyacrylic acid. Based on the concentration of this inhibitor (3.2 ppm as product) in the circulation water shortly after the incident, and the factor of two dilution previously estimated (using sodium and chloride as indicators), the concentration in the reactor water of PESA would have been about 320 ppb and polyacrylic acid would be about 80 ppb. These organic compounds are expected to be partially removed by the various cleanup systems being used. However, upon restart, the unremoved organic matter will decompose in the presence of high temperature and the radiation field, increasing the reactor water conductivity. Typical total organic carbon (TOC) monitors may not quantitatively measure these compounds and other organic compounds that may have entered the reactor, and that may be present in other systems. DECo chemists should be alert to the presence of organic matter that is resistant to breakdown in conventional TOC analyzers so that a correct evaluation of organics present in various systems can be made.

1.1.2.4 Chloride Carryover

Due to the high concentrations of chloride in the reactor water shortly after the reactor scram, there are some concerns about its concentration in the steam phase, which could affect the corrosion of drain lines and other components in the main steam piping system. Here, it may be fortuitous that the coolant pH was very alkaline. Under acidic conditions (ca. pH 4), chloride in the form of hydrochloric acid is volatile, resulting in substantial carryover with the steam phase. Neutral sodium chloride has a volatility of about 0.0001%. Mechanical carryover is expected to be less than 0.1%. With relatively low steam flows, the chloride concentration in the steam phase as a result of mechanical carryover is estimated to be less than 10 ppb. At pH 10, the volatile carryover is expected to be significantly less.

1.1.2.5 Hot Spots/Recirculation Piping Dose Rates

The significant vibrations associated with the scram and the chemistry transient may have liberated significant quantities of activated crud from fuel surfaces and other reactor internals. Accordingly, there may be several localized areas within the drywell where this crud has resettled in dead legs or other low flow areas. Although not found during RF04, higher than normal radiation levels in some areas may be anticipated during operation and RF05.

1.1.2.6 Startup TSP Passivation/System Flushing

Trisodium phosphate (TSP) was used at Fermi 2 for piping system passivation during the initial startup. Since the plant has been in operation for a number of years, the corrosion/passivation film is well established; therefore, no "repassivation" step is required prior to restart. Some major piping and instrument line flushing still remains to be performed and should be completed prior to startup.

1.1.2.7 Reactor Water Chemistry History

During 1993, prior to the turbine damage event, Fermi 2 reactor water conductivity averaged 0.091 μS/cm. Figure 1.1-10 displays the improving trend since the beginning of plant operation. Fermi 2 was one of the plants in the top quartile for reactor water conductivity in 1993.

1.1.2.8 Fuel Pool Water Chemistry

The fuel pool water conductivity is displayed in Figure 1.1-11. Prior to and after the turbine damage event, the fuel pool water chemistry remained good. However, about mid February a leaking valve (G41-F015) allowed a small amount of contaminated water to enter the fuel pool. This valve is normally a "Locked Closed" valve that supplies makeup condensate water to the Fuel Pool Cooling and Cleanup (FPC&C) skimmer surge tank. The condensate storage jockey pump was pressurizing the reactor building condensate supply header, which was providing degraded demineralized water from the Condensate Return Tank to the Control Rod Drive System. The valve was repaired on 17 February 1994. For a two-week period, the fuel pool conductivity increased to 2-3 μS/cm. During this period, the chloride concentration was measured at 100-200 ppb and the sulfate concentration was measured at 200-260 ppb. Normally, these impurities are present at levels less than 10 ppb. A new resin precoat was applied to the Fuel Pool filter/demineralizers on 21 February 1994, allowing the conductivity to decrease to a more acceptable value (below 1 μS/cm). It is believed that the short time period above 1 μS/cm did not affect fuel and components located in the fuel pool.

1.1.3 Comparison to Previous Transients

1.1.3.1 Description of Transients

Many chemistry related transients have occurred at operating BWRs. Rather than present many cases, the two transients closest to Fermi 2 in terms of reactor water conductivity levels and types of impurities were chosen for comparison. Additionally, these plants have attributed later failures to these particular chemical intrusions. One transient occurred at a BWR/3 in 1972 (designated as plant AL). Condenser tube leakage resulted in seawater intrusion into the reactor. The predominant species was chloride. The other transient occurred at a BWR/4 beginning on April 1974 (designated Plant N). Resins were inadvertently injected into the reactor water via the RWCU System. The predominant species from resin degradation in the vessel was sulfate. It should be noted that no transient has included both chloride and sulfate in the same magnitudes as the Fermi 2 transient. The two transients are compared to the Fermi 2 transient in Table 1.1-5.

1.1.3.2 Chloride Intrusion Transient at a BWR/3

During the course of a normal plant startup on 1 September 1972, seawater contaminated the reactor primary system through condenser leaks (Ref. 1). The reactor was at rated pressure for less than one hour when a high reactor water conductivity was recorded. A plant shutdown was then initiated. During the transient, the reactor water reached a maximum chloride level of 15 ppm, a maximum conductivity of 84 μS/cm, and the pH dropped to a value of 3. The RWCU System remained in service and restored the reactor water conductivity to 5 μS/cm within 18.5 hours of the high conductivity indication. The reactor reached the cold shutdown condition approximately 19.5 hours after the reactor water high conductivity was first observed.

1.1.3.3 Sulfate Intrusion Transient at a BWR/4

The sulfate intrusion transient of interest was followed by several cycles of reactor heatups and shutdowns that were performed in an attempt to degrade and subsequently clean up the resin that entered the reactor water.

On 3 April 1974, and perhaps later, resins were accidentally injected into the reactor via the RWCU System (Ref. 2). On 26 April 1974, during initial heatup, the reactor water conductivity went from 1 μS/cm (1230 hours) to 33 μS/cm in a 4.5 hour period. Reactor water pH dropped to about 4. Nuclear and thermal degradation of the resins was determined to be the cause. The reactor water was maintained at 85°C (195 °F) for approximately 1.5 hours while cleanup with the RWCU System was attempted. When this proved ineffective, a normal shutdown was initiated (1822 hours). The reactor water conductivity reached 5 μS/cm within 24 hours (27 April 1974, 1530 hours) of the high reactor water conductivity indication. A second attempt to heat the reactor on 28 April 1974 was stopped when the reactor water conductivity reached 7.8 μS/cm. The subsequent cleanup was accomplished by heating the reactor until a conductivity level of 10 μS/cm was reached, shutting down, cleaning up the water, and then repeating the cycle. This took 11 cycles over a period of 18 days. Between 27 April and 15 May 1974, the reactor water conductivity had been above 5 μS/cm for 244 hours, and for 89 hours of that time it was above 10μS/cm.

Table 1.1-1

Reactor Water and Circulation Water Samples

Parameter	Units	Reactor Water	Circulation Water	Ratio Reactor Water to Circ Water	Reactor Water
Sample I. D.		RWCU influent			RWCU Influent
Sample Date		12/29/93	12/29/93	12/29/93	1/10/94
Sample Time		?	?		15:10
pH		10.2	-	-	9.8
Conductivity	(µS/cm)	113	364	0.31	93
Chloride as Cl	ppm	10.4	19.4	0.54	8.4
Nitrate as NO_3	ppm	0.46	3.9	0.12	0.400
Sulfate as SO_4	ppm	5.3	33.8	0.16	3.9
Total Alkalinity as $CaCO_3$	ppm	32	170	0.19	2.04
Sodium as Na	ppm	5.6	11.9	0.47	5.3
Potassium as K	ppm	EST 0.744	-	-	0.704
Magnesium as Mg	ppm	EST 0.973	-	-	0.93
Calcium as $CaCO_3$ as Ca	ppm	20 8	72 28.8	0.28	 7.65
Fluoride as Fl	ppm	-	-	-	< 0.066
Phosphate as PO_4	ppm	-	-	-	< 0.235
Chromate as CrO_4	ppm	-	-	-	< 0.100
Iron as Fe	ppm	0.010	-	-	< 0.100
Copper as Cu	ppm	INS <0.005	-	-	< 0.100
Nickel as Ni	ppm	INS <0.005	-	-	< 0.100
Zinc as Zn	ppm	INS <0.005	-	-	< 0.100
Manganese as Mn	ppm	INS <0.005	-	-	< 0.100
Ammonium as NH_4	ppm	-	-	-	< 1.25
[redacted] Scale Inhibitor	ppm	-	[redacted]	-	-

Table 1.1-2

Fermi 2 Reactor Water Conductivity Balance - 29 December 1993 Sample

Cation Species	Conc. ppb	Equivalents per liter	Conductivity µS/cm	Anion Species	Conc. ppb	Equivalents per liter	Conductivity µS/cm
H^+	-	6.31E-11	0.00	OH^-	-	1.59E-04	31.59
Na^+	5600	2.44E-04	12.21	Cl^-	10400	2.93E-04	22.40
Ca^{+2}	8000	3.99E-04	23 75	SO_4^{-2}	5300	1.10E-04	8.83
				NO_3^-	460	7.42E-06	0.53
EST K^+	744	1.90E-05	1.40	EST HCO_3^-	6018	9.86E-05	4.39
EST Mg^{+2}	973	8.00E-05	4.25	EST CO_3^{-2}	2200	7.33E-05	5.28
Total		**7.42E-04**	**41.60**			**7.42E-04**	**73.02**

Calculated Conductivity	**114.6**
Measured Conductivity	**113**
Calculated pH	**10.2**
Measured pH	**10.2**
Calculated Total Alkalinity	**20.2**
Measured Total Alkalinity	**32**

Table 1.1-3

Fermi 2 Reactor Water Conductivity Balance - 10 January 1994 Sample

Cation Species	Conc. ppb	Equivalents per liter	Conductivity μS/cm	Anion Species	Conc. ppb	Equivalents per liter	Conductivity μS/cm
H^{+}	-	1.59E-10	0.00	OH^{-}	-	6.31E-05	12.55
Na^{+}	5300	2.31E-04	11.55	Cl^{-}	8400	2.37E-04	18.09
Ca^{+2}	7650	3.82E-04	22.71	SO_4^{-2}	3900	8.12E-05	6.50
				NO_3^{-}	400	6.45E-06	0.46
K^{+}	704	1.80E-05	1.32	EST HCO_3^{-}	15023	2.46E-04	10.96
Mg^{+2}	930	7.65E-05	4.06	EST CO_3^{-2}	2186	7.29E-05	5.25
Total		**7.07E-04**	**39.65**			**7.07E-04**	**53.80**

Calculated Conductivity	**93.5**
Measured Conductivity	**93**
Calculated pH	**9.8**
Measured pH	**9.8**
Calculated Total Alkalinity	**22.75**
Measured Total Alkalinity	**2.04**

Table 1.1-4
Microbiological Analyses Results

Sample	Date	Aerobic	Anerobic	Acid Producing	Sulfate Reducing
		(organisms per milliliter)			
Reactor Water	1/28/94	ND	ND	ND	ND
Torus Water	1/28/94	ND	ND	ND	ND
Fuel Pool Water	1/28/94	ND	ND	ND	ND
Condensate Storage Tank	1/28/94	10 to 100	1 to 10	ND	ND
Condensate Return Tank	1/28/94	100 to 1000	1 to 10	ND	ND
Turbine Building Closed Cooling Water System	1/28/94	ND	ND	ND	ND
Hotwell	2/4/94	1 to 10	ND	ND	ND
Feedwater Heater #4 (tube side)	2/4/94	ND	ND	ND	ND
Reactor Building Closed Cooling Water System	2/4/94	ND	ND	ND	ND

ND = not detected

Table 1.1-5

Comparison of Transients at Two Plants with the Fermi 2 Recent Transient

Parameter	Plant AL	Plant N	Fermi 2
Start Date	1 September 1972	26 April 1974	25 December 1993
Maximum Conductivity	84 μS/cm	33 μS/cm	182 μS/cm
Maximum Chloride	15 ppm		12 ppm
Maximum Sulfate	2 ppm (estimated)	Not measured (3.7 ppm estimated)	10 ppm
Minimum or Maximum pH	3	4	10
Duration (time from when high conductivity noted until cold shutdown)	19.5 hours	Above 5 μS/cm for 244 hours Above 10 μS/cm for 89 of those hours	28 hours

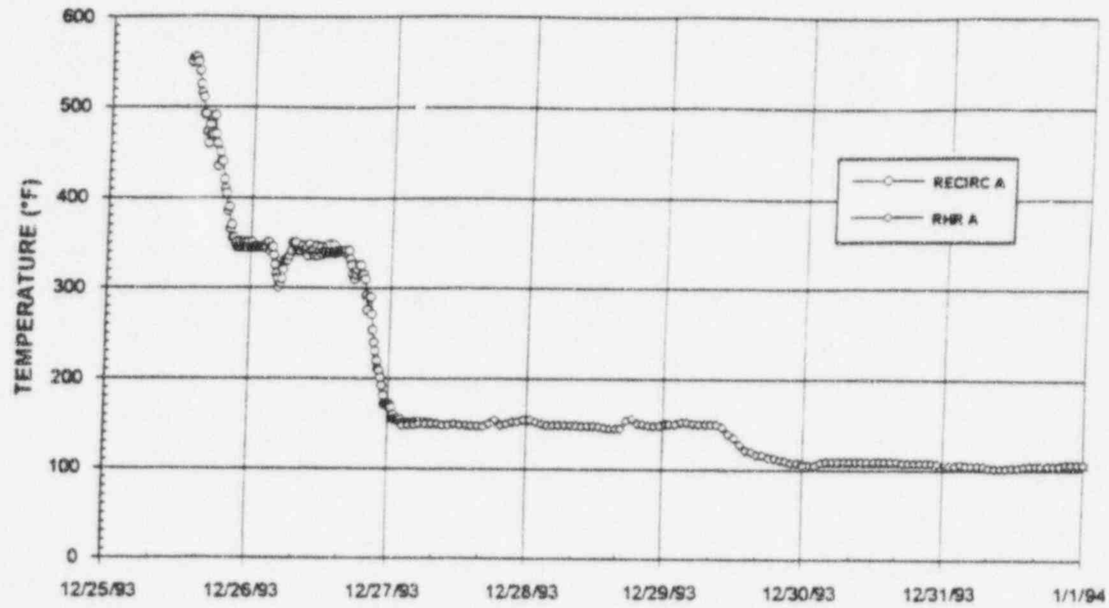

Figure 1.1-1 Reactor Water Temperature as a Function of Time, from the 25 December 1993 to 1 January 1994

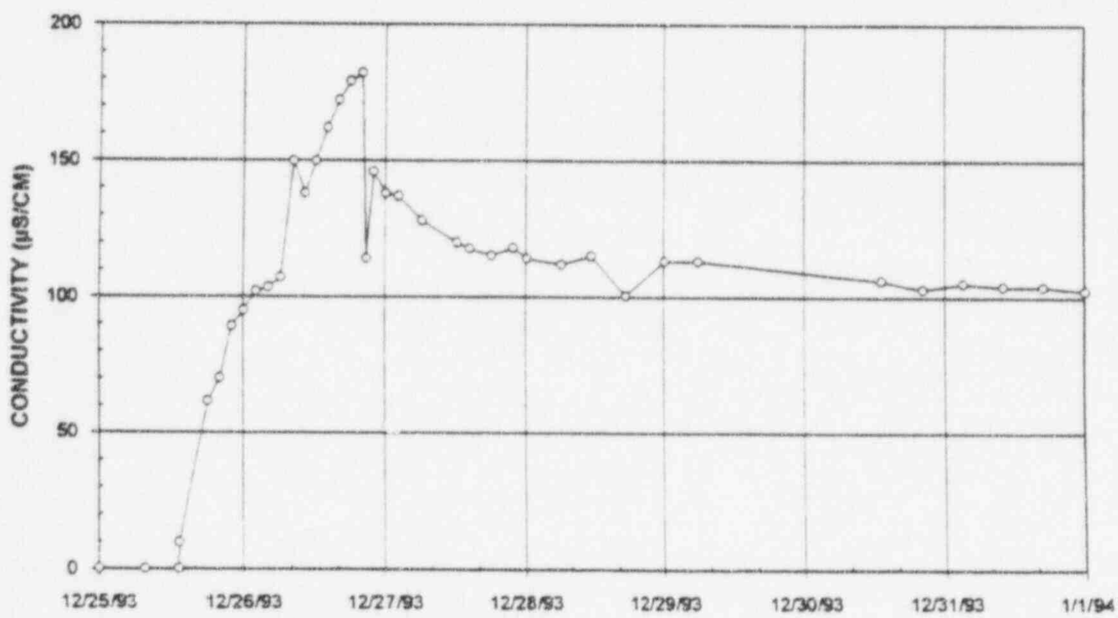

Figure 1.1-2 Reactor Water Conductivity as a Function of Time, from 25 December 1993 to 1 January 1994

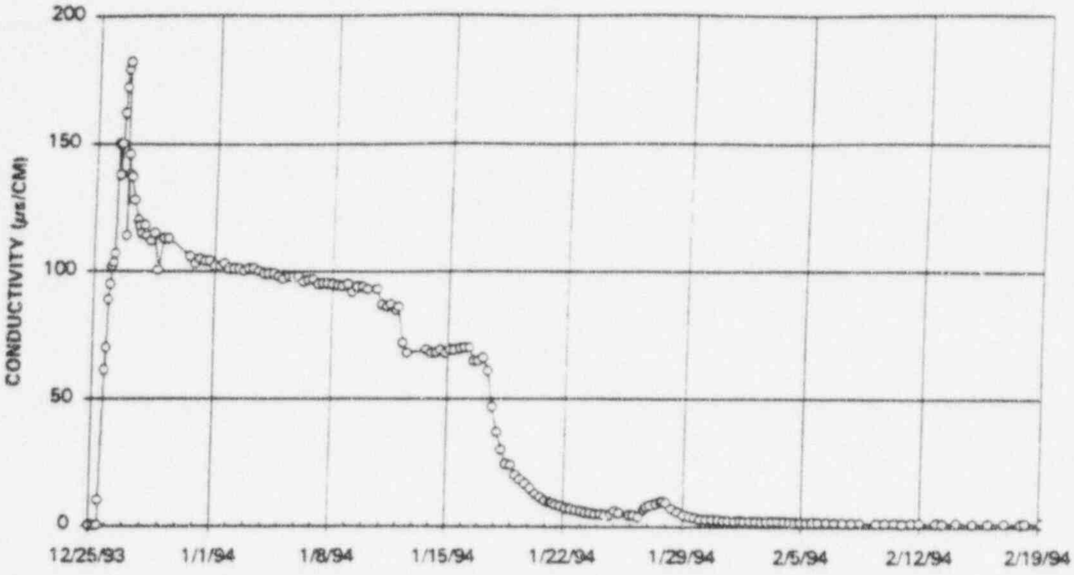

Figure 1.1-3a. Reactor Water Conductivity as a Function of Time, from 25 December 1993 to 10 February 1994

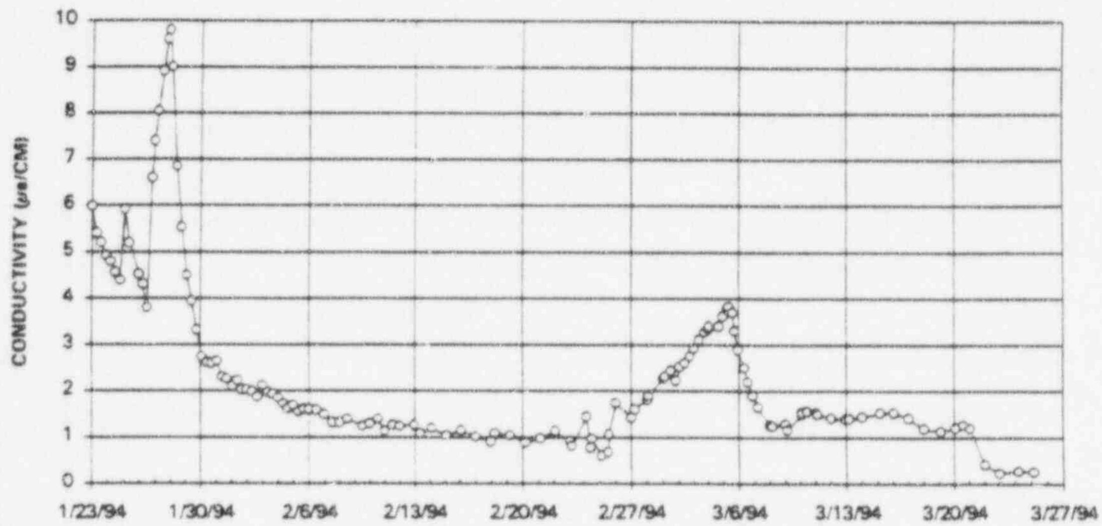

Figure 1.1-3b. Reactor Water Conductivity as a Function of Time, from 23 January 1994 to 25 March 1994

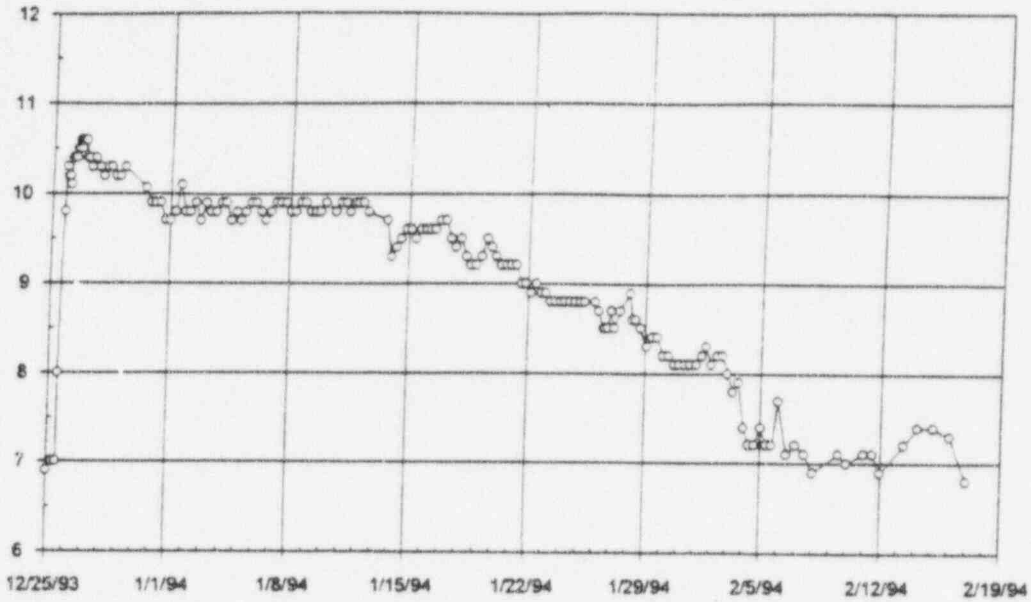

Figure 1.1-4a. Reactor Water pH as a Function of Time, from 25 December 1993 to 17 February 1994

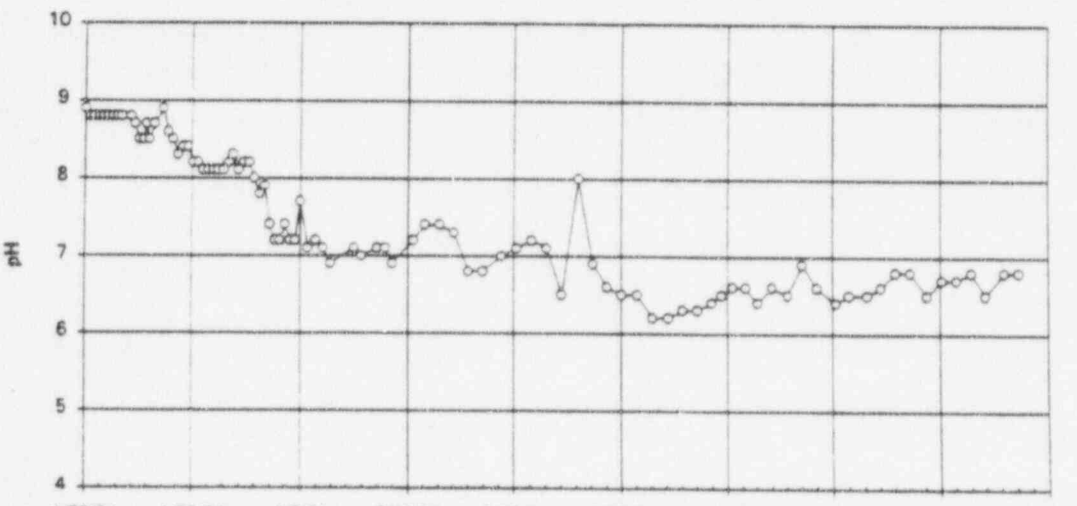

Figure 1.1-4b. Reactor Water pH as a Function of Time, from 23 January 1994 to 25 March 1994

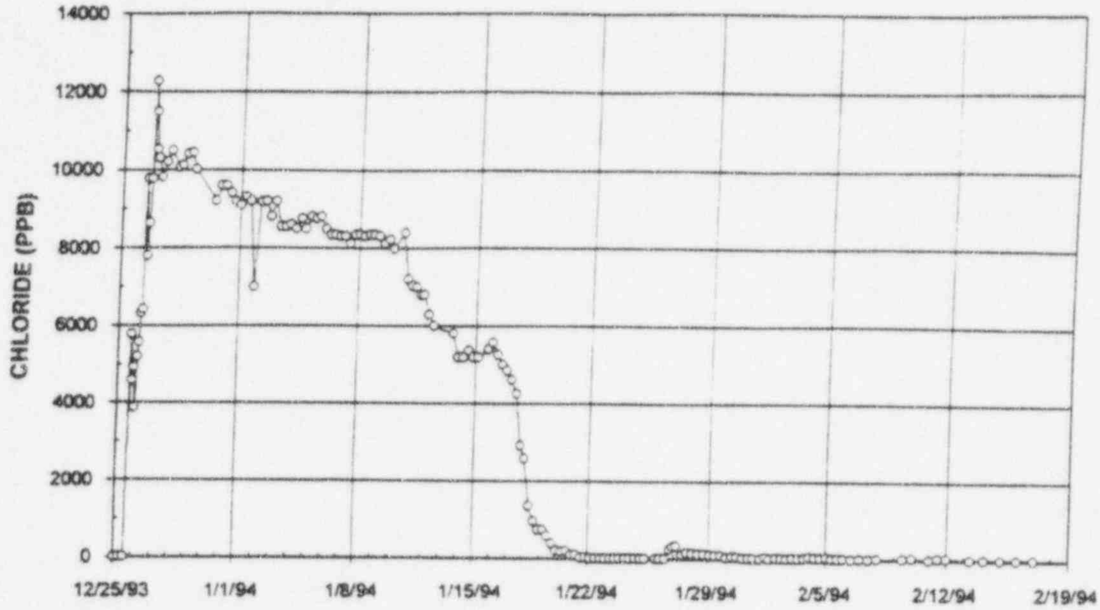

Figure 1.1-5a. Reactor Water Chloride Concentration as a Function of Time, from 25 December 1993 to 17 February 1994

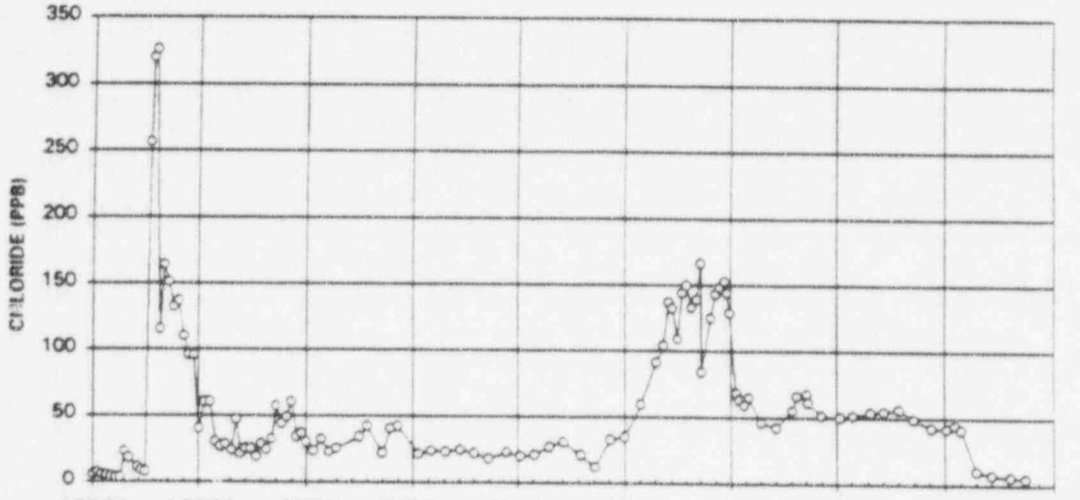

Figure 1.1-5b. Reactor Water Chloride Concentration as a Function of Time, from 23 January 1994 to 25 March 1994

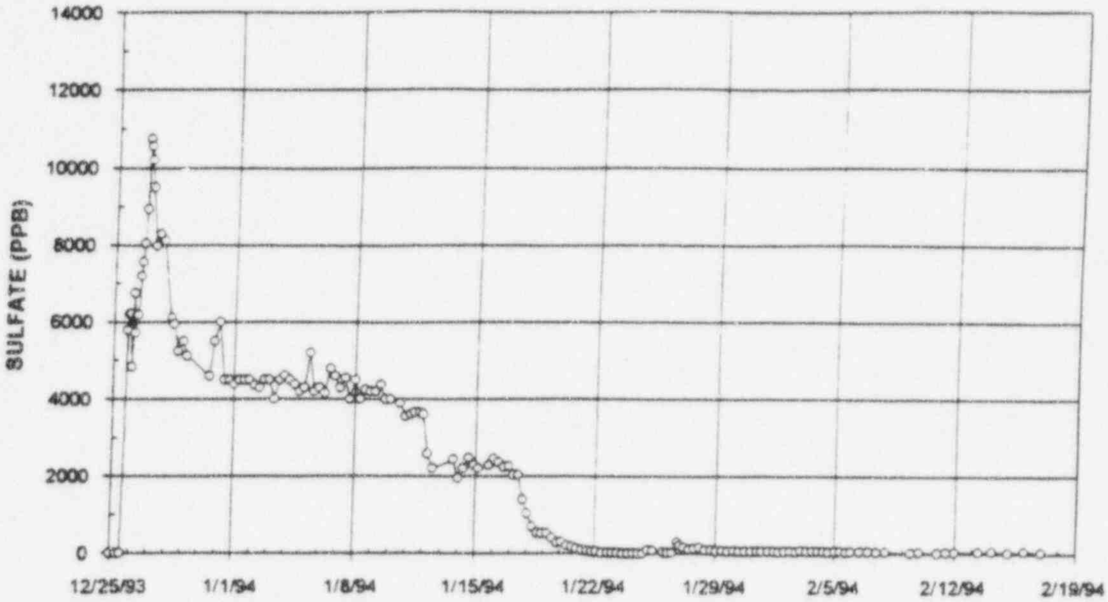

Figure 1.1-6a. Reactor Water Sulfate Concentration as a Function of Time, from 25 December 1993 to 17 February 1994

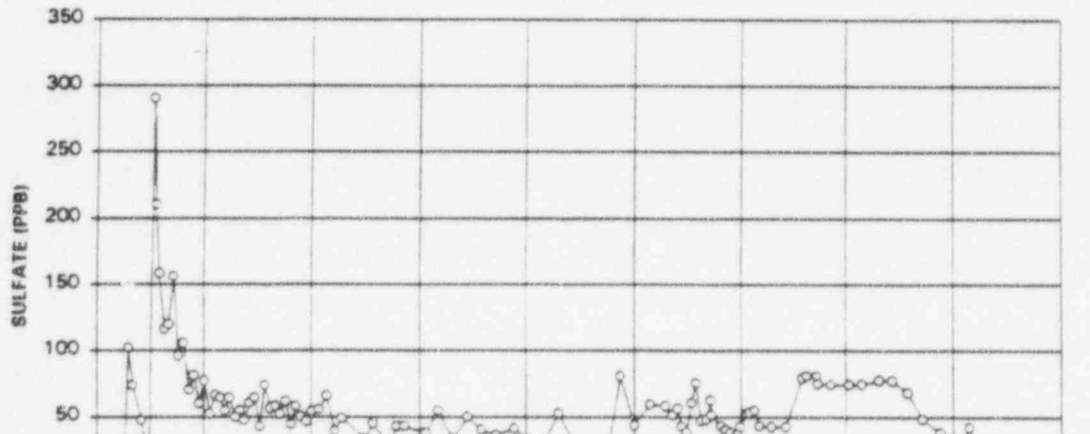

Figure 1.1-6b. Reactor Water Sulfate Concentration as a Function of Time, from 23 January 1994 to 25 March 1994

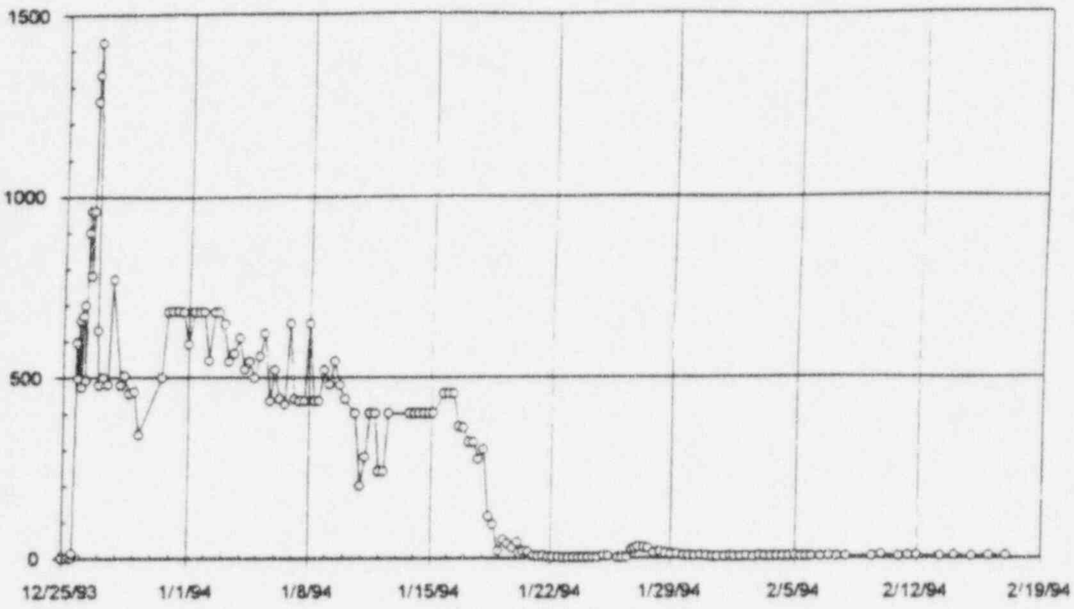

Figure 1.1-7a. Reactor Water Nitrate Concentration as a Function of Time, from 25 December 1993 to 17 February 1994

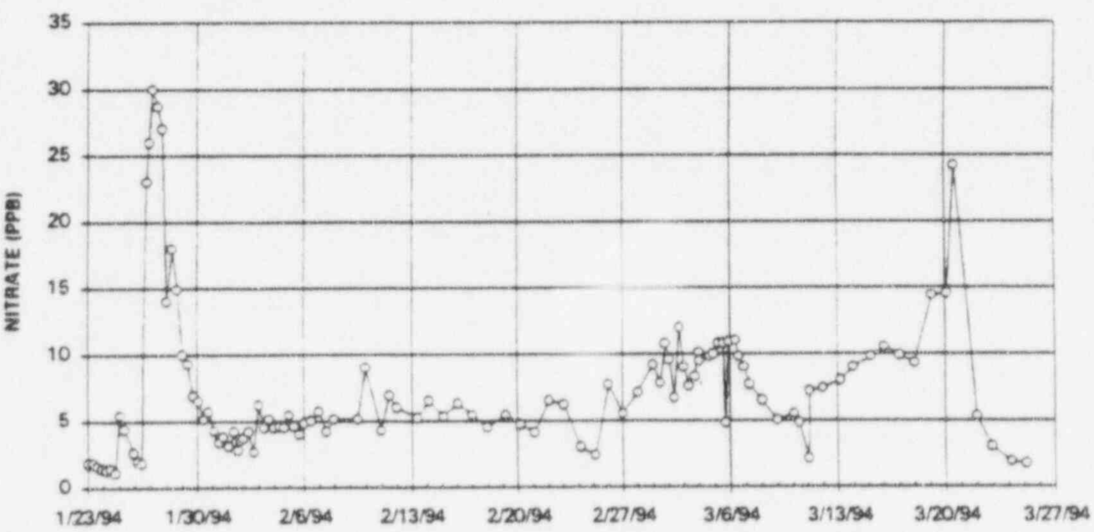

Figure 1.1-7b. Reactor Water Nitrate Concentration as a Function of Time, from 23 January 1994 to 25 March 1994

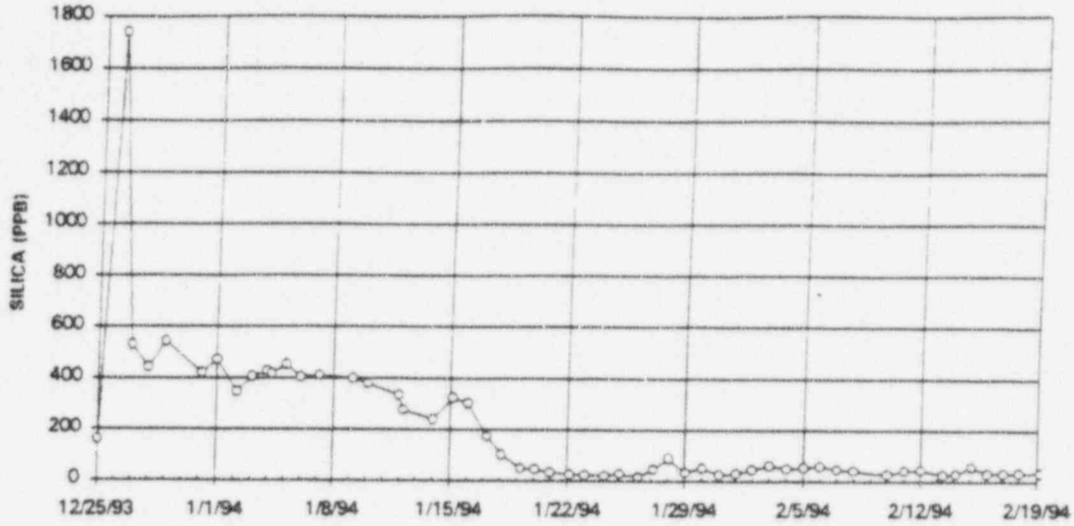

Figure 1.1-8a. Reactor Water Silica Concentration as a Function of Time, from 25 December 1993 to 17 February 1994

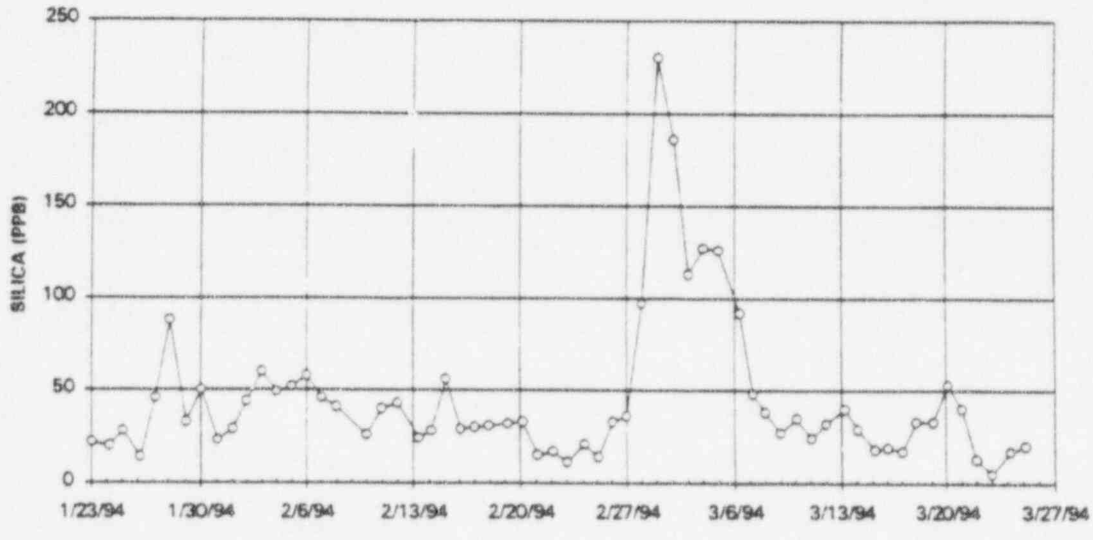

Figure 1.1-8b. Reactor Water Silica Concentration as a Function of Time, from 23 January 1994 to 25 March 1994

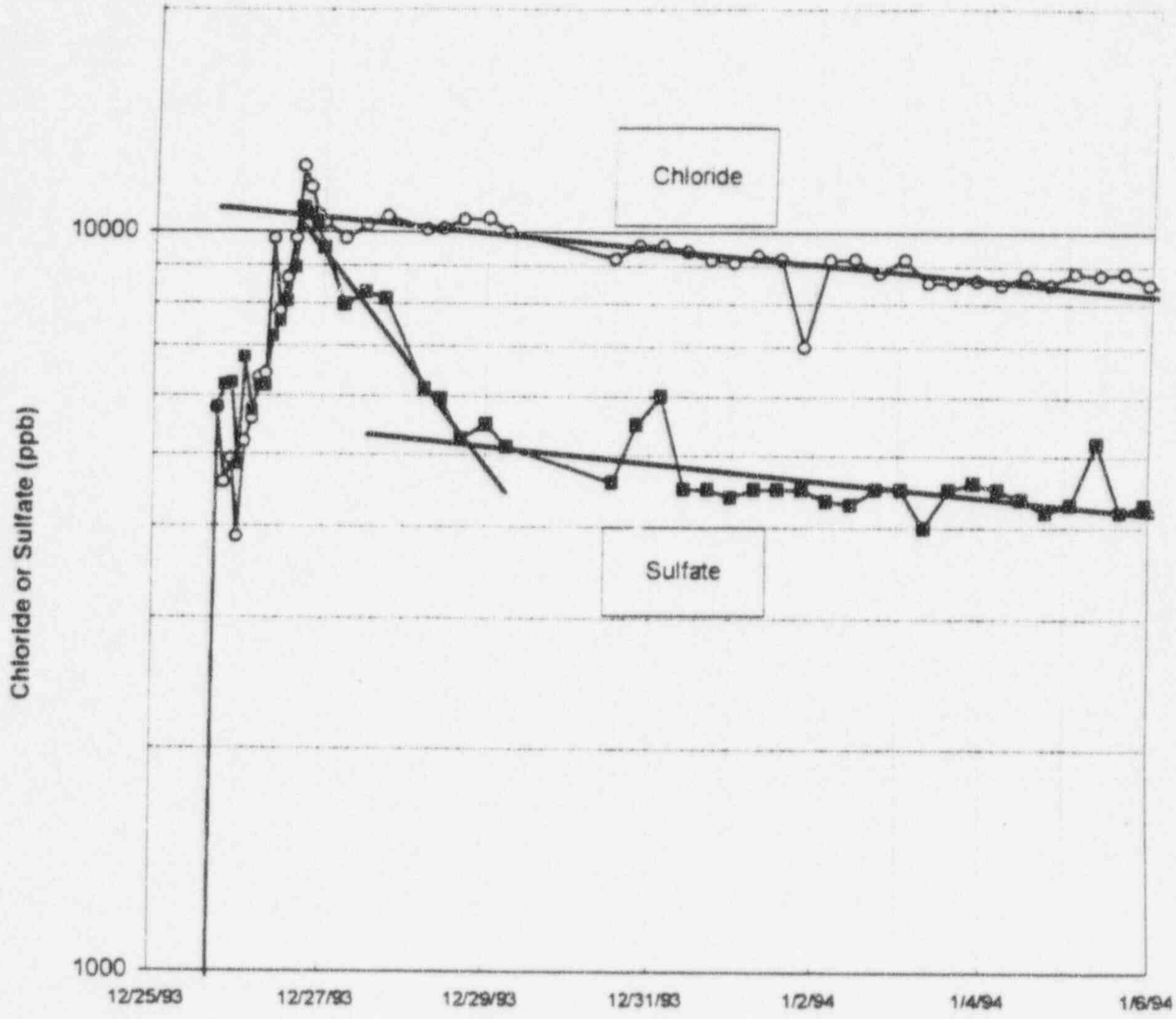

Figure 1.1-9. Changes in Chloride and Sulfate Levels During First Few Days of Incident

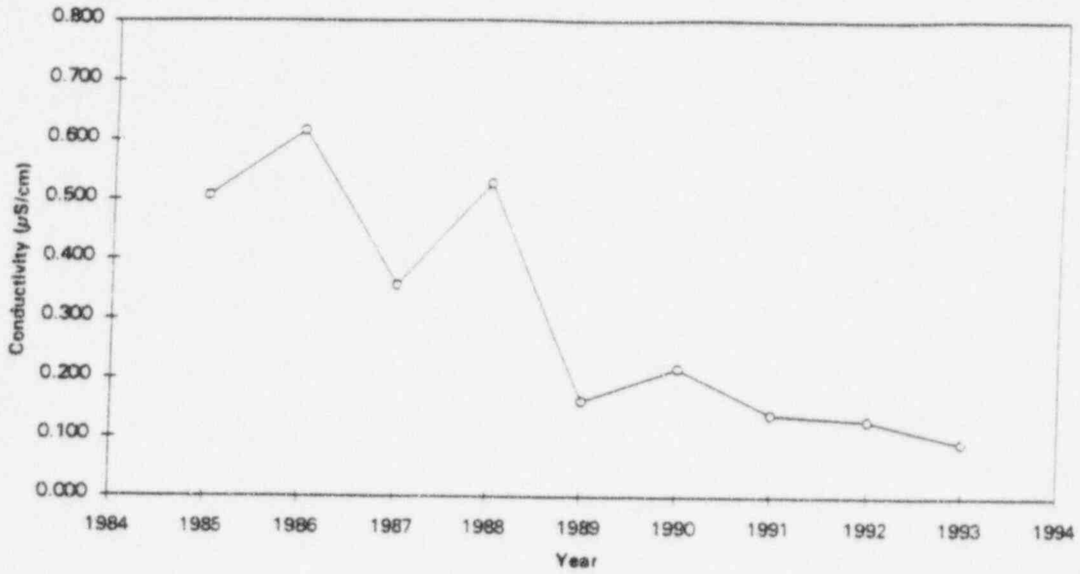

Figure 1.1-10 Fermi 2 Annual Reactor Water Mean Values

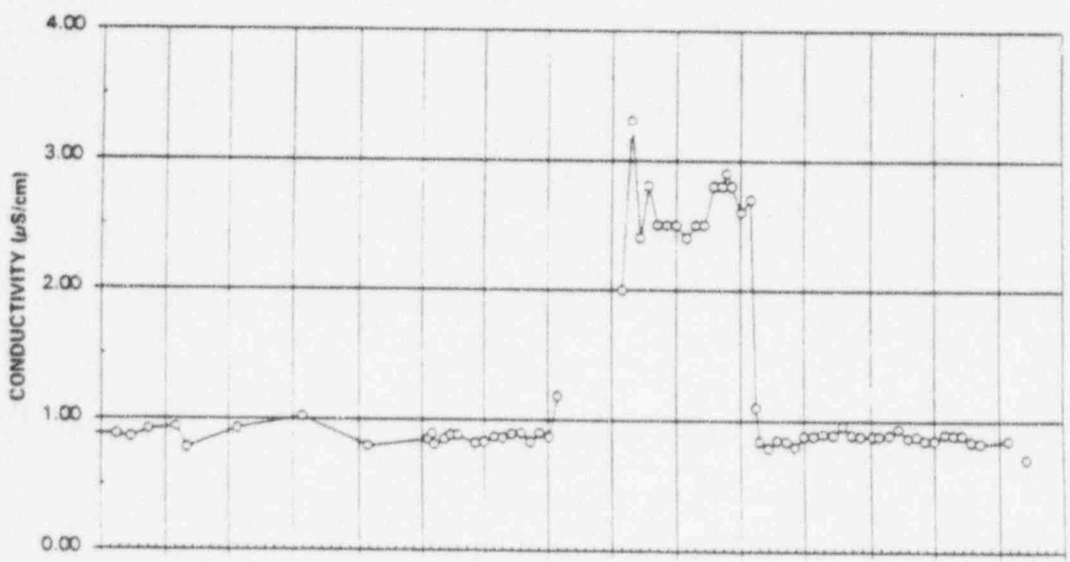

Figure 1.1-11. Fuel Pool Water Conductivity as a Function of Time

1.2 Background

Motivated by the corrosion chemical concerns discussed in Section 1.1, it was considered prudent to evaluate the potential degradation in the structural integrity of Fermi 2 reactor internals and other components attached to the reactor, such as control rod drives (CRDs), LPRM and SRM/IRM dry tubes. A review of the Fermi 2 components revealed that there exists both welded stainless steel and Alloy 600 components that are subjected to a significant stress in the proximity of a crevice. Similar evaluations for fuel and associated hardware and control rod components were performed.

A priority of generalized concerns for IGSCC for the various reactor internal components was constructed based on the presence of a crevice and stress estimates from similar plant designs. Table 1.2-1 presents such a relative ranking where position is suggested by an estimated priority of inspection. The ranking was based on the presence of [redacted] as the worst combination of parameters. Subsequent rankings were estimated by [redacted] and then by the [redacted] The utilization of more IGSCC resistant materials was also considered. However, [redacted] "Nuclear Grade" materials are not immune to IGSCC. Prudent judgment should be exercised in the application of this table, since the rankings are only a best estimate and cannot be warranted for absolute completeness or correctness.

1.2.1 Reactor Pressure Vessel Internals

Table 1.2-1 represents a subset of the complete listing of reactor pressure vessel internal components except for the fuel assemblies, control rod blades, and in-core sensors. Also, the reactor vessel components which are not in contact with the reactor water (e.g., the reactor pressure vessel closure flange bolting and the seal leak detector nozzle) are not included.

The table identifies the critical factors which could lead to component cracking. In the crevice column, components were identified as having a crevice concern when [redacted] In other cases, there are crevice conditions present in base materials, but since the crevice is not expected to have a detrimental effect, it has not been identified as such in this table.

In generating Table 1.2-1, the materials which were of greatest concern were [redacted] which have crevice conditions. These conditions plus [redacted] result in the components which have the most susceptibility to IGSCC. In general, most of the reactor internal components have high structural margins, and the effect of the water chemistry transient will not have an immediate impact on the function or structural integrity of the reactor pressure vessel components. A good indicator of where problems may occur is from the field experience at older BWR operating plants; however, the material conditions which led to cracking must be compared to the Fermi 2 conditions to make correct assessments.

1.2.2 Comparison of Fermi 2 Reactor Internals to other BWR Plants

The following components have experienced IGSCC at other operating BWR plants:

- CRD stub tube
- CRD return nozzle
- In-core housing
- Recirc inlet nozzle safe ends
- Recirc outlet nozzle safe ends
- Core spray nozzle safe ends
- Core spray internal piping
- Jet pump beams
- Jet pump instrument nozzle safe ends
- Shroud
- Shroud head bolts
- Access hole covers
- Steam dryer

In reviewing the above list against the material conditions at Fermi 2, there were several components where the materials and/or geometry were improved at Fermi 2 to provide more resistance to IGSCC prior to startup of the plant. The recommendations in Table 1.2-1 took into account material improvements. In general, the Fermi 2 components that have improved IGSCC resistance were not recommended for additional inspection as a result of the transient. For components that are similar to those that have experienced IGSCC at other BWRs, additional inspection was recommended, unless an inspection program was already in place or unless another component was judged to be more critical.

A review of other reactor internals which have not experienced cracking, but are considered susceptible to IGSCC, was completed. Appendix 6-1.3 discusses these components in detail.

1.2.3 Discussion of Recommendations

In reviewing the water chemistry event, there were three categories of recommendations:

- **Replacement of Components** - This type of recommendation was only made for highly susceptible components which have short times to failure once a crack has initiated, and where the water chemistry condition could have caused a crack to initiate.

- **Inspection** - Inspection is generally a visual or ultrasonic test, and there are two separate reasons for making the recommendation: (1) to examine a component which may already have defects which will be further aggravated by the water chemistry event (immediate impact), and (2) to obtain a baseline examination of a susceptible component which is anticipated to have cracking issues at a later time. If defects are detected, it may be necessary to make a repair or replace the component and extend inspection to other components. A good example of a component in this category was the shroud head bolts, which have had a number of cases where cracking has been detected at BWR operating plants.

- **Flushing** -For components which had stagnant areas where normal circulation in the vessel was not likely to remove contaminants before the reactor is brought to full temperature conditions. A flush such as with a hydrolazing wand was recommended.

The only component designated for replacement was the jet pump beams. Due to the recent cracking at a BWR/6, there was concern that beams which did not have the new heat treatment may not be capable of operating another fuel cycle if they had cracks which initiated at the ends of the beam. Also, since there is currently no means of performing an adequate ultrasonic examination, it was not possible to determine the exact structural integrity of the beams. Therefore, since a broken beam would cause the plant to shut down and cause other damage within the reactor vessel, it was recommended that the beams be changed-out prior to restart of the plant.

The [redacted] materials which are creviced are the most susceptible. The components which have [redacted] crevices of concern were the shroud head bolts and the shroud-to-shroud support weld. Since shroud head bolts have cracked at several operating plants, this is potentially a component which could already have IGSCC present (see Section 2.2.2 for the detailed evaluation).

The shroud-to-shroud support weld was constructed with a backing ring, which forms a crevice. Because of the backing ring, the access for inspection is restricted, and has prevented any worthwhile inspections from being performed at any operating plants. Therefore, this is a location which should be inspected, but no inspection methods are currently available to perform an adequate inspection. An ultrasonic inspection has been under evaluation for this location and is considered feasible, but the equipment is not yet available. It is recommended that this location be examined whenever inspection techniques are available.

The [redacted] components which were judged to be most susceptible to IGSCC are the safe ends on the recirculation inlet nozzles, recirculation outlet nozzles and the jet pump instrumentation nozzles. The recirculation inlet and outlet nozzles experience pressure and pipe reaction loads, and differential thermal expansion stresses which can lead to IGSCC. The jet pump instrumentation nozzle primarily experiences pressure and differential thermal expansion stresses, but also has restricted circulation of reactor water due to the sensing lines routing through the nozzle. In addition to having [redacted] safe end materials, these nozzles have an [redacted] on the end of the nozzles which is susceptible to IGSCC. To reduce the susceptibility to IGSCC, the Mechanical Stress Improvement Process (MSIP) has previously been applied to the recirculation nozzle safe end welds, but because of geometry and differential expansion of materials, the full benefit of this process to reverse stresses may not have been accomplished. Therefore, the ultrasonic examinations, for baseline purposes, were recommended at the nozzle-to-safe end weld location. For the recirculation inlet nozzle, it was recommended that two or three nozzles be ultrasonically inspected at the nozzle-to-safe end weld. This should be performed on nozzles which have not been inspected at outages following the application of the MSIP process and is intended to be a representative sample of this nozzle. Also, for the recirculation outlet nozzle, only one examination was specified, since the other nozzle was examined at a subsequent outage following application of the MSIP process.

The next component identified for inspection was the feedwater nozzle inner blend radius. This area has [redacted] material which is susceptible to pitting under poor water chemistry conditions. The feedwater nozzle was selected as a representative location for visual inspection, since it is a location which potentially could have high stresses due to thermal cycling, and at other BWR plants had fatigue cracks when gross thermal sleeve leakage was present.

The last components identified for inspection were the jet pump riser braces and the steam dryer support brackets. The construction of these brackets is typical of all the stainless steel brackets in the vessel. The steam dryer support brackets are a [redacted] material which is resistant to IGSCC, but the attachment weld was made with [redacted] weld materials. The [redacted] weld material was used because it is a good transition material between [redacted] connections. The [redacted] weld materials are not creviced, but are considered susceptible to IGSCC. Although there have not been any field problems identified, it was felt that at least one representative reactor vessel attachment component should be visually inspected as a baseline examination. The steam dryer support bracket was identified for inspection, since it may have come into contact with the reactor water during or after the transient. Due to the thermal expansion deadweight loads from the jet pump, the jet pump riser braces experience the highest loads of the group of in-vessel internal attachments. A visual inspection should be performed, since these brackets are readily accessible for inspection. The attachment of the riser brace to the reactor pressure vessel is [redacted] instead of [redacted]

It was also recognized that NRC IE Bulletin 80-13 requires that a visual inspection be performed on all core spray piping and sparger welds in the reactor pressure vessel at each refueling outage. Therefore, these components have not been selected, since they were already identified in the in-service inspection program at Fermi 2.

The recommendations for flushing were indicated for locations where the reactor flow is stagnant. These areas have been common sites for corrosion and crud buildup, which are technical concerns, since contaminants in the water could concentrate in these areas and become part of the crud composition. The specific areas identified were the annulus spaces between the nozzle and the thermal sleeve for the recirculation inlet, core spray and feedwater nozzles, and the CRD return nozzle, which is capped off. These are areas that have IGSCC susceptible materials and have experienced large amounts of crud. It has been common to hydrolaze these areas to remove crud and reduce dose rates. Other areas which were recommended to be cleaned by vacuuming were the flat areas on the horizontal plates of the shroud support, which can collect corrosion products and have susceptible [redacted] materials. Included in this area were the pocket areas around the jet pump diffusers, where significant amounts of corrosion products were expected. Areas around the diffusers and the corners formed by the gusset plates, were identified for hydrolazing, since vacuuming alone would not completely clean the area. Another area where crud deposits have been common is the bottom head region near the drain nozzle. This area contains [redacted] materials on the CRD stub tubes. Because cleaning this area involves complete disassembly of fuel cells, and because Fermi 2 has been a relatively low iron plant since reactor startup, this area was not included as a recommended area for cleaning. The flushing specified for the core spray internal piping and the jet pump instrument nozzle involve injecting water into the lines to flush the internal surfaces. Additionally, for the jet pump instrument nozzle, the nozzle annulus space contains stagnant areas created by the sensing lines routing through the nozzle base.

Table 1.2-1
Inspection Status

Component	Material	Wetted Crevice	Stresses	Rank	Inspection Recommendations: Replace	Inspection Imm. Imp.	Inspection Baseline	ISI Method	Flush
Shroud Support	[redacted]	No	Low-Medium						x-vacuum-complete
CRD Return Nozzle/Cap	[redacted]	No	Low-Medium						x-complete
Recirc Inlet Nozzle Safe End	[redacted]	No	Medium	4				UT/2 OR 3-complete	x (Note B)-complete
Recirc Outlet Nozzle/Safe End	[redacted]	No	Medium	4			x	UT (Note C)-deferred	
Feedwater Nozzle/Safe End	[redacted]	Yes	Medium	5			x	VT (Note A)-complete	
Feedwater Nozzle Thermal Sleeve	[redacted]	Yes	Low-Medium						x (Note B)-complete
Core Spray Nozzle Thermal Sleeve	[redacted]	Yes	Low						x (Note B)-complete
Core Spray Internal Piping	[redacted]	Yes	Low						x (Note D)-complete
Core Spray Sparger	[redacted]	Yes	Low						x-after RPV reassembly
Jet Pump Riser Brace	[redacted]	Yes	Medium-High	3			x	VT-Complete	
Jet Pump Diffuser	[redacted]	No	Low						x-complete
Jet Pump Beam	[redacted]	Yes	High	2	x-complete				
Jet Pump Instrument Nozzle	[redacted]	Yes	Medium	6			x	UT-complete	x (Note B, D)-complete
Shroud Head Bolts	[redacted]	Yes	Medium	1	17 replaced		x	UT-complete	
Steam Dryer Support Br	[redacted]	No	Low-Medium				x	VT-complete	

Note A Unclad Nozzle Inner Blend Radius
Note B Nozzle annulus
Note C 1 Nozzle By end of RF05
Note D Flush inside of piping/lines

2.0 Detailed Assessment

The interim reports concentrated on assessing the effects of the transient water chemistry associated with the 25 December 1993 incident. As the final analyses were completed and test results evaluated, focus shifted to provide emphasis on recommendations for reactor startup and the upcoming operating cycle. Revision D, the final report, was restructured to provide for this operational transition. The sections detailing the results of current literature review and engineering judgment of the transient impact can be found in Appendix 6 of this report.

2.1 Current Chemistry Status and Evaluations

2.1.1 Vessel/Fuel Pool/Condensate Storage Tank/Water Quality

The overall water quality of the Fermi 2 reactor water and spent fuel pool water has been remarkably good since the beginning of the refueling outage. Plots of the reactor water conductivity, pH, sulfate and chloride ion concentrations since 1 April 1994 are shown in Figures 2.1-1-2.1-4. The Mode 5 refueling outage commenced on 15 April 1994. The conductivity in both systems has been maintained below 1 µS/cm effectively for the duration of the outage. The conductivity of pure water that is air saturated is approximately 0.8 µS/cm, and is the result of dissolved carbon dioxide which produces the conductive bicarbonate, and, to a lesser extent, carbonate ions. The resultant pH of pure water that is air saturated is approximately 5.6. For the past two months, the pH of the Fermi 2 reactor water has been maintained between 5.6 and 6.5.

This indicates that the ionic impurity levels in these systems are low, as evidenced by the reported sulfate and chloride concentrations which recently have been less than 5 ppb, with many June and July readings below 1 ppb. The dominant impurity in the Fermi 2 reactor water and spent fuel pool water is currently silica, with concentrations between 200 and 300 ppb. Silica is not efficiently removed by the conventional plant water treatment systems when the source term water is air saturated. Increased removal efficiencies for silica by the Reactor Water Cleanup (RWCU) System should be observed with the vessel head in place, provided there are no additional inputs. Current levels of organics in the spent fuel pool are less than 20 ppb, which is satisfactory. Organics are further discussed in Section 2.1.4.

The RWCU System has been out of service since 23 May 1994, and the Fuel Pool Cleanup (FPC) System has been able to maintain a chemistry consistent with the current EPRI BWR Water Chemistry Guidelines (Ref. 50) values for cold shutdown conditions, which are a conductivity of less than 2.0 µS/cm, with chloride and sulfate concentrations less than 100 ppb. It is imperative that the availability and efficiency of both treatment systems be maximized for the duration of the outage in order to maintain good water quality prior to the restart.

GE has requested that soluble calcium and magnesium analyses be performed on a periodic basis on samples from the inlet and effluents from the RWCU System. If calcium and magnesium are efficiently removed by the RWCU System, but the inlet concentration remains constant, this may indicate the observation of the equilibrium solubility product concentrations from the leaching of deposits. While the chemistry group has attempted to measure the concentration of both ions in solution, the current detection limit for each is 5 ppb, which is not adequate to assess the removal efficiency of these ions. There are plans to improve the sensitivity of these determinations.

Some occasional problems with the water clarity in the spent fuel pool and the reactor vessel have been observed at various stages of the outage. These clarity problems have largely been associated with fuel movements. Plant personnel indicate that the severity of the water clarity, when it has been a problem, has been more extensive in RF04 than in previous outages. Localized clouds have adversely affected the performance of various equipment systems used during the refueling outage, including the latching mechanism on the fuel grapple.

GE believes that this is a direct result of the 25 December 1993 transient and the ingress of circulation pond water to the reactor vessel. The presence of alkaline earth impurities, specifically calcium and magnesium, coupled with the alkaline pH of the reactor water during the first several weeks after shutdown, may have reduced the tenacity of the fuel deposits, making them more susceptible to release from fuel rod surfaces with minimal movement. As the core is reloaded for startup, water clarity problems may resurface, providing additional rationale for maintaining good availability and efficiency of both water treatment systems.

The restart of the Fermi 2 reactor may be influenced by hideout-return of many chemical species, despite comprehensive system flushing and good water quality prior to heatup. It would be prudent to have on-line chemistry monitoring of the reactor water to provide guidance on the power ascension process to determine hold points if off-chemistry conditions exist. Continuous monitoring of monovalent and divalent cations, anions and organic acids are recommended.

During the latter part of May, the Condensate Storage Tank was drained for cleaning. A considerable inventory of grease and sludge was removed from the tank utilizing aqueous solutions of "Simple Green" which is a mixture of various long chain alkyl ammonium chlorides. While this compound is effective for the removal of grease, the compound cannot be considered as a nuclear grade material because of the presence of chlorides. The tank surfaces were thoroughly rinsed with good quality water which was discharged before filling. The tank was filled with water from the Condensate Return Tank during the first part of July. As of August 12, the water quality of the Condensate Storage Tank is within the EPRI Guidelines values, which are a conductivity of less than 1.0 µS/cm, chloride and sulfate concentrations less than 100 ppb, and TOC concentrations less than 200 ppb. The Guidelines suggest a 50 ppb upper limit for silica. The concentration of post-UV anions has typically been below 10 ppb.

As of this writing, the Condensate Return Tank has been drained for cleaning. Upon refilling this tank, it would be desirable to have comparable water quality to that of the Condensate Storage Tank. The practice of daily monitoring of both tanks should continue, with the frequency increased if there are water transfers to these tanks from other systems.

2.1.2 Corrosion Product Sample Determination ("Brown Slick")

Since the beginning of the refueling outage in April, there have been several signs of unusual corrosion observed in various parts of the system. The first of these was the appearance of a "brown slick" of deposits that were on the surface of the vessel water when the vessel head was removed. Plant personnel indicated that such slicks had not been observed in previous refueling outages. A site radiochemical analysis of this sample collected on April 16 revealed the usual complement of corrosion product isotopes (i.e., Co-60, Co-58, Mn-54, Zn-65, and Fe-59). The specific activity of the deposits indicated that this material had not resided on fuel surfaces for a long period of time.

A sample of this insoluble material dispersed in reactor water had been collected in a 1-liter plastic container. The contents were shaken, and a portion of the solution was filtered through a 0.45 µM Millipore filter. The precipitate was washed with demineralized water, and the filter placed in a petrie dish for transport to VNC for chemical analysis.

At VNC, the sample was divided for analyses by [redacted] Five analyses were performed on each sample to obtain an average value. The results of these analyses are indicated in Table 2.1-1.

The dominant element in this sample is iron, with lesser amounts of manganese, nickel and chromium, which is indicative of typical stainless steel corrosion products. The small, but apparently real indications for the presence of zirconium supports the hypothesis that the material had originated from fuel surfaces. The very small calcium abundance would tend to indicate that, if insoluble calcium salts were precipitated from solution immediately after the circulation water intrusion, they were removed from the system by the purification methods used to restore reactor water quality prior to removing the vessel head and the beginning of the refueling outage.

[redacted]

The only crystalline phase identified in the [redacted] analysis was the α-Fe_2O_3 hematite structure. No pure or substituted Fe_3O_4 type spinel structures were detected in this sample. This single-phase hematite structure is consistent with the [redacted] analysis which indicated that the material is predominantly iron. Substances specifically looked for in this analysis, but which were not found, were all insoluble salts of calcium and magnesium, which might have been anticipated because of the high concentrations of these ions in the reactor water during the transient peak. As systems are opened for inspections, more forms of unusual corrosion may be observed. If elemental analyses of any unusual deposits are performed in the Fermi 2 chemistry lab, the analyses should include the concentrations of calcium and magnesium, along with the usual corrosion product determinations of iron, nickel, chromium, copper, and zinc. GE has speculated on the precipitation of calcium and magnesium salts in the reactor during the transient. Since these elements are dominant impurities in the circulation pond water, the assumption should be made that they are present in the deposits found on any surface that at one time was in contact with the off-standard chemistry during the transient.

2.1.3 Transient Simulation Experiments

In an attempt to simulate the chemical reactions which occurred in the vessel during the December transient, autoclave experiments have been conducted at the GE Corporate Research and Development Laboratories in Schenectady. While the temperature profile of the reactor during the incident could be carefully followed when the operating temperature was achieved, the progressively increasing conductivity of the reactor water could not be duplicated. As such, the intent of this experiment was to qualitatively determine what species participated in high-temperature reactions.

Samples of the Fermi 2 circulation pond water were collected for this study. A static 1-gallon autoclave cleaned with [redacted] used in all studies. The first autoclave run was conducted as follows [redacted]

[redacted]

The system was cooled down, and the autoclave opened for inspection. A thin white powdery layer was visible on all sides of the autoclave. Scrapings of this adherent layer were analyzed by [redacted] The constituents of these white deposits were a mixture of calcium carbonate and magnesium hydroxide. A chemical analysis of the soluble species in the sample by [redacted] before and after the autoclave experiment was performed to assess the extent of disappearance, if any, of the major species from solution. The water volume at the completion of the experiment was 2.22 liters, indicating some losses during the venting periods. These results are indicated in Table 2.1-2.

Of the species that were measured, the only soluble ions that decreased in concentration over the course of the experiment were calcium and magnesium, which is consistent with the [redacted] analysis of the insoluble material in the autoclave at the end of the experiment. Concentrations of chloride, nitrate, sulfate, and sodium were higher at the end of the experiment. The percentage increases in the concentrations are consistent with the water volume decrease from the venting periods. This also indicates that under these experimental conditions, these ions did not appreciably participate in high temperature chemical reactions.

Reasonable conductivity balances were obtained using the equivalent conductances of the separate ions on the samples before and after the experiment. Soluble carbonate and bicarbonate were not analyzed in either sample, and most likely contributes significantly to the unaccountable conductivity in the sample prior to the autoclave experiment. With some carbon dioxide removed during venting, and the observation of a $CaCO_3$ precipitate, the conductivity balance of the sample after the completion of the experiment is closer to the actual measured conductivity. The increase in sample pH provides additional support that some carbon dioxide was removed from the system during venting.

The observation that sulfate did not form any measurable precipitates in this experiment is not consistent with the plant data presented in Figure 1-1.9, where a more rapid disappearance of sulfate from the system was indicated. No sulfate compounds were observed in any of the fuel deposit structures, nor in the various corrosion samples from the vessel walls and feedwater nozzles. This may suggest that, if sulfate compounds did precipitate from solution, they were largely removed by the various cleanup demineralizers that were used in the early stages of the recovery. If calcium and magnesium were the cationic carriers for these precipitated sulfates, this may suggest that the concerns for redissolution during startup may be less than originally anticipated. Nonetheless, these ions should be frequently monitored during the startup.

2.1.4 Organic Analyses

A considerable inventory of lubricating oil was introduced to the system during the transient. The chemistry group is routinely monitoring for the presence of organics in various areas of the plant using conventional laboratory Total Organic Carbon (TOC) instrumentation. While this technique affords an estimation for the concentration of organics, it does not provide any qualitative information as to the structure of the organics in the water. Alcohols, oils, resin particles, etc. all will register as some fraction of a TOC signal. In addition, many organic compounds are resistant to the oxidative processes performed with TOC determinations. As such, some TOC readings may be artificially low for some compounds if the oxidative processes used in the analyses are not complete.

The concern for organics in BWR systems is that the water treatment facilities were not designed for their efficient removal. As these compounds are largely non-ionic, they are not readily removed from the water with demineralizer ion exchange resins in the Condensate Treatment System, RWCU System, FPC System, or in the Radwaste Treatment System. When the reactor is operating, some complex organic structures can be broken down by the combination of temperature and radiation field strength to smaller fragments that can promote IGSCC in a variety of BWR materials.

To this end, we have recommended additional monitoring for organics at Fermi 2 using the technology of gas chromatography with a mass spectrometer (GCMS) for a detector. This technique affords the identification for thousands of specific organic compounds, with detection limits at the part per billion level. These analyses will be performed at the GE Corporate Research and Development Laboratory in Schenectady. Specially cleaned sample bottles have been prepared for this evolution and have been shipped to the site. Instructions for sample collection have been provided to the chemistry group. Initially, the samples can be selected to monitor the efficiency of the processes that are planned or currently in use at Fermi for the removal of organics, such as reverse osmosis, ultraviolet light treatment, and activated charcoal adsorption. At some point prior to startup, it would be prudent to submit samples of Condensate Storage Tank water (when recharged) Condensate Return Tank water, the Condenser Hotwell, Suppression Pool, and the reactor water to assess the nature of the impurities in these systems, and the need for additional treatment, in the event it is necessary.

2.1.5 Consequences of Microbial Treatments

With the confirmation of microbiological activity (Section 2.2.4.3) in selected corrosion samples from the Fermi 2 reactor, information has been provided on chemical eradication treatments, with pilot tests initially on small scale systems, such as storage tanks, and, pending success of the pilot program, a full system treatment to arrest microbial activity and the attendant corrosion. All of the solvents suggested for the microbial eradication involve treatment with strong oxidizing agents, generally containing some concentration of peroxide species at the 100-2000 part per million level. Many of these formulations were successfully implemented at TMI, albeit with full knowledge that TMI would not operate after treatment.

Coupon tests were conducted to determine the effectiveness of the treatment solvents on coupon surfaces that have been cultivated using water from the Fermi 2 circulation pond. Many of the solvents contain stabilizing agents for the peroxide species. While these solvents may be totally effective for the microbial problem, the tradeoffs for microbial corrosion against the possibility of increased intergranular stress corrosion from the solvent addition along with potential crud bursts must be evaluated.

Table 2.1-1 [redacted] of "Brown Slick" Deposits

Normalized Elemental Weight Percent									
Run	Al	Si	Cl	Ca	Cr	Mn	Fe	Ni	Zr
1	0.00	0.16	0.00	0.05	1.56	3.75	92.46	1.22	0.81
2	0.00	0.07	0.03	0.18	1.49	2.02	94.31	0.68	1.21
3	0.02	3.48	0.03	0.21	1.67	2.77	90.48	.043	0.91
4	0.00	0.02	0.06	0.12	1.53	3.40	93.43	0.67	0.77
5	0.00	0.20	0.07	0.01	1.41	5.19	89.83	0.61	2.67
Avg	**0.00**	**0.79**	**0.04**	**0.08**	**1.53**	**3.43**	**92.10**	**0.72**	**1.27**
1-σ	**0.01**	**1.35**	**0.02**	**0.08**	**0.09**	**1.06**	**1.71**	**0.26**	**0.71**

Table 2.1-2 Chemical Analyses from First Autoclave Experiment

Constituent	Concentration Before Autoclave Experiment	Concentration After Autoclave Experiment
Chloride (PPM)	17.8	19.3
Nitrate (PPM)	1.4	1.5
Sulfate (PPM)	27.0	29.6
Sodium (PPM)	9.5	10.5
Calcium (PPM)	34.8	17.4
Magnesium (PPM)	9.2	1.2
pH	8.05	9.45
Measured Cond. (μS/cm)	270	180
Accountable Cond. (μS/cm)	249	178
Accountability (%)	92.3	98.9

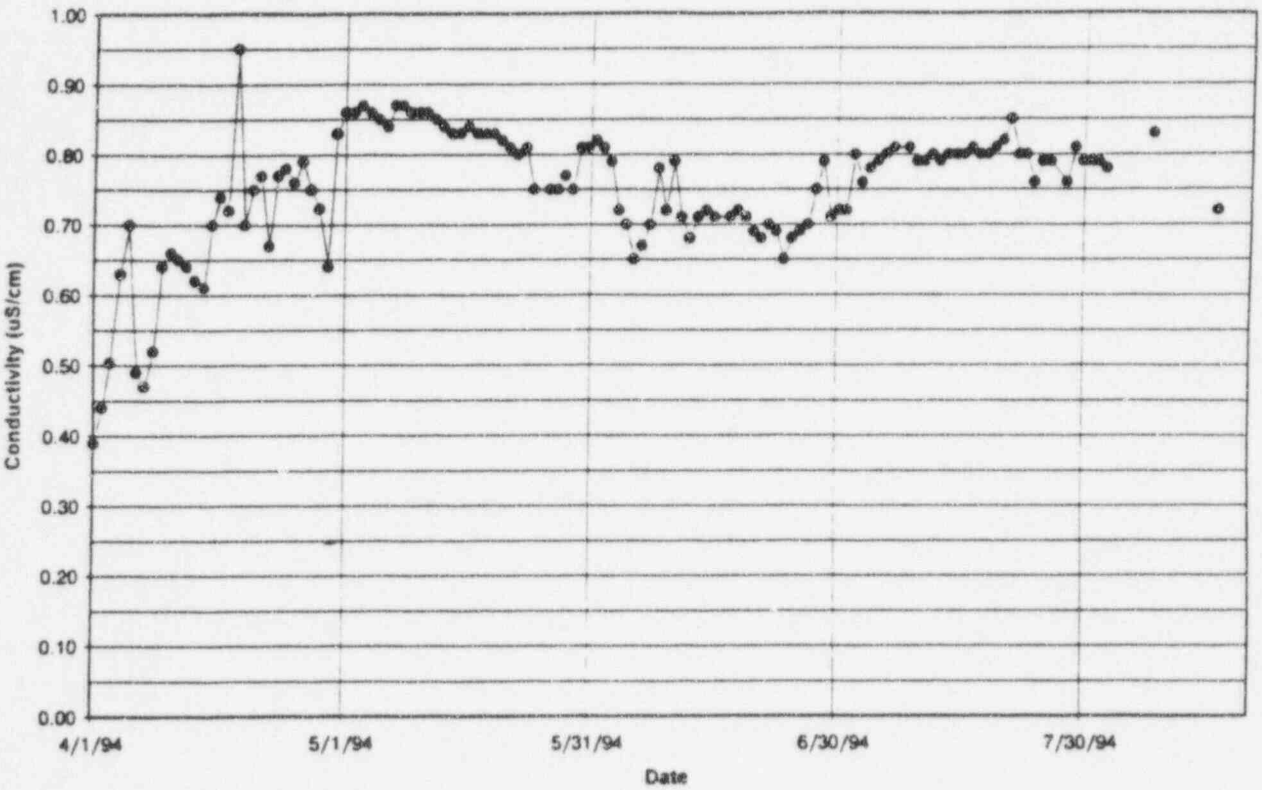

Figure 2.1-1. Graph of Reactor Water Conductivity

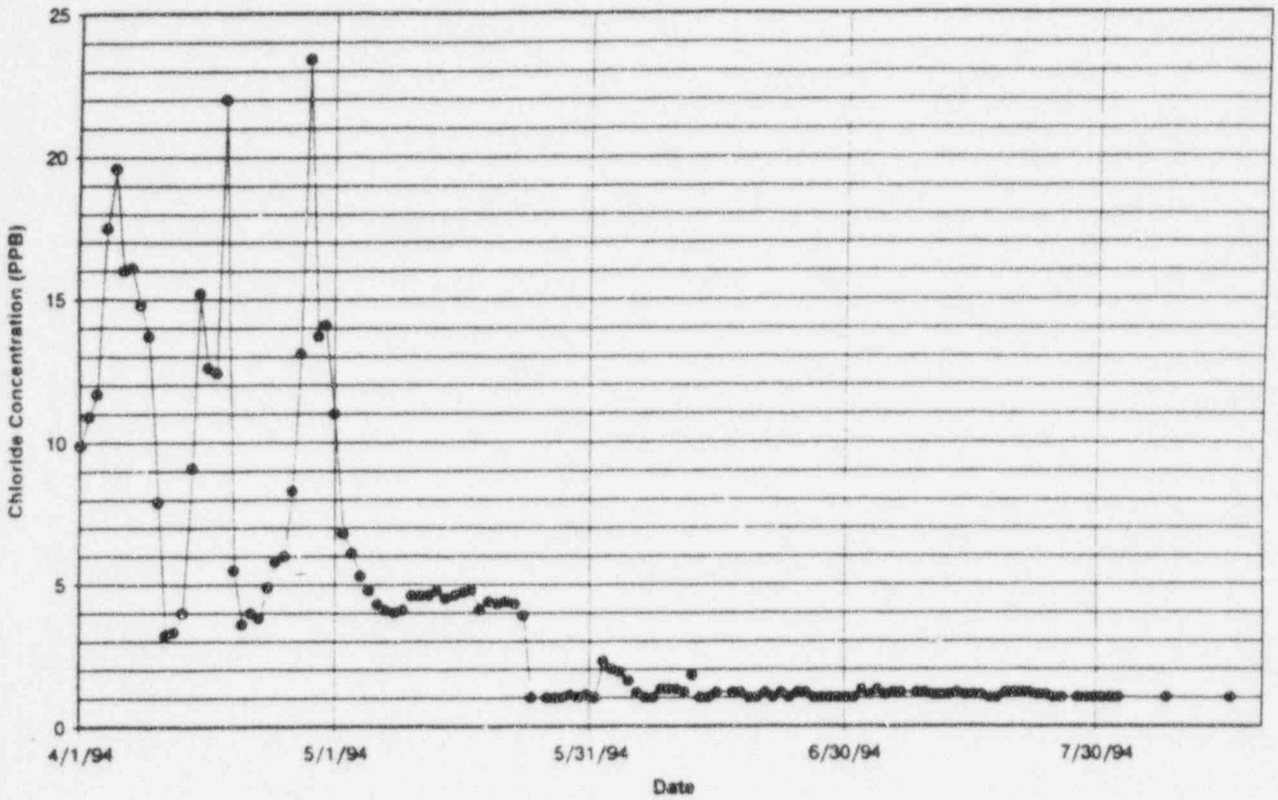

Figure 2.1-2 Graph of Reactor Water Chloride Concentration

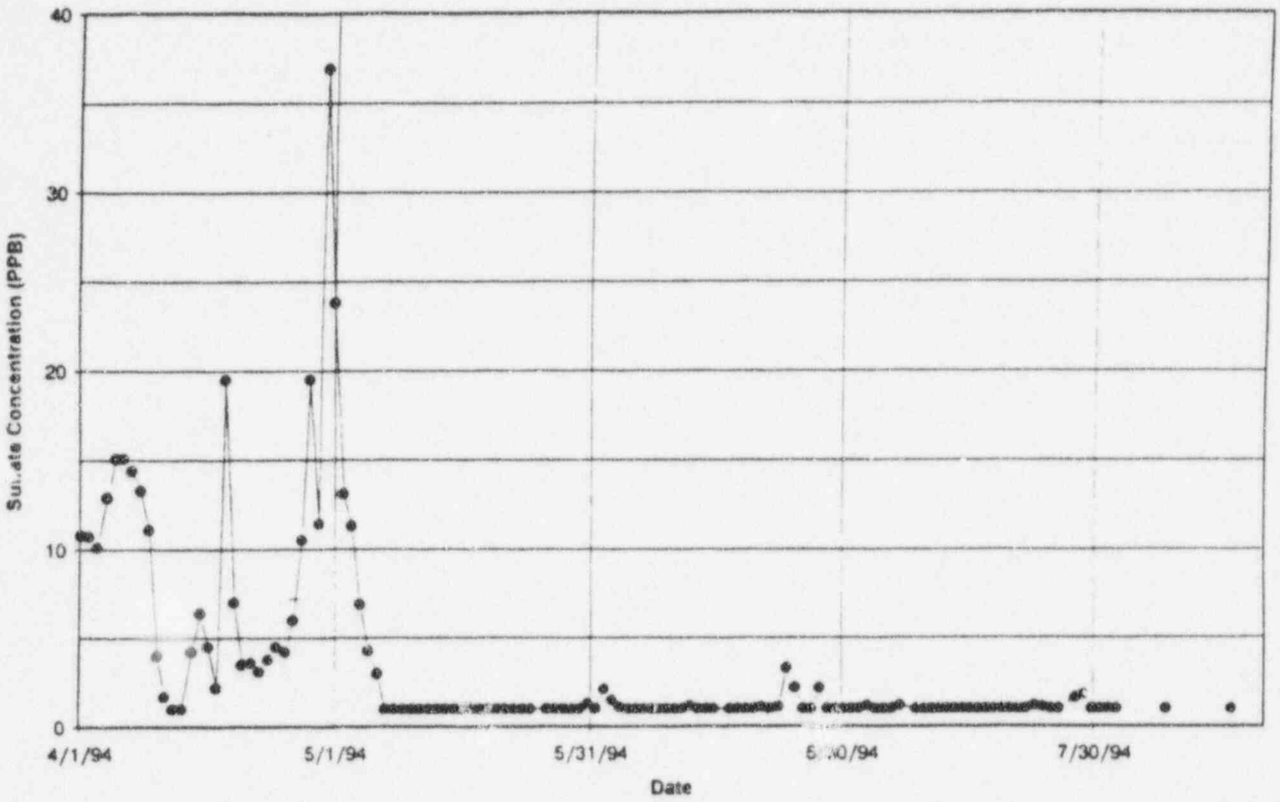

Figure 2.1-3 Graph of Reactor Water Sulfate Concentration

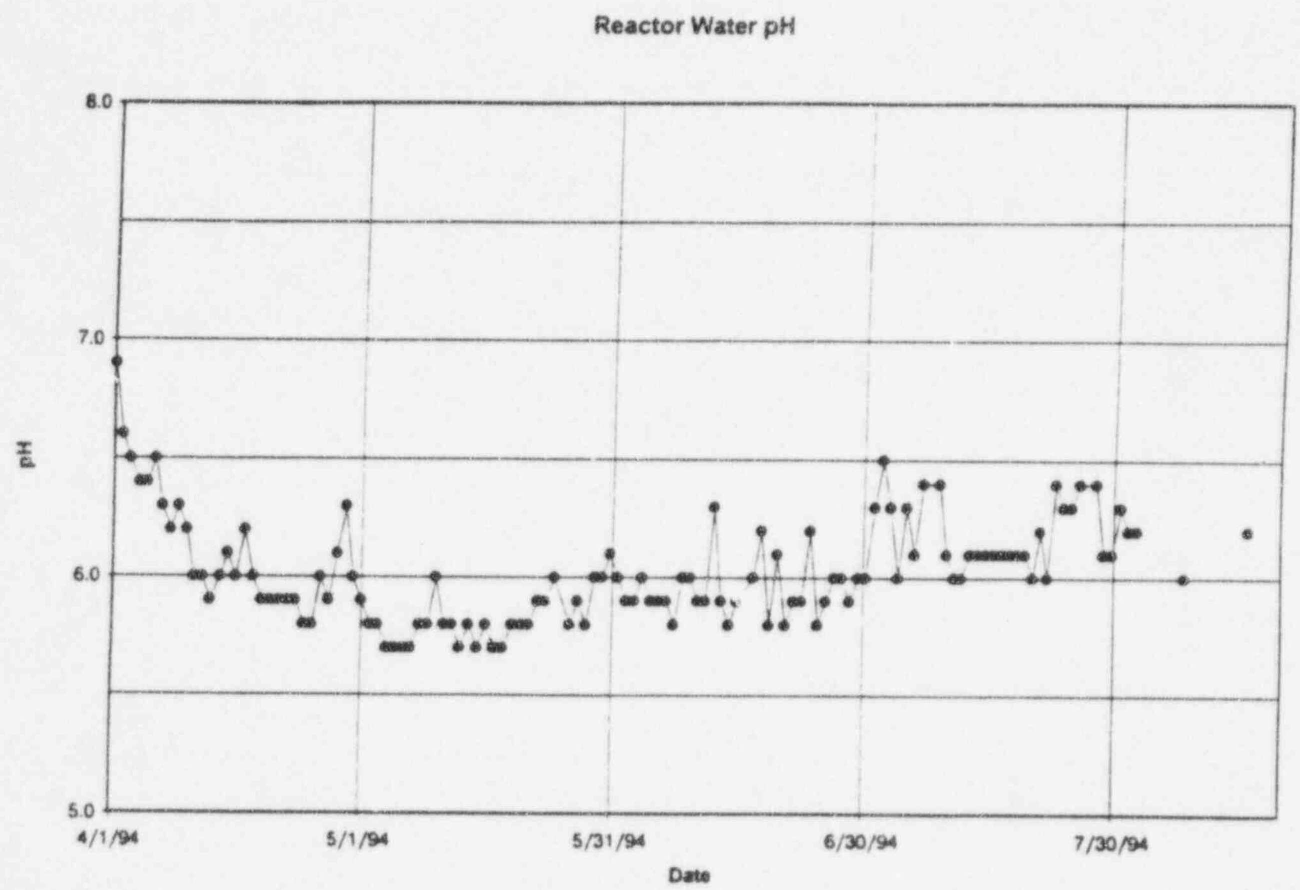

Figure 2.1-4 Graph of Reactor Water pH

2.2 Components Evaluation

As discussed in Section 1.2, components and systems were identified that were deemed to be either susceptible to a water chemistry transient (for example, SCC or general corrosion) or to possibly harbor harmful ionic species. An action items list was then generated to accomplish specific tasks in support of assessing:

- The status of the system flushing.
- The status of the transient on specific components.

Components singled out for extensive evaluation included the control rod drives, the shroud head bolts, fuel, the reactor pressure vessel (RPV) (due to observed corrosion) and other selected items where abnormalities were found. Each of these components is addressed separately below.

2.2.1 Control Rod Drives (CRDs)

Components of the CRDs which were judged to be most affected by the water chemistry transients are the collet retainer tube, index tube, and the piston tube of the older style CRD assemblies (7RDB144G001) (Table 2.2-1). These components have been shown to be susceptible to intergranular attack (IGA), stress corrosion cracking (SCC) and pitting under normal water chemistry conditions. Their susceptibility is expected to be aggravated by the higher conductivity water experienced during this event. Improvements made to newer versions of the CRDs (7RDB144G006) have essentially eliminated their susceptibility under normal water chemistry conditions.

The CRD System provides constant cooling water flow to maintain the CRDs below the temperature alarm setpoint of 121°C (250°F). Temperature data for rod 26-31 (typical for other rods) (Figure 2.2-1) indicated that the CRDs were subjected to temperatures up to 232°C (450°F) and 149°C (300°F) for approximately one hour and less than 20 hours, respectively. These relatively short temperature excursions should not adversely affect the CRD components, including the [redacted] seals and bushings. However, it was recommended that the [redacted] seals and bushings be visually inspected when the CRDs were examined during the outage (Section 2.2.1.1).

It was recommended that, during the outage, a representative sample of CRD be examined using normal CRD rebuilding techniques to establish the baseline present condition. The baseline criterion for the collet retainer tube was established using the inspection recommendations of SIL 139, revised Supplement 1, Attachment 2 for crack location and size (Ref 42). For the index tube and piston tube, corrosion products and pitting were recorded in report GE-NE C1100297-01, Rev 1, issued July 1994, which detailed the inspection findings. Appendix 4 of this report contains the color photographs of the examined CRDs.

2.2.1.1 CRD Inspection

Six CRDs were inspected to establish an assessment of current conditions and to evaluate the extent of degradation taken place due to the circulation water intrusion and the idle water condition (from time of incident to present). These CRDs were among 20 CRDs selected by DECo for refurbishment. The criteria for refurbishment were based on those CRDs exhibiting inadvertent uncoupling, high stall flows, and operational anomalies such as difficulty notching out from position 00. High CRD temperature was another basis for refurbishment.

The majority of the CRD parts were fabricated from Type 304 stainless steel. Of these parts, the piston tube, index tube, collet piston, guide cap and the collet retainer tube were [redacted] The [redacted] index and piston tubes were of particular interest, since pitting of these parts has been observed in other BWR plants, even in high quality BWR environments. The [redacted] collet retainer tube inner diameter that forms the annulus for the collet assembly was not accessible for inspection. The parts consisting of bi-metallic (i.e., [redacted] components were the collet assembly (fingers and retainer), cylinder, tube and flange assembly (top of cylinder, spacer), and the inner filter. Parts that were [redacted] were the spud, inner filter spring and the main flange inner diameter. All components that were accessible were visually inspected.

All six CRDs [30-51 (SN 4126), 30-23 (SN 4092), 26-15 (SN 3395), 34-27 (SN 3324), 26-39 (SN 45772), 10-43 (SN 6177)] exhibited corrosion on th[redacted] index and piston tubes. A high concentration of corrosion debris was noted at notch 00 where the collet fingers resided and formed a crevice on the index tube surface when the CRD was in the full-in position. Areas above notch 00 were noted to have very few scattered, small regions of corrosion. Significant corrosion was noted at the top region of the piston tube where the internal drive piston seals had formed a crevice when the CRD is in the full-in position. Analyses of a [redacted] seal, C-spring, seal retaining spring and oxides from a piston tube were performed at VNC. No evidence of damaging ionic species from the transient was found. Appendix 7 contains the detailed results of the analyses. The lower portion of the piston tubes, including the lower boundary at the [redacted] stop-off interface, was relatively free of corrosion activity.

The other [redacted]arts (e.g., guide cap, collet assembly) accessible for visual inspection displayed relatively minor evidence of pitting corrosion or deposits. Only minor evidence of corrosion activity (i.e., superficial discoloration) was observed on [redacted] CRD parts. No relevant indications were reported on five of the six CRD collet retainer tubes that were liquid penetrant examined. A 9/16-inch linear indication was reported in the collet retainer tube of CRD S/N 4126. Traces of white deposits of an unknown composition were noted on the collet fingers and on the upper region of one Cylinder, Tube and Flange Assembly.

Photographs of two other CRDs [10-31 (SN 4475), 34-07 (SN 4230)] and Table 1 (Ref. 58), listing the inspection observations, are shown in Appendix 4. The photographs show typical corrosion degradation observed in the other six CRDs inspected.

2.2.1.2 CRD Crevice Flush

As noted in the previous sections, the creviced [redacted] parts were most vulnerable to corrosion degradation in the circulation water transient environment. The three [redacted] crevice areas are formed by (1) the drive piston seals/bushings and the piston tube OD, (2) the collet fingers and the index tube notch, and (3) the collet piston rings and the collet retainer tube ID. The recent CRD inspection determined that pitting corrosion and crevice corrosion initiated in the [redacted] index and piston tubes.

Periodic crevice flush has been recommended to minimize the effects of crevice corrosion; therefore, the following techniques for CRD flushing, listed in their order of effectiveness, are as follows:

1. **Single Notch Cycle** - Exercising the CRD by jogging it one notch in and out is deemed the most effective means of flushing the three [redacted] crevice areas.

2. **Single Notch Withdrawal** - The single notch withd aw command consists of two deliberate actions to unlatch the collet and to withdraw the control rod.

3. **Single Notch Insertion** - The single notch insert command consists of pressurizing only the under-piston area. Notching or partially inserting the CRD will effectively flush the index tube and piston tube [redacted] crevice areas.

4. **Control Rod Drift or Scram** - The scram or drift-in mode, which pressurizes the under-piston area to insert the control rod, would have similar flushing effectiveness as the single notch insertion (3) discussed above.

It should be noted that flushing methods (3) and (4) may not insert all control rods similarly. This is due to the variations in CRD under-piston pressure, which is influenced by the CRD pump capacity, hydraulic line losses and individual CRD seal leakages. To verify that the control rods were sufficiently inserted, the position indicator probe must be operational.

During reactor operation, the CRD System draws its intake water from the condenser hotwell, which is typically low in chloride, sulfate and oxygen. Therefore, a weekly "exercising" (when possible) would be sufficient to flush the crevice regions and minimize the autocatalytic corrosion processes.

For short-term forced outages during fuel cycle 05, weekly "exercising" along with continuous cooling water flow will be adequate. However, the final recommendation for flushing during the next refuel outage (RF05) will be determined following inspection of additional CRDs during that refuel outage.

CRD Reinspection

The selection criteria for CRDs refurbished in RF04 should be implemented for the next refuel outage (RF05). It is reasonable to anticipate that an increased number of CRDs (e.g., >20) will require refurbishment during RF05. A minimum of six CRDs should be inspected during RF05 to determine trends of corrosion degradation with respect to current conditions. This population should consist of three CRDs refurbished during RF04 and at least three CRDs not refurbished during RF04. Additional replacement of index tubes and piston tubes may be required if the corrosion pitting condition has increased significantly. Additionally, any XM-19 piston tube or index tube that may have been in service during the circulation water intrusion should be inspected at the next refuel outage.

CRD Operating Data Trend Documentation

The insert/withdraw stall flows should be recorded monthly, when possible, during reactor shutdown and operation. CRDs exhibiting insert/withdraw stall flows greater than 5.0 gpm and 4.0 gpm, respectively, should be considered for refurbishment. CRDs experiencing operational anomalies, including notching difficulties requiring higher operating drive water pressures (>250 psid) should be noted. The rate of change, consistency, and magnitude of these operating parameters should be documented for evaluation of significant trends.

2.2.1.3 Conclusions

- The CRD scram function would not be adversely affected by the observed corrosion condition.
- Continued corrosion degradation may result in excessive seal degradation and leakage which may lead to the need for early CRD refurbishment.
- Corrosion deposits were found on the CRD components, especially on the index tube and piston tube surfaces. The deposits suggest that the index tube and piston tube corrosion was promoted by the circulation water transient. In comparison to CRDs of similar service life, Fermi 2 CRDs appear to be worse than the average.
- The general corrosion observed on the index tubes and piston tubes is worse than average. However, stress corrosion cracking is not expected to initiate from these corrosion sites.
- Based on the results, it is concluded that it would be prudent to periodically flush the crevice areas formed by the seals/bushings and the collet fingers with the [redacted] surfaces of the piston and index tubes.
- Based on the condition of the CRDs inspected, it is concluded that there is no immediate need for refurbishment of additional CRDs beyond those planned for RF04. This conclusion is based on the condition that the CRDs are exercised daily when possible during RF04 and weekly during operation to minimize the effect of crevice corrosion in the regions of the seals/bushings and collet fingers in contact with the [redacted] surfaces.

2.2.2 Shroud Head Bolts

2.2.2.1 Shroud Head Bolt Ultrasonic Inspection

The Fermi 2 original design shroud head bolts (SHBs) were identified for baseline inspections because of the following:

- The SHBs were fabricated from [redacted] materials (IGSCC susceptible).
- The presence of a wetted crevice design along a (HAZ) weld heat-affected zone.
- The presence of medium mechanical stresses.

Because of the above conditions, the shroud head bolts were deemed highly susceptible to crevice-accelerated IGSCC.

SIL 433 and SIL 433 Supplement 1 (see Appendix 2) recommend performing full length ultrasonic testing (UT) of original design SHBs. GE performed UT examinations of all 48 SHBs on 20 May 1994 and found 16 with rejectable indications at approximately 9.5 inches from the bottom of the bolt. This location was typical of IGSCC found at other sites (BWR4s and earlier plants). Figure 2.2-2 compares rejection rate trends for SHBs for Fermi 2 and other comparable BWRs. In comparing the rejection rate trends, it was deemed prudent to replace the rejected SHBs.

In July, GE replaced the 16 original design SHBs (P/N 920D232G002) with bolts of an improved design (P/N 112D3485G002). To minimize the impact of further SHB cracking during the upcoming operating cycle, the new bolts were placed in a symmetrical pattern. Due to bowing of an original SHB scheduled to be returned to the separator, an additional new SHB was installed. There now exists 17 of 48 new improved SHBs in the separator.

The remaining original design SHBs will be replaced on an "as needed" basis at subsequent refueling outages.

2.2.2.2 Seismic and Stress Analysis

An evaluation was performed to reevaluate the minimum number of shroud head bolts to assure the structural integrity of the shroud head/shroud joint. Previous analyses used conservatively high seismic loads and assumptions. This resulted in the requirement that all of the shroud head bolts were required and thus no margin existed for cracked bolts.

The major contributor to the loading on the shroud head bolt is the seismic load. Thus by using more realistic assumptions, the seismic loads may be reduced, thereby reducing the number of required shroud head bolts.

The minimum number of shroud head bolts was determined by using the loads for two conditions:

- SSE plus normal ΔP
- SSE plus LOCA ΔP

The maximum number of bolts required using these two loading conditions defined the minimum number of bolts. Based on the results of the analysis, the condition using SSE plus normal resulted in the limiting condition.

The primary structure seismic analysis was performed to obtain the maximum shear force and bending moment for the shroud head bolt stress calculation. The horizontal mathematical model was reconstructed from the original seismic analysis (Ref. GE document 22A5676, Rev. 2) using current fuel properties. The input motion for this analysis corresponds to NRC Regulatory Guide 1.60. Safe Shutdown Earthquake (SSE) free field spectra were generated for a peak ground acceleration of 0.15g. SSE spectrum consistent synthetic acceleration time histories were generated in two horizontal directions. The horizontal seismic time history analysis for the Fermi 2 primary structure was performed using NRC Regulatory Guide 1.60 time histories and NRC Regulatory Guide 1.61 damping values. The maximum SSE shear force and bending moment at the shroud head locations were determined to be:

- Maximum shear force due to SSE = 249 kips

- Maximum bending moment due to SSE = 40645 in-kips.

These results represent a significant reduction in the loads when compared to the previous analysis.

The stress analysis of the SHBs was performed using the results of the seismic analysis described above. The analysis also considered the pressure drop across the shroud head. The analysis considered the limiting number of bolts based on the SHB analysis and SHB bracket analysis.

Based on the results of the stress analysis, the minimum number of shroud head bolts was determined to be 20.

2.2.3 Fuel Inspections

In May 1994, an irradiated fuel inspection was to assist in evaluating the impact of the intrusion event on the irradiated fuel. A summary of the items sampled or inspected is provided below.

- Six bundles were selected for inspection:
    - Two Initial Core Bundles (LJK961, LJK962)
    - Two Reload 1 Bundles (LYS486, LYS488)
    - One Reload 2 GE9 Bundle (LYX594)
    - One Reload 3 GE11 Bundle (YJ2809)

Specific inspections and sampling of these bundles and components are provided in Table 2.2-2.

2.2.3.1 Fuel Bundle Component Evaluations

Fuel components from four fuel bundles (ID #s LYX594, YJ2809, LYS488, and LJK962) were received at GE's Vallecitos Nuclear Center (GE-VNC) for evaluation. The components from each bundle were four lock tab washers, eight hex nuts, and two springs. In addition, one channel fastener from bundle LYX594 was provided.

The supplied components were initially examined through the Kollmorgen (periscope). The intent of this examination was to characterize the surface conditions of the fuel components. Figure 2.2-3 shows a typical region of a lock tab washer; this particular washer was removed from fuel bundle LYS488. The washer is covered with a reddish oxide, characteristic of Type 304 stainless steel that has been exposed to the reactor environment. The shiny regions visible are areas where the oxide has been removed by handling operations. No unusual surface features were noted.

Four hex nuts and a spring from bundle LYS488 can be seen in Figure 2.2-4. These components have a similar surface to that observed for the lock tab washer (i.e., coated with a reddish oxide). No evidence of anomalous surface conditions was observed. A channel fastener bolt (from bundle LYX594) (Figure 2.2-5) again shows a surface characteristic of exposure to a BWR environment. No evidence of degradation was observed. The surface of the channel fastener (Figure 2.2-6) shows a slight discoloration, but this appears to be staining and is not indicative of an anomalous condition.

To confirm the results of the visual examination, optical metallography was performed on representative specimens from each of the components. One nut from each of the bundles, one spring and a section of the channel fastener bolt were selected for examination.

Figure 2.2-7 is a 250X view of the cross section of the spring from bundle LJK962. The surface does not appear degraded from exposure to the BWR environment. No evidence of cracking or other anomalous conditions was observed. A cross section of a nut from the same bundle (Figure 2.2-8, 50X) shows a typical microstructure for a Type 304 material. The thread roots show no evidence of degradation. A cross section of the channel fastener bolt (Figure 2.2-9, 50X) shows a microstructure characteristic of [redacted] No evidence of service-induced cracking or other anomalous conditions was observed.

Visual and optical metallographic examination of the various fuel components found the materials to have surface conditions characteristic of exposure to the BWR environment. No evidence of service-induced degradation consistent with stress corrosion cracking or microbiologically induced corrosion was found.

2.2.3.2 Fuel Deposits Analyses

Fuel deposit sampling was performed to assess the effects of the reactor water transient of 25 December 1993 on fuel cladding. While no significant impact was expected on the zircaloy cladding material, it was deemed prudent to perform fuel deposit sampling, as the fuel rod cladding is the major repository of waterborne crud.

Three bundles were selected for deposit sampling (Table 2.2-3). Bundle LJK961 was selected as the reference bundle for "normal" (pre-transient) water chemistry. This three-cycle bundle was discharged following the end of Cycle 3. Bundle LYS486 was exposed during Cycles 2-4 and was incore during the reactor water intrusion. This bundle was discharged following the end of Cycle 4. Bundle YJ2809 was exposed only during Cycle 4. This bundle will be reinserted into the core for future duty.

All bundles were inspected and/or handled in accordance with the Test Plan and Procedures (Ref. 51). Bundles selected for fuel deposit sampling were previously determined to be non-leaking bundles. Bundle YJ2809 was visually inspected by the GE fuel inspection crew following fuel deposit sampling. Visual examinations were not performed on discharge bundles LJK961 and LYS486; however, the sister bundles (LJK962 and LYS488) were visually examined. Inspection results for these bundles are reported in the Fermi 2 EOC-4 Irradiated Fuel Inspection Exit Report (Ref. 48). A final, comprehensive Fermi 2 EOC-4 Fuel Deposit Report will be issued prior to startup (Ref. 51). This report will contain a complete account of the fuel deposit sampling program, analysis results and detailed evaluation.

Fuel deposit sampling was performed in the spent fuel storage pool during 24-26 May 1994. Bundle disassembly was not required, as only peripheral rods were sampled. Two rods were sampled per bundle -- rods A1 and J1 of bundle YJ2809, and rods A1 and E1 from bundles LJK961 and LYS486. Seven elevations were sampled approximately every 20 inches along the length of the fuel rod. Two samples were removed per position; a "brush" sample was first removed with a nylon brush. Then, in the same position a "scrape" sample was removed with a diamond-grit stone. The brush and scrape sample results were then added for a "total" deposit loading per sample position. The six sample positions were averaged to achieve a rod average value. Rod averages were then combined to achieve a bundle average value.

Samples were analyzed for elemental and isotopic loading concentrations. Concentrations are reported in μg/cm² and μCi/cm² of fuel rod surface area, respectively. [redacted] analysis was also performed on selected samples. Results are reported in terms of relative percent of detected crystal structures.

Table 2.2-4 lists the bundle average elemental determinations for the brush, scrape and total loading concentrations of the typical corrosion product species. The major constituent of the fuel deposit samples was iron -- 85-96% of the brush samples and 80-89% of the scrape samples. The next predominant species were nickel and zinc. All other species comprised ~2% or less of the deposit material. The majority of the deposit loading (~80%) for the multi-cycle bundles was in the outer, brushable layer. Zirconium was detected in all the scrape samples, indicating that sufficient removal of the fuel crud material was performed. The concentration of zirconium varied from 53-987 μg/cm². Zirconium was not included in the total, as it was not considered one of the waterborne corrosion product deposits. Zirconium that was removed from the fuel rod was in the form of ZrO_2, the outer oxidation layer of the zircaloy fuel cladding material.

Samples were also analyzed for aluminum, calcium, magnesium, sodium, silicon, and titanium. The majority of the samples did not contain these species above the background detection limit. Where these species were detected, the concentrations were very low and not considered significant.

Figure 2.2-10 compares the Fermi 2 fuel deposits with the GE fleet of BWRs. The database includes fuel deposit data from over 160 bundles taken from 24 reactors. Clearly, fuel deposits from Fermi 2 are well within the distribution band for BWRs. Experience has shown that fuel deposits are feedwater driven (i.e., the higher the feedwater concentration of metallic species, the higher the fuel deposit loading). The lower loading of bundle LYS486, when compared to bundle LJK961, was due to the reduced feedwater concentrations during Cycles 3 and 4. Bundle YJ2809 showed very low fuel deposits; part of this was attributed to the low feedwater concentrations during Cycle 4. Fermi 2 reported average feedwater iron concentrations of 0.5 ppb for the majority of Cycle 4. Bundle YJ2809 was also sipped prior to fuel deposit sampling, which resulted in the perturbation and partial loss of the outer deposit layer. However, even if the removal of the majority of the outer fuel deposit occurred, the low loading of the inner deposit layer indicated that the total deposit loading of the one-cycle bundle would still remain well within the range of experience for BWRs.

The major fuel deposit activities detected were Co-60 and Zn-65. Figures 2.2-11 and 2.2-12 compare the Fermi 2 fuel deposit Co-60 and Zn-65 activities with the fleet. Deposit activities were also within the experience band. No unusual activities were detected.

The crystal composition of the fuel deposits was determined by [redacted]tion.] Hematite (α-Fe_2O_3) was the predominant crystal structure observed. Mixed spinel structures, such as Fe_3O_4, $ZnFe_2O_4$ and $NiFe_2O_4$, were also determined in some samples. The [redacted] could not distinguish between the different spinel structures, but the elemental data suggests the zinc and nickel structures. No other crystal structures other than ZrO_2 and artifact diamond (from the sampling stone) were detected. Hematite and mixed spinels have been the predominant crystal structures observed in all previous BWR fuel deposit sampling campaigns. Spinel structures have been more common in plants with reactor water zinc concentrations >1 ppb. Historically, scrape samples have contained higher concentrations of mixed spinel structures due to the tendency of non-ferrous species to incorporate and remain in the inner deposit layer. The majority of BWR brush samples have contained only hematite. The selected Fermi 2 fuel deposit samples followed the crystal structure composition of previous BWR experience.

In summary, the fuel deposits from the Fermi 2 bundles were determined to be within the experience band of other BWRs. No unusual loading patterns, deposit species or crystal structures were observed. The sipping of the one-cycle bundle resulted in the loss of some deposit material, but the removal of the outer deposit layer could be beneficial, in that Fermi 2 will resume operation with a "cleaner" core of fuel. The reduced amount of loose fuel deposits could also be beneficial by reducing the amount of activated species available for transport throughout the primary reactor system.

It is recommended that fuel deposit sampling be performed at the next refueling outage only if reactor water chemistry is poor (i.e., high conductivity, significant pH variations, high metallic feedwater concentrations), or if another transient is experienced.

2.2.3.3 Irradiated Fuel Examination

While the failed bundles were included in this examination primarily to assess the cause of failure, the non-failed bundles were examined to assess the effects of the Lake Erie water intrusion during Cycle-4 operation and to establish a base line (starting point for comparison) to investigate the effects of subsequent operation. Note that the two fuel rod failures, which occurred prior to the chemistry event and were therefore not caused by the event, were evaluated independently. Details and evaluations (such as observations and failure mechanisms) pertaining to these two failed bundles (LJK962 and LYS488) were documented in a separate report.

2.2.3.3.1 Fuel Inspection

Prior to the inspection of the bundles, the channels were left on for a cursory visual examination. After removal of the channels, bundle visual examinations were performed to identify unusual or abnormal conditions attributable to the Lake Erie water intrusion and to qualitatively assess the condition of the bundles.

After this bundle examination, the bundles were disassembled for single rod examinations. Single rod examinations included rod corrosion thickness measurements and visual examinations. These individual rod examinations included rod brushing with a stainless steel brush and visual examinations of the rods through a high resolution underwater video system. For the GE11 bundle, this also included examinations of a few of the partial length rods and the spacer contact areas of the fifth spacers.

2.2.3.3.2 Fuel Inspection Results

The visual examination of the channels showed that the channels were only lightly covered with crud. Most of the channel surfaces were covered with a non-uniform layer of nodular and sheet corrosion, with thickness difficult to assess visually. The corrosion layer on the GE11 channels appeared to have the lightest layer of very fine nodules, with areas of shiny black autoclaved surfaces. All of the various channel components appeared normal and, in general, in excellent condition.

The bundle visual examination showed all of the fuel rods to be covered with a (normal) layer of heavy, fluffy crud. Most bundle components showed only a light dusting of crud, with all components appearing normal and in excellent condition. The crud deposition on the fingersprings was heavy (normal) with some appearance of corrosion. The spacers on all the bundles appeared to have less than normal nodular corrosion for equivalent bundle exposures. There appeared to be no corrosion on the GE9 and GE11 spacers.

For bundles LJK962 and LYS488, the inspections of individual rods showed nodular corrosion coverage ranging from 60% to 100% for all rods. The rod examined from bundle LJK962 showed large white nodules with center pitting, with much of the surface exhibiting the shiny "mother of pearl" appearance. Portions of the shiny surface were scraped away, leaving the filigree appearance. The visual appearance of the rods from LYS488 was a typical visual standard 2 (VS-2) with the nodules much finer than those noted in LJK962. Nodular corrosion coverage for rods in bundles LYX594 and YJ2809 varied greatly, ranging from almost zero to 70%, with many having retained their black lustrous autoclaved surface appearance and bordering on a VS-1 classification.

Individual rod examinations also included measurements for corrosion thickness (ROXI). These ROXI measurements generally corresponded with what was observed on the rods and their surface conditions. For bundle LJK962, the corrosion thickness typically ranged from 0.001 to 0.0025 inches. For bundle LYS488, thickness was up to 0.001 inches. For bundles LYX594 and YJ2809, corrosion thickness ranged between 0.0 and 0.0005 inches. There appeared to be no difference between Gd and regular UO_2 rods.

Finally, three partial length rods were visually examined to check the contact locations of the fifth spacer (top spacer for partial length rods). The spacer contact locations were visible, but not well defined. Some of the contact points were shiny bare metal, but there was no depth to these contact points.

2.2.3.3.3 Fuel Inspection Summary

During the irradiated fuel inspection, there were no unusual or abnormal conditions observed that were attributable to the Lake Erie water intrusion encountered during operating Cycle 4.

2.2.4 Reactor Pressure Vessel Corrosion Evaluation

On 15 March 1994, microbiological results were published for reactor water and other areas potentially contaminated with recirculation pond water. These results showed no detectable biological activity within the reactor.

In April 1994, while performing IVVI, unusual deposits were observed in the reactor pressure vessel (RPV). The identification of two visually distinct types of localized deposits on the RPV clad, unclad surfaces, and a feedwater check valve raised concerns about the nature of the potential corrosion mechanism(s). On 2 June 1994, the feedwater nozzle area was sampled remotely for the presence of biological organisms. Their presence was confirmed on 15 June 1994. Additionally, to assess the extent of the potential corrosion damage in the RPV, a diver was sent to inspect both regions on 29 June 1994.

It was important to attempt a determination of the mechanism(s) of both of the corrosion types observed on the RPV surfaces by characterization of corrosion products. Several mechanisms (including microbiologically induced corrosion [MIC]) could produce subsurface cavities beneath the surface point of entry. The surface indications could be more serious than visual inspections indicate. Conversely, the buildup may be due to a localized breach in the RPV clad surface; the corrosion product composition would be characteristic of alloy steel oxidation with possible concentration of foreign ionic species resulting from the transient.

2.2.4.1 Diver Observations

A RPV Corrosion Evaluation plan (Appendix 3) was established to address the issue of possible corrosion related degradation of the RPV wall as a result of the chemistry transient. The specific objectives were:

- To assess the extent of corrosion damage associated with the observed deposits.
- Gather information to determine mechanism.

Type 'A' ("bathtub ring" deposits)

The first type of corrosion product observed was a crusty, reddish brown colored "island" of corrosion products with a possible pit at or near the center. These "islands" or corroded areas were detected in an 18-inch-wide band on the stainless steel cladded surfaces of the RPV in an area just below the main steam lines. This area corresponded to the shutdown water level following the transient. The location and distribution of the corroded areas were consistent with the kind of corrosion activity associated with a water/air interface. The deposits are shown in Figures 2.2-13 and 2.2-14. As noted in Figure 2.2-14, the corrosion spots typically ranged in size from 3/32" to approximately 3/16".

DECo and GE found corrosion conditions to be uniformly distributed about the circumference. After careful assessment of video images, it was decided that diver visual inspection and corrosion sampling would be performed at azimuth 150. In addition, the video was used to acquaint diving personnel with conditions present in the RPV.

The diver's direct inspection confirmed the RPV wall corrosion spots ("bathtub ring") to be uniformly distributed about the circumference of the vessel in a band approximately 18 inches wide. Many spots seemed to be associated with the valley at the junction of adjacent clad weld beads. Each corrosion location appeared to have a dark spot or "pit" at or near its center (Figure 2.2-15). This originally suggested the possibility of a subsurface cavity caused by corrosive action such as MIC.

Exploratory inspections by probing these corrosion spots as "islands" for MIC related penetration beneath the clad surface using a dental tool verified no corrosion pit or opening to a subsurface cavity (Figure 2.2-16). Scraping the surface to qualitatively assess the general characteristics of the corrosion deposit suggested the material was fairly brittle, tightly adhering but removable with moderate effort. Dressing the surface with an air-powered rotary brush removed the material with ease. Figures 2.2-17a & 17b are before and after video photos of a cluster of corrosion spots removed by brushing. (The spot in the lower right of Figure 2.2-17b is a corrosion spot probed and scraped with a dental probe.) The surface cleaned to a bright shiny clad surface with no evidence of pitting. Figure 2.2-18 is a photo of the result of brushing/cleaning of a cluster of spots in the region of adjacent clad beads. Again, pitting was not found.

Samples of the "bathtub ring" corrosion deposit were collected with a suction tube device (Figure 2.2-19) for determination of biological activity and the corrosion product composition. Since each corrosion spot contained only a very small quantity of corrosion debris, a large number (15-20) of spots were scraped to capture a usable quantity of debris (see Section 2.2.4.2 for an elemental analysis of the collected deposits).

Type 'B' ("corn flake" deposits)

The second type of corrosion product observed was a crusty, white to tan colored "corn flake" buildup of corrosion products. Figure 2.2-20 is a general view. The morphology was significantly different from the first type in that the shape was more linear than round. Distribution appeared to follow a "flow" pattern. Corrosion products were observed near the feedwater nozzle and sparger on the uncladded surface of the low alloy steel [redacted] RPV. These indications were unique in appearance with no visible pit associated with the corrosion products. A closeup view is provided in Figure 2.2-21.

The deposits, located at the feedwater nozzles in the unclad region, did not suggest surface penetration. The diver's direct inspection results verified the results of the IVVI.

Exploratory inspections of numerous corrosion patches were performed to characterize the extent and adherence of the deposits, and to look for possible pitting or surface damage. Probing with a dental probe indicated the deposits could be characterized as follows:

- Loose, brittle deposits
- Small volume of corrosion debris
- Easily removed by superficial scraping
- Dark high temperature oxide beneath deposits
- No corrosion involvement of nozzle material

Figures 2.2-22 through 2.2-25 is a sequence of photos which demonstrate the ease with which a typical corrosion deposit was removed, revealing the typical high temperature oxide present on surfaces exposed to BWR water. No pitting was found.

Samples of the "corn flake" corrosion product were collected with the "suction tube" device and collected in sterilized bottles. (Figure 2.2-26 is a video image taken during the sample collection.) The sample was used to determine corrosion product composition.

See Section 2.2.4.2 for an elemental analysis of these deposits. Based on the results of the diver inspections and evaluations, the following conclusions and recommendations were made:

- Conclusions
  - No significant pitting of surfaces

- Deposits removable with little to moderate effort

• Recommendations
  - Remove both types of deposits to extent practical
  - Reinspect next refuel outage

2.2.4.2 Chemical Analyses of Deposits

The appearance of circumferential corrosion areas ("bathtub ring") on the vessel surface cladding at the waterline level during the weeks following the transient has significance. A sample of this material was dislodged from the surface and collected in a one-liter plastic bottle during an underwater dive evolution to assess the extent of pitting in these localized areas. The insoluble material sample was filtered in the laboratory onto a Millipore filter paper, and sent to VNC for the same chemical analyses that were performed on the "brown slick" sample. Table 2.2-5 shows the [redacted] results from this sample.

Like the "brown slick" sample, the composition of this "bathtub ring" sample is predominantly iron, with lesser amounts of nickel and chromium, which again are typical of stainless steel corrosion products. The next most abundant elements are silicon and aluminum. The silica composition of this sample can perhaps be explained from the relatively high concentrations in the reactor water following the transients. At least one measurement indicated a concentration greater than 1500 ppb. The presence of aluminum in this sample is perhaps explained by inputs from the Condensate Storage Tank on December 25, when excess circulation water from the condenser was routed to this tank. The relatively high pH of the circulation water may have initiated some aluminum corrosion from the tank surfaces, with ingress to the vessel via the standby feedwater pumps when they were used to maintain vessel level control.

The [redacted] analyses revealed three crystalline phases in this sample with the following weight percentage distributions: α-Fe_2O_3 (88%), pure or mixed spinel-type Fe_3O_4 (magnetite) structures (12%), and a trace of FeOOH (< 1%). The relative abundances of the crystalline phases in samples of this type should be treated with some caution due to homogeneity effects in working with small sample sizes. Most iron bearing BWR corrosion deposits typically contain lesser amounts of spinel, relative to the dominant hematite phase. The absence of aluminum and silicate structures in the diffraction pattern suggests that they may be amorphous, non-diffracting compounds. Again, no calcium or magnesium compounds were observed in the patterns.

The more localized deposits ("corn flakes") that have been documented on the feedwater nozzles have also been analyzed. Two samples were received for analysis. The first sample obtained on June 2 was collected by vacuum filtration using a stainless steel tipped edge that was connected to the vacuum pump suction line. The insoluble material from this sample was collected at poolside on a membrane filter. A second sample was collected during the dive evolution on June 29 by dislodging material from the surface with a probe, and collected by vacuum filtration. The insoluble material from this sample was filtered in the laboratory on a membrane filter. Both samples were analyzed at VNC. [redacted] analyses for these samples are indicated in Tables 2.2-6 and 2.2-7.

The elemental composition of the first cornflake sample is remarkably similar to that of the bathtub ring sample with respect to the relative distribution of iron, aluminum and silicon. The second sample is mostly iron. The variance in the composition between the two cornflake samples may be a reflection of the differences in which the samples were collected. The [X-ray diffraction] results from the two samples were very similar. Only two patterns were identified in each sample. These were α-Fe_2O_3 and Fe_3O_4. The relative abundance of hematite in the samples was 78% and 88%, for the samples collected on June 2 and June 29, respectively. The absence of aluminum and silicate structures in the June 2 sample is again attributed to the apparently amorphous nature of these compounds.

Despite physically different appearances of the "cornflake" deposits and the vessel "bathtub ring" deposits, their chemical properties are remarkably similar, perhaps suggesting that both deposits originated from the same event (i.e., the December 25 intrusion). Iron, in the form of α-Fe_2O_3, is the principal component in all samples. More important to the recovery is the general absence of calcium and magnesium compounds in these samples. As these samples are representative of the most severe corrosion in the vessel, the likelihood of calcium and magnesium incorporation into the more common corrosion films is reduced, along with the release of these ions to the water upon the restart of the reactor.

2.2.4.3 Microbiological Analyses of Deposits

Microscopic examinations were performed by Mr. Todd Kenney of Bioindustrial Technologies Incorporated (BTI) on the "cornflake" sample. Direct examination of the sample using [redacted] method revealed a variety of rod-shaped bacteria, spherical bacteria and a few filamentous bacteria. In addition, several objects which appeared to be empty sheaths were detected.

Direct examination usin[redacted]found deposits believed to be bacterial filaments encrusted in reddish-brown material (presumptive metal deposits). This method also found numerous objects which appeared to be microorganisms and/or deposits of unusual morphology.

Filaments with sheaths and/or associated deposits are morphological features characteristic of certain groups of bacteria that have been implicated in microbiologically induced corrosion (MIC). These observations serve as presumptive evidence for metal-oxidizing/depositing bacteria. However, many bacteria capable of oxidizing metals do not have characteristics which separately identify them from other bacterial groups.

Viable bacteria analyses using th[redacted]technology revealed a high level of viable aerobic bacteria (biological cell counts of > 100,000 cells/ml), low levels of viable anaerobic bacteria and viable acid-producing bacteria. No viable sulfate-reducing bacteria were found. Based on other samples analyzed, most biological growth appears to be slow growing and non-aggressive toward metal surfaces.

2.2.5 Shroud Inspection and Evaluation

Two small linear indication (approximately 2 in.) were found at weld H2 during the recent inspection of the Fermi 2 shroud. The indications were axially oriented (perpendicular to H2). Reference 1 provides the screening criteria for the evaluation of detected indications. Reference 56 provides additional guidance on the evaluation of detected indications. Based on the results of Reference 1, the allowable through-wall flaw lengths were determined to be:

- Circumferential Flaws: 100 inches
- Axial Flaws: 70 inches

The observed indications are negligible compared to the allowable through-wall flaw size. Thus, the integrity of the Fermi 2 shroud with the observed indications is assured.

In addition, the Reference 56 document proposes an acceptance standard which states that indications less than 15 inches in length are acceptable and do not require further evaluation. Since Fermi 2 indications would satisfy this acceptance standard, the indications are acceptable.

2.2.6 Inspection of Other Components

Other selected vessel internal components were identified based on containing a [redacted] area. The presence or absence of IGSCC resistant materials was also considered. The following lists the results were obtained:

- The Core Spray Piping inspection was completed on 2 June 1994 with no abnormalities found.

- The Steam Dryer Support Brackets inspection was completed 2 June 1994 with no abnormalities found.

- The reactor recirculation inlet nozzle/safe end-UT was completed the week of 13 June 1994. Nozzle 101-304E was the only nozzle UT inspected. No anomalous readings were obtained.

- The "B" Jet Pump Instrument Nozzle -UT was completed the week of 13 June 1994. No anomalous readings were obtained.

- The bottom head region was not specifically identified as requiring an inspection. During the jet pump beam replacement, the opportunity presented itself to send a camera down the diffuser to view the peripheral bottom head. This was done at two locations with very little debris found.

- The steam dryer had the same "bathtub ring" of corrosion as the RPV. Hydrolazing of this ring has been performed to remove the corrosion to the extent possible.

Table 2.2-1
Fermi 2 CRD Alloys and Major Alloying Elements

[redacted]

Table 2.2-2

Fuel Bundle and Component Inspections and Sampling

Component	Inspection or Sampling
Channels (general)	All channels, prior to removal from the bundles, were given a cursory visual examination.
Bundles (general)	After the channels were removed, bundle visual examinations were performed to identify abnormal or unusual attributes.
Fuel Rods	Rod corrosion thickness measurements (ROXI) and visual examinations were conducted on eight (8) preselected rods per bundle.
Fuel Rods	Rods from bundles YJ2809, LJK961 and LYS486 were crud sampled for analysis at the Vallecitos Nuclear Center (VNC).
Locktab Washers Nuts Expansion Springs	Bundles LJK962, LYS488, LYX594 and YJ2809 were reassembled with new locktab washers and nuts. The irradiated locktab washers were provided to VNC for analysis. Two expansion springs from each of these bundles were also replaced, with the irradiated components again provided to VNC for analysis.
Channel Fastener	The fastener on bundle LYX594 was replaced with a new channel fastener. The irradiated fastener was provided to VNC for analysis.

Table 2.2-3

Selected Fuel Bundles for Inspection

Bundle ID	Fuel Type	Exposure [GWD/MT]	Cycles Exposed	Incore During Intrusion	Reload for Future Duty
LJK961	GE-6	26.5	1, 2, 3	No	No
LYS486	GE-8	27.0	2, 3, 4	Yes	No
YJ2809	GE-11	11.0	4	Yes	Yes

Table 2.2-4

Bundle Average Fuel Deposit Loading [μg/cm²]

Bundle	Sample	Fe	Cu	Zn	Ni	Cr	Mn	Co	Total
LJK961	Brush	3664	11	39	92	16	30	3.6	3866
LJK961	Scrape	966	26	58	59	18	31	2.9	1160
LJK961	Total	4631	37	96	151	44	61	6.5	5026
LYS486	Brush	2269	3	17	37	12	18	2.9	2359
LYS486	Scrape	346	4	18	21	7	14	2.0	412
LYS486	Total	2615	7	31	58	19	32	4.9	2767
YJ2809	Brush	85	0.2	6	2.5	1.4	0.9	0.08	96
YJ2809	Scrape	77	0.5	9	1.6	0.6	0.8	0.22	89
YJ2809	Total	162	0.7	14	3.1	1.4	1.3	0.18	183

Table 2.2-5

[redacted] Analyses of "Bathtub Ring" Deposits

Normalized Elemental Weight Percent									
Run	Al	Si	Cl	Ca	Cr	Mn	Fe	Ni	Zr
1	1.80	5.83	0.00	0.00	1.11	0.00	89.56	1.70	0.00
2	2.40	5.43	0.00	0.00	1.16	0.00	89.46	1.56	0.00
3	1.82	3.12	0.00	0.00	1.83	0.00	92.18	1.04	0.00
4	6.36	7.40	0.00	0.00	0.31	0.00	84.82	1.11	0.00
5	1.44	3.23	0.00	0.00	1.71	0.00	93.09	0.52	0.00
Avg	**2.76**	**5.00**	**0.00**	**0.00**	**1.22**	**0.00**	**89.82**	**1.19**	**0.00**
1-σ	**1.82**	**1.63**	**0.00**	**0.00**	**0.54**	**0.00**	**2.88**	**0.42**	**0.00**

Table 2.2-6
[redacted] Analyses of "Cornflake" Deposits (6-2-94)

Normalized Elemental Weight Percent									
Run	Al	Si	Cl	Ca	Cr	Mn	Fe	Ni	Zr
1	2.13	4.93	0.83	1.06	0.52	0.42	88.54	1.57	0.00
2	2.35	4.35	0.27	0.00	0.00	0.00	91.94	1.10	0.00
3	1.68	3.39	0.47	0.00	0.00	0.00	93.15	1.32	0.00
4	2.21	4.30	0.31	0.00	0.00	0.00	91.72	1.45	0.00
5	5.72	14.95	0.56	3.08	0.00	0.00	75.69	0.00	0.00
Avg	**2.82**	**6.38**	**0.49**	**0.83**	**0.10**	**0.08**	**88.21**	**1.09**	**0.00**
1-σ	**1.47**	**4.31**	**0.20**	**1.20**	**0.21**	**0.17**	**6.44**	**0.57**	**0.00**

Table 2.2-7
[redacted] Analyses of "Cornflake" Deposits (6-29-94)

Normalized Elemental Weight Percent									
Run	Al	Si	Cl	Ca	Cr	Mn	Fe	Ni	Zr
1	0.00	0.09	0.00	0.00	0.48	0.84	97.72	0.87	0.00
2	0.00	0.00	0.00	0.00	0.49	1.13	97.42	0.97	0.00
3	0.00	0.20	0.00	0.00	0.60	0.95	96.99	1.27	0.00
4	0.00	0.10	0.00	0.00	0.45	0.86	97.84	0.75	0.00
5	0.01	0.35	0.00	0.00	0.14	0.44	98.07	0.98	0.00
Avg	**0.00**	**0.15**	**0.00**	**0.00**	**0.43**	**0.84**	**97.61**	**0.97**	**0.00**
1-σ	**0.00**	**0.12**	**0.00**	**0.00**	**0.15**	**0.23**	**0.37**	**0.17**	**0.00**

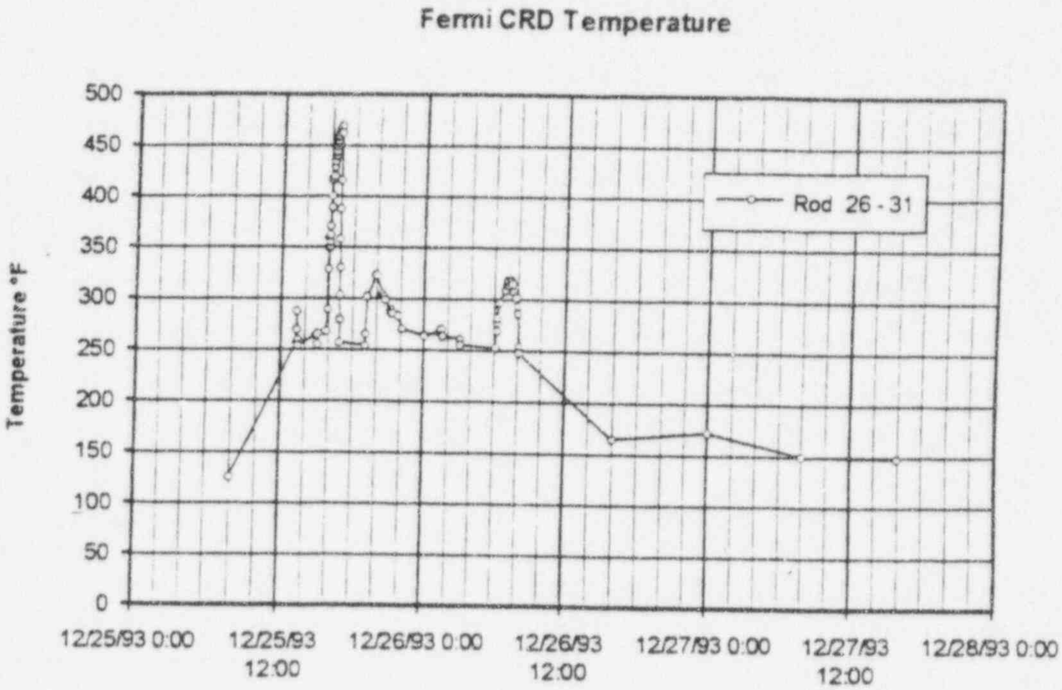

Figure 2.2-1. Temperature Data for Rod 26-31

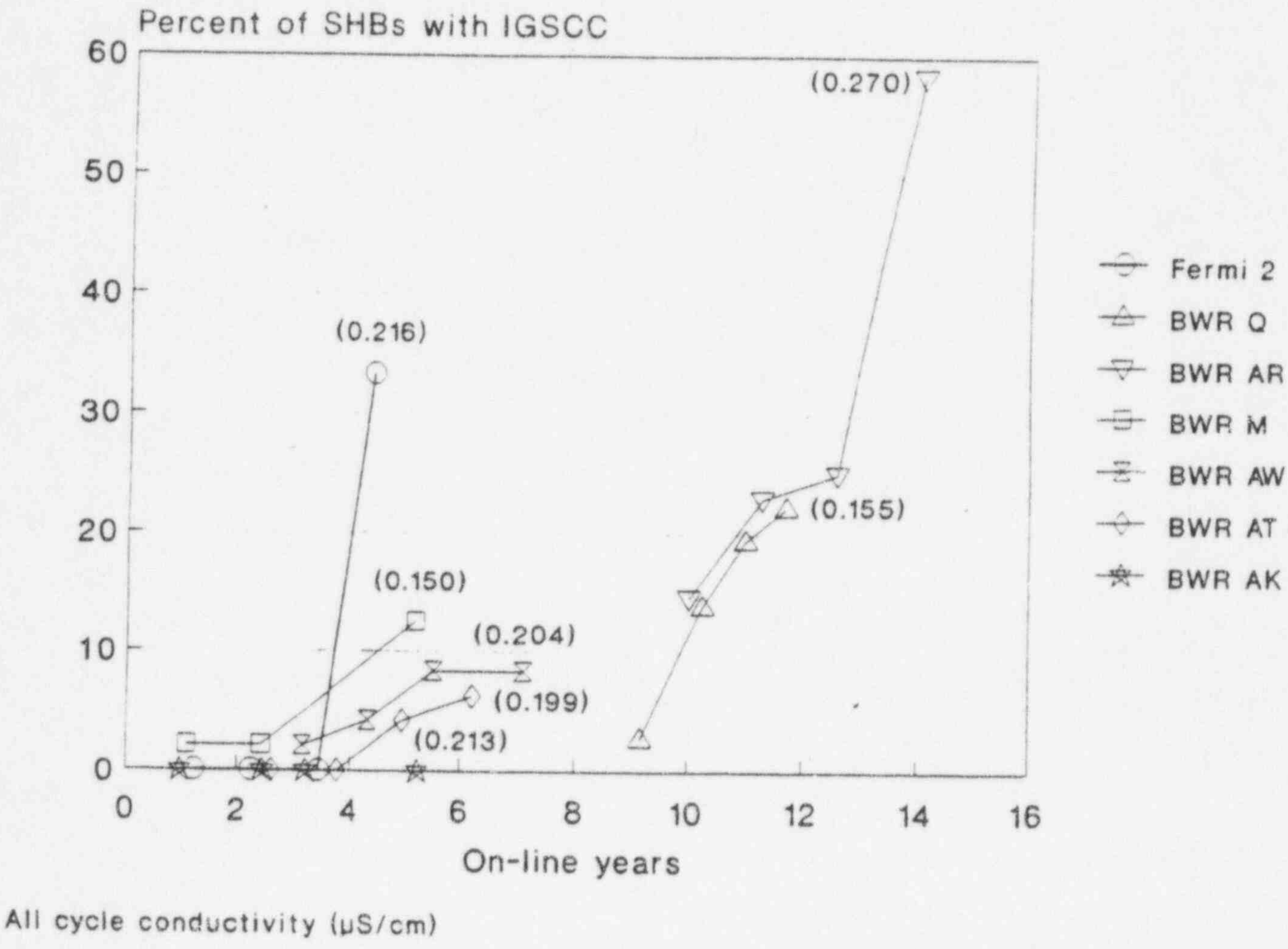

Figure 2.2-2. Shroud Head Bolt Failure Rate Trends for Fermi 2 and Other Comparable BWRs

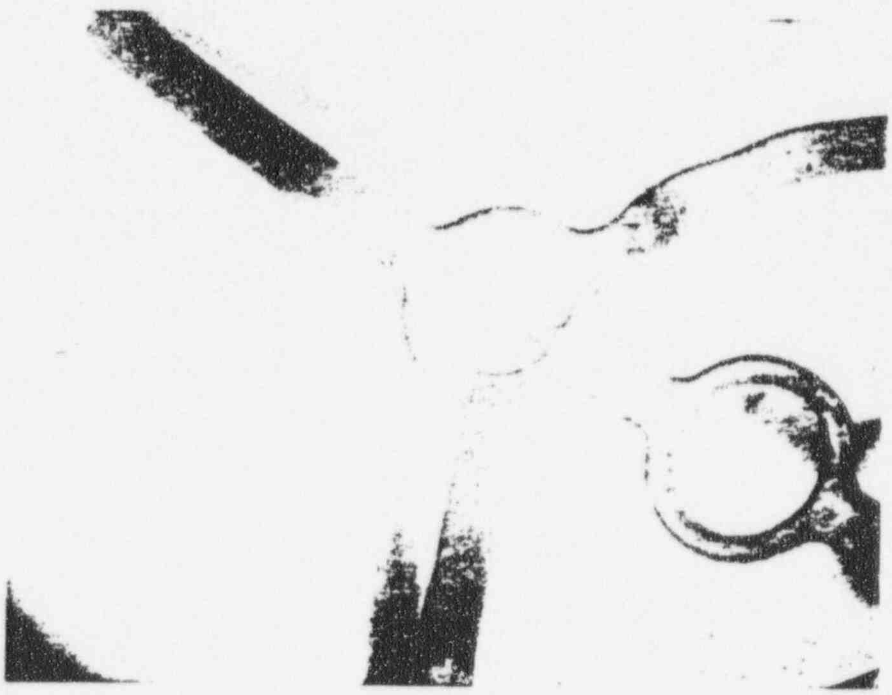

Figure 2.2-3. Lock tab washer: surface is coated with oxide

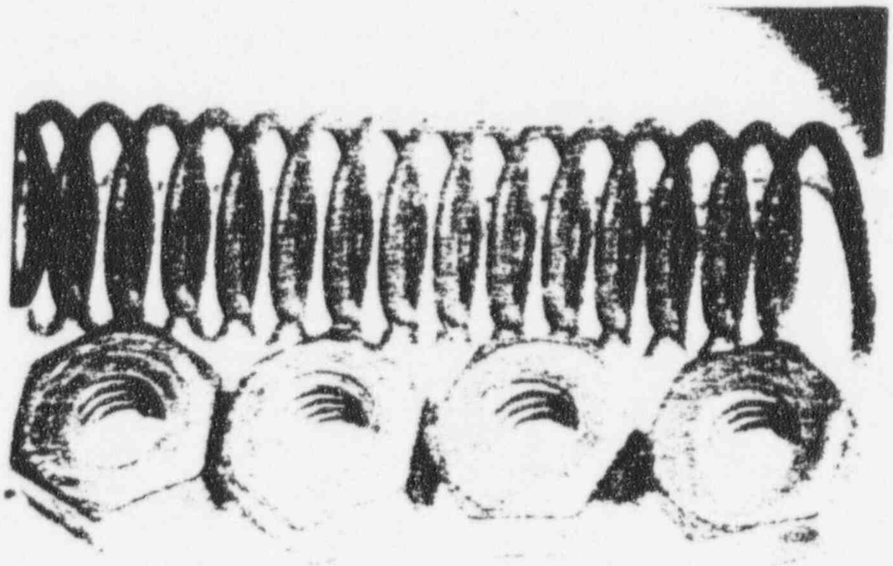

Figure 2.2-4. Hex nuts and spring: no evidence of anomalous surface conditions.

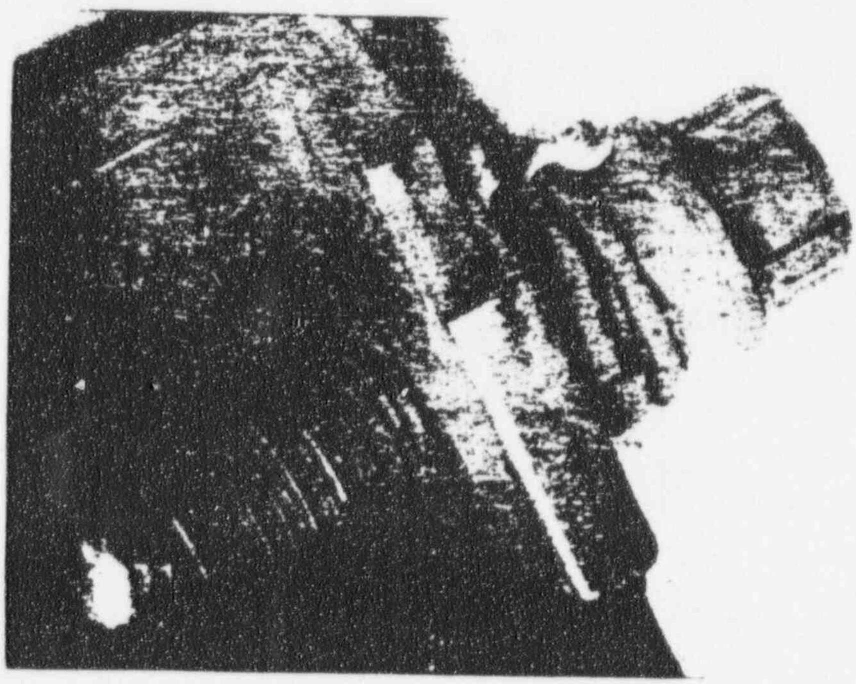

Figure 2.2-5. Channel fastener bolt: appearance is similar to other components.

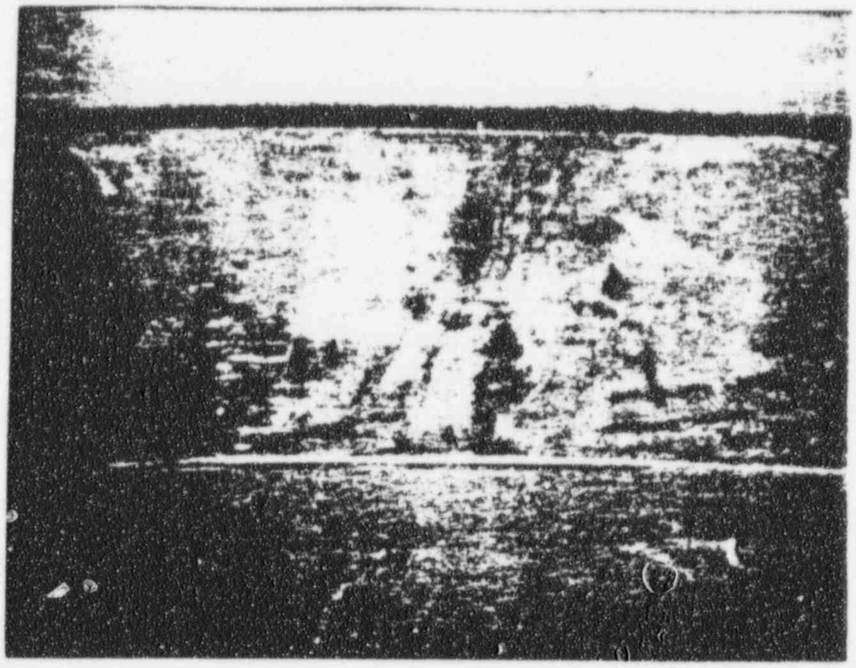

Figure 2.2-6. Surface of channel fastener; discoloration appears to be a stain.

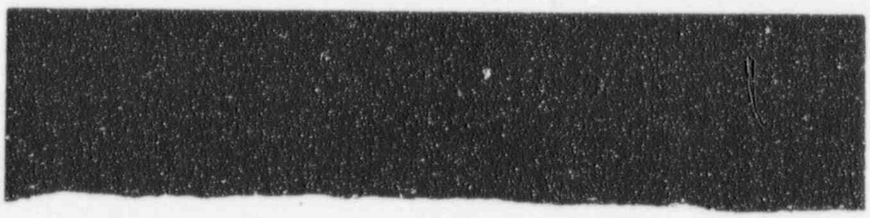

Figure 2.2-7. Cross section of spring; no evidence of degradation observed. (250X)

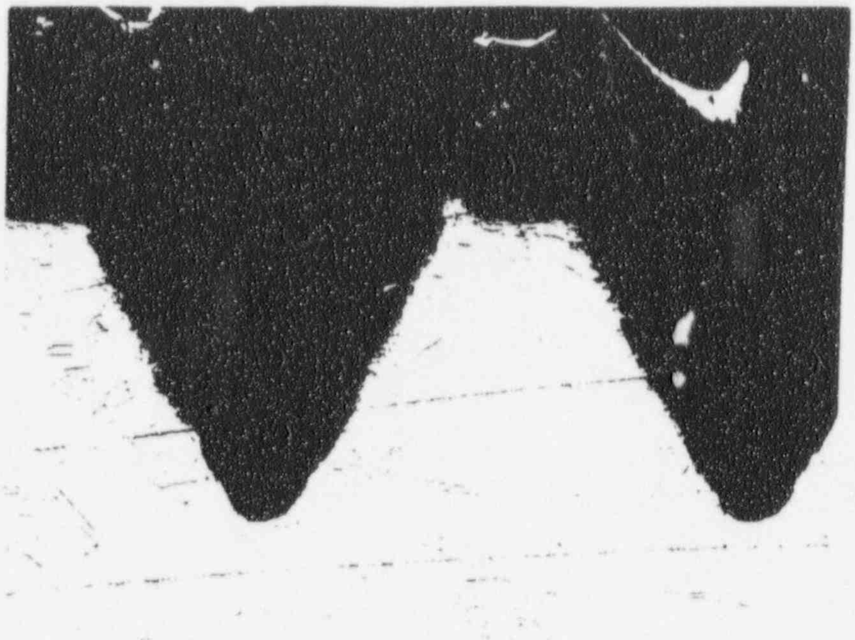

Figure 2.2-8. Hex nut cross section: thread root is undamaged. (50X)

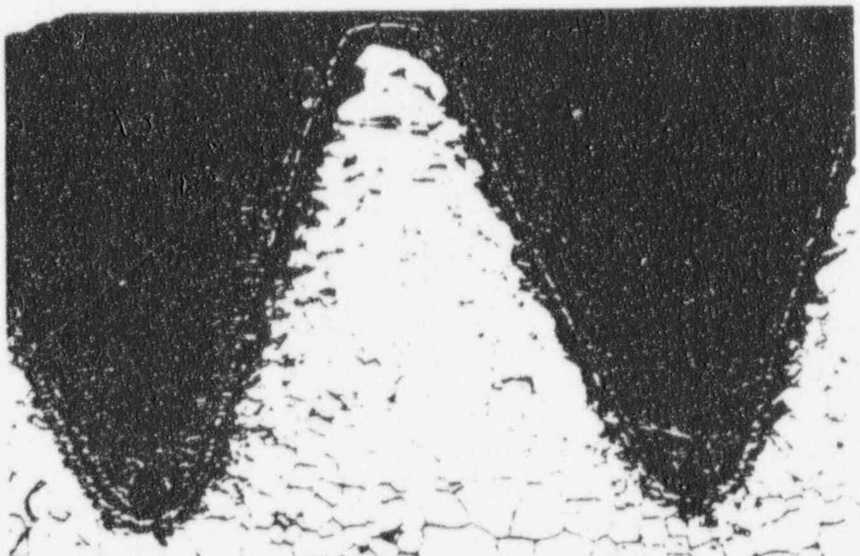

Figure 2.2-9. Channel fastener bolt: no evidence of degradation was observed. (50X)

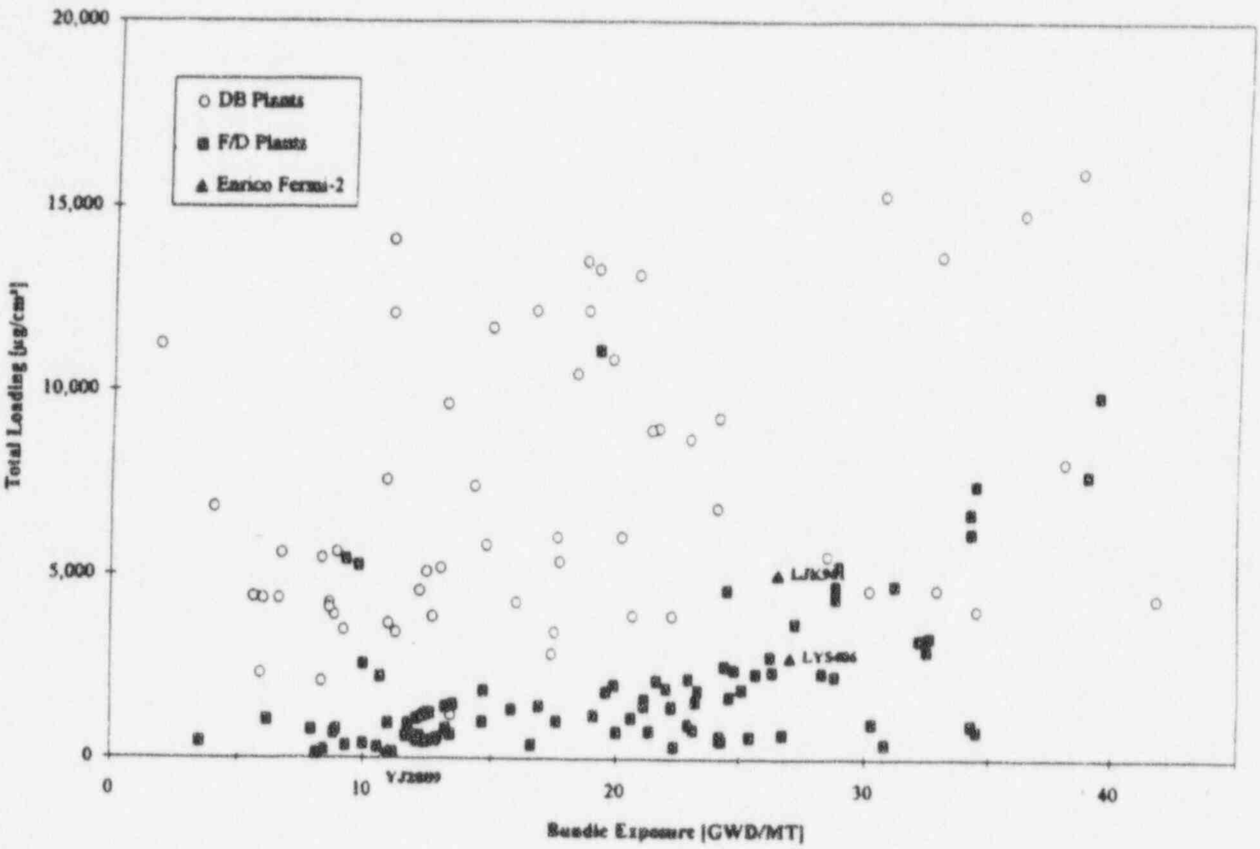

Figure 2.2-10. Fuel Deposit Loading Fleet Comparison. Total Loading.

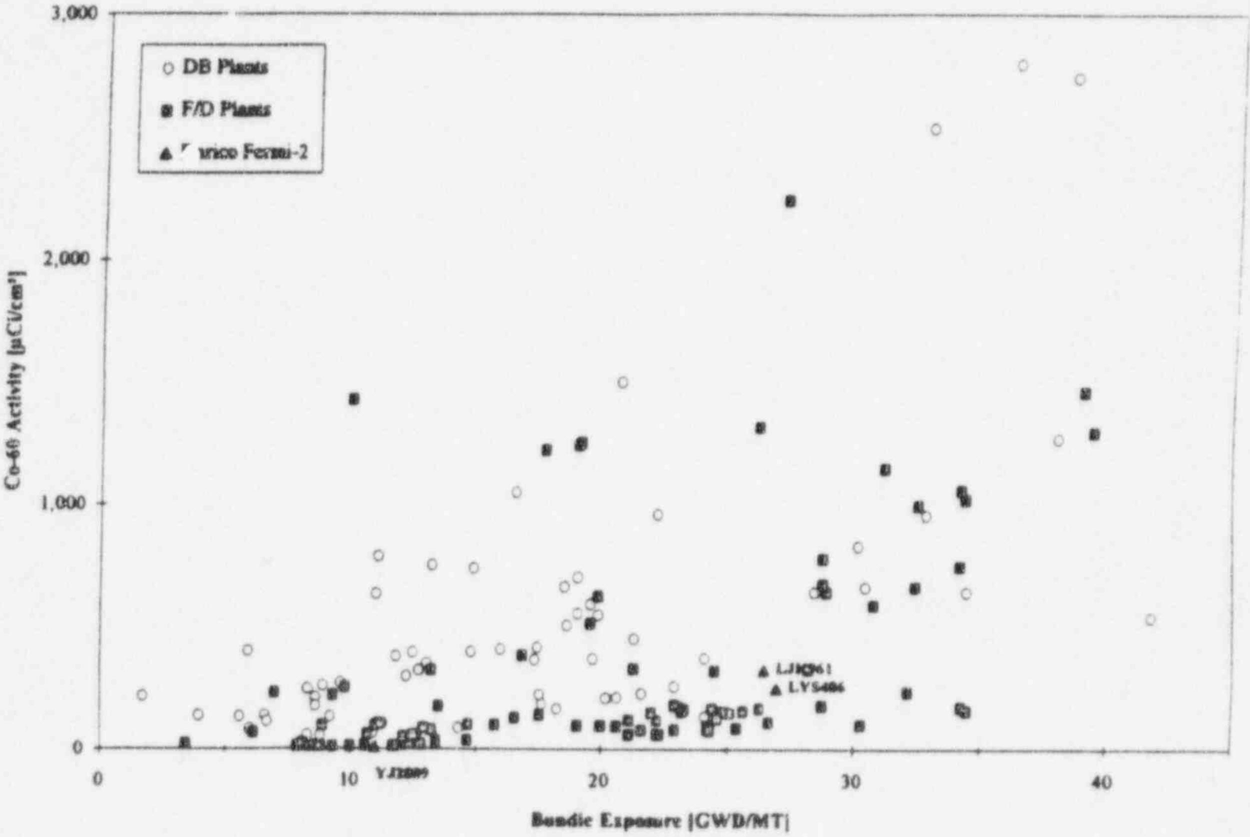

Figure 2.2-11. Co-60 Fuel Deposit Loading Fleet Comparison. Co-60 Activity.

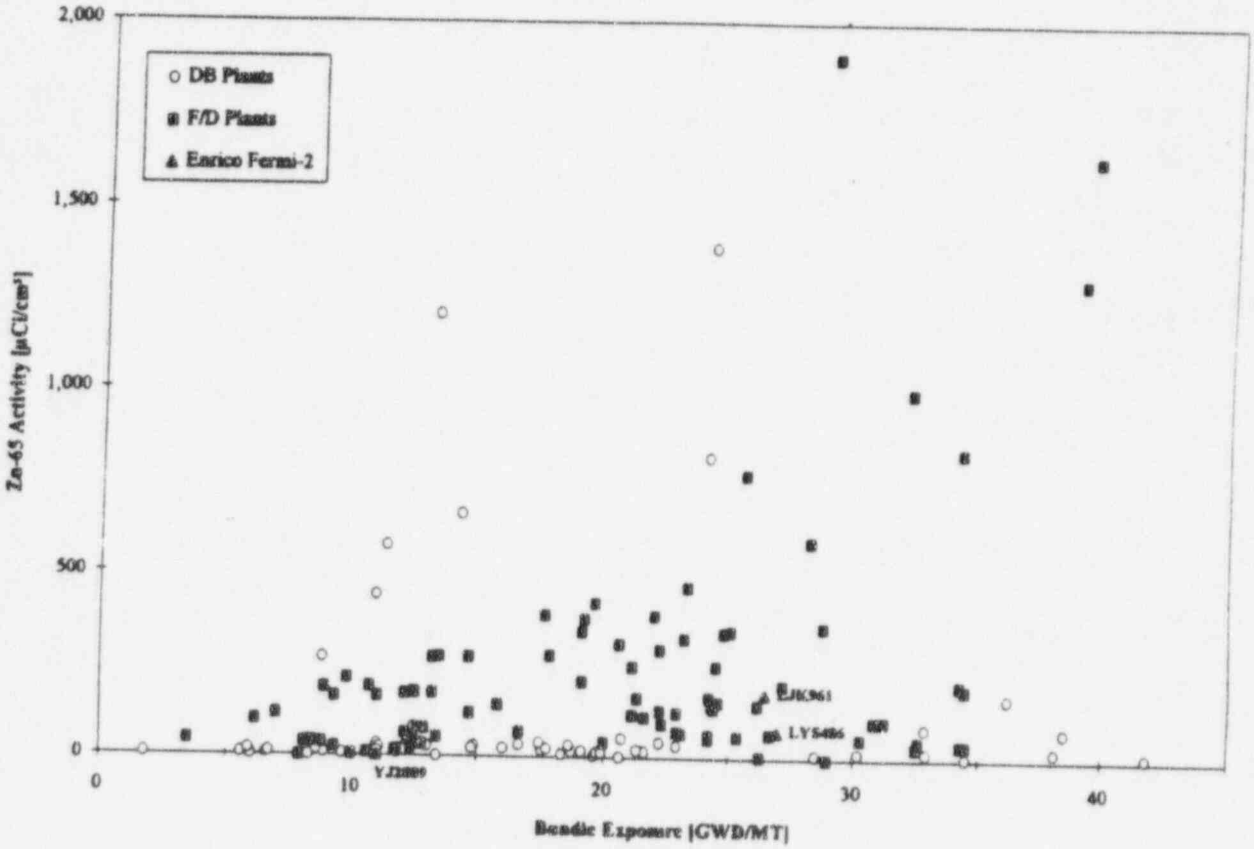

Figure 2.2-12. Fuel Deposit Loading Fleet Comparison. Zn-65 Activity.

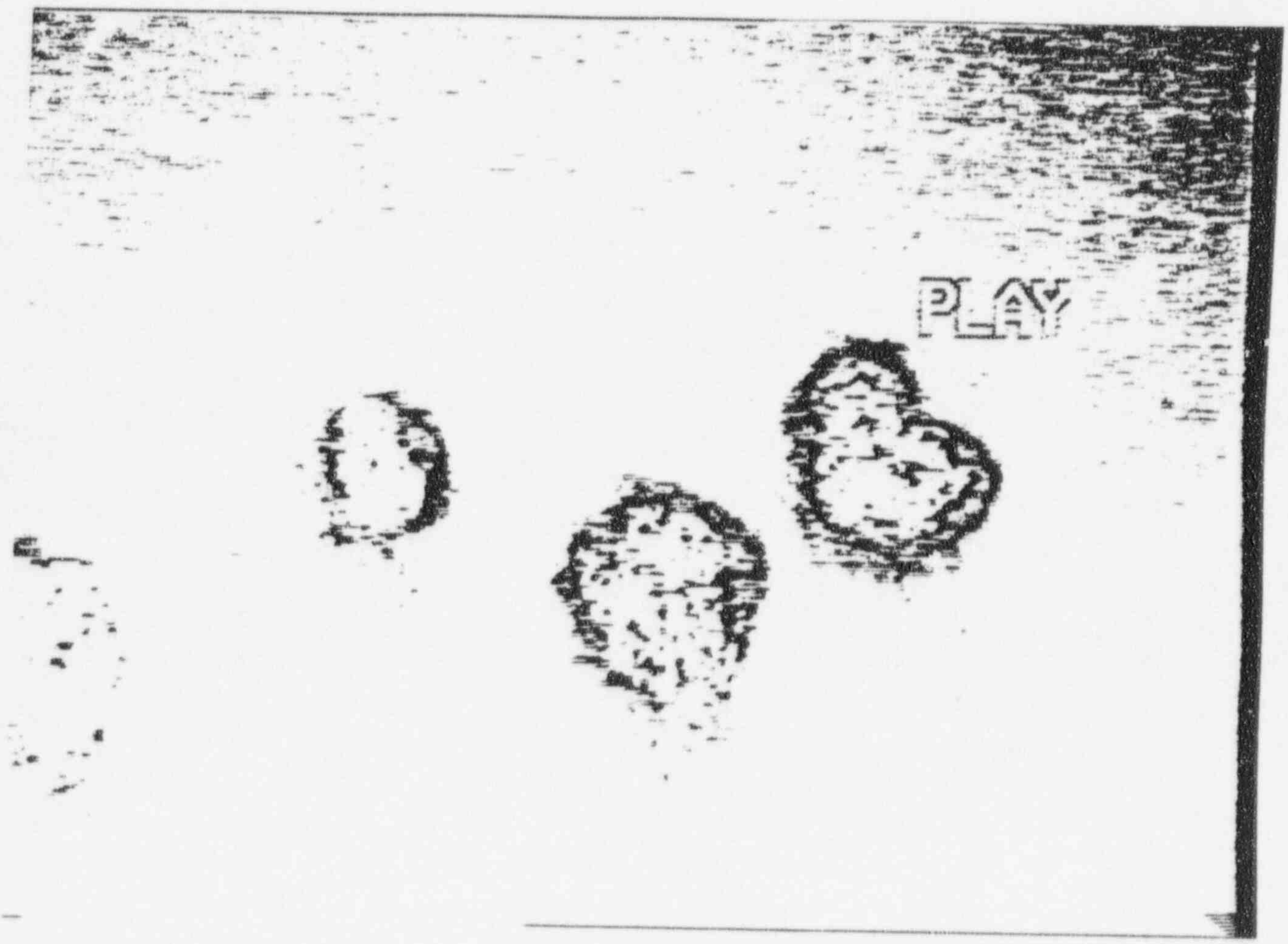

Figure 2.2-13. RPV wall corrosion deposits associated with "bath-tub ring". (View enlarged approximately 4x)

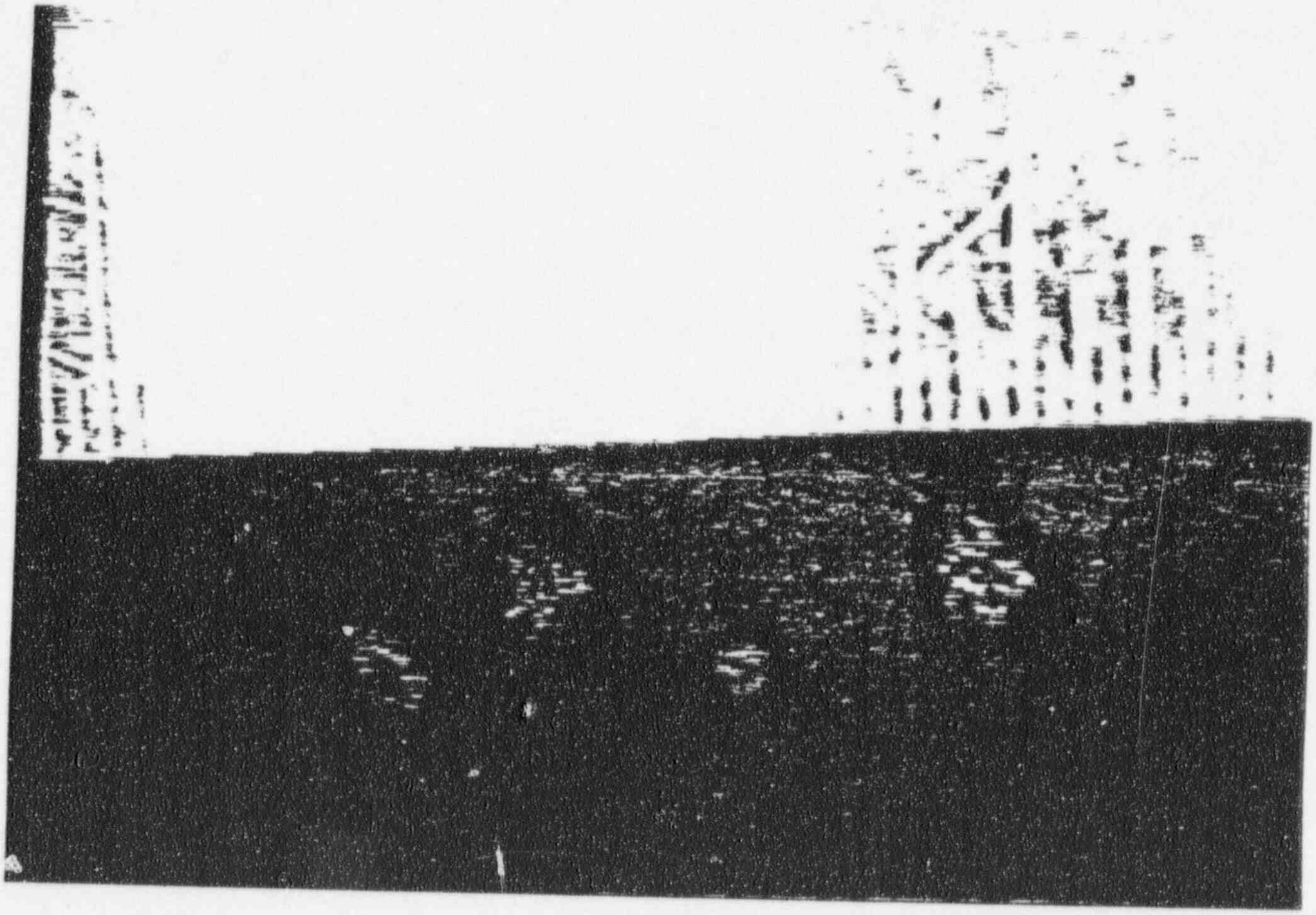

Figure 2.2-14. "Bath-tub ring" corrosion deposits shown with scale. Typical size ranged from 3/32" to approximately 3/16".

Figure 2.2-15. Corrosion deposit at juncture of adjacent RPV wall clad weld beads.

Figure 2.2-16. Exploratory probing of corrosion spot for MIC related penetration into clad surface. None was found.

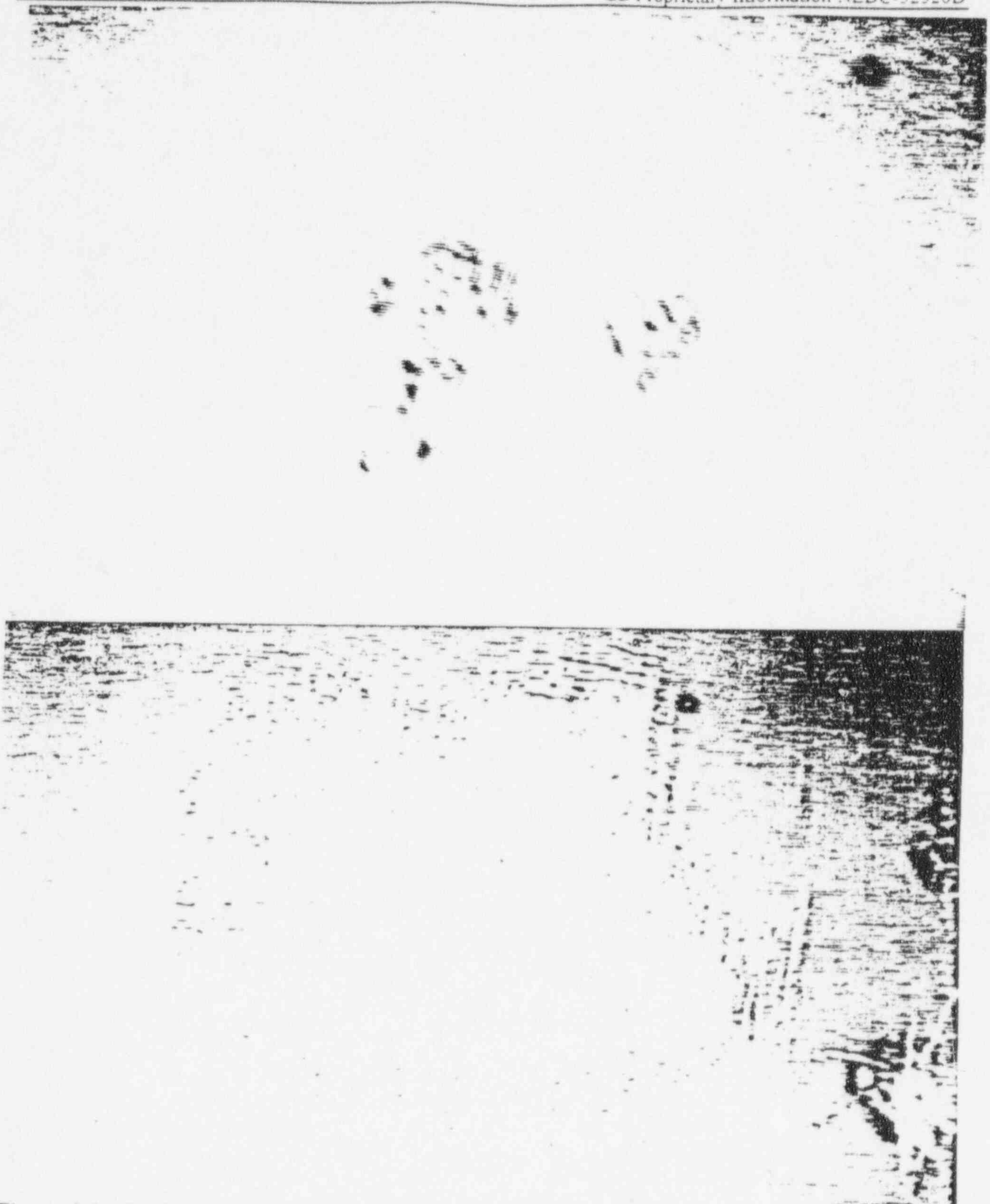

Figure 2.2-17a & 17b. "Before" and "after" views of corrosion spots removed by brushing.

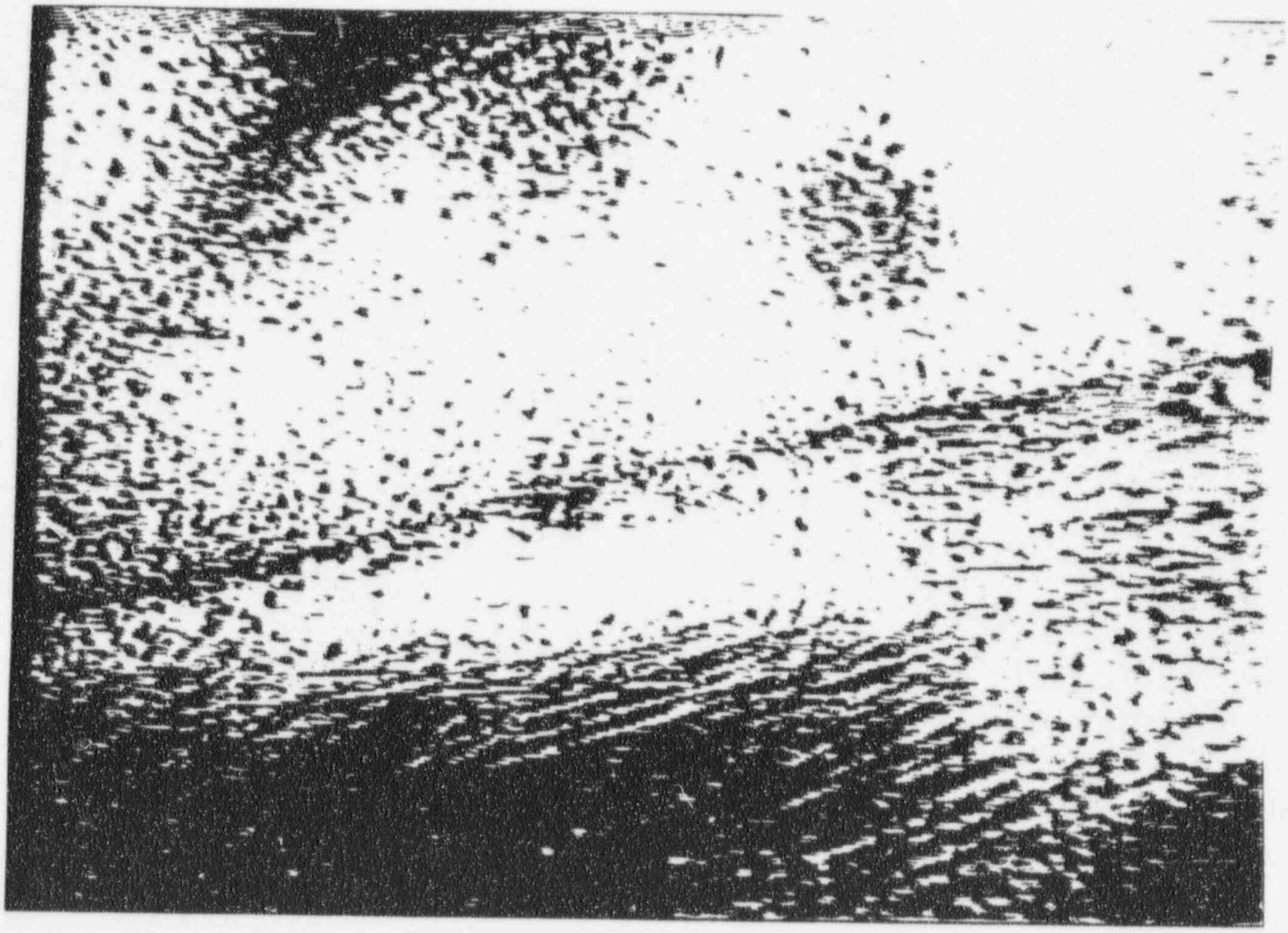

Figure 2.2-18. Result of brushing/cleaning of a cluster of spots in the region of adjacent clad beads.

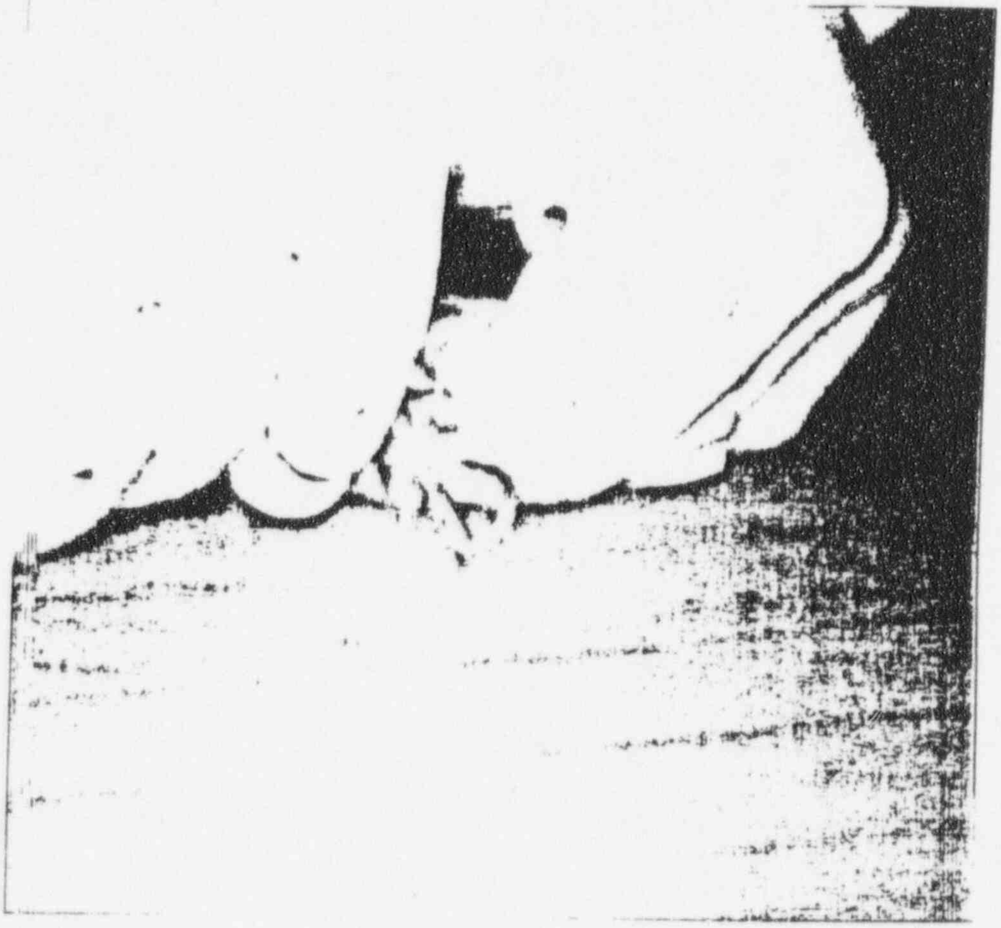

Figure 2.2-19. Removal of "bath-tub ring" corrosion deposit, and collection with a suction tube device

Figure 2.2-20. General view of corrosion product buildup on unclad alloy steel feedwater nozzle surface.

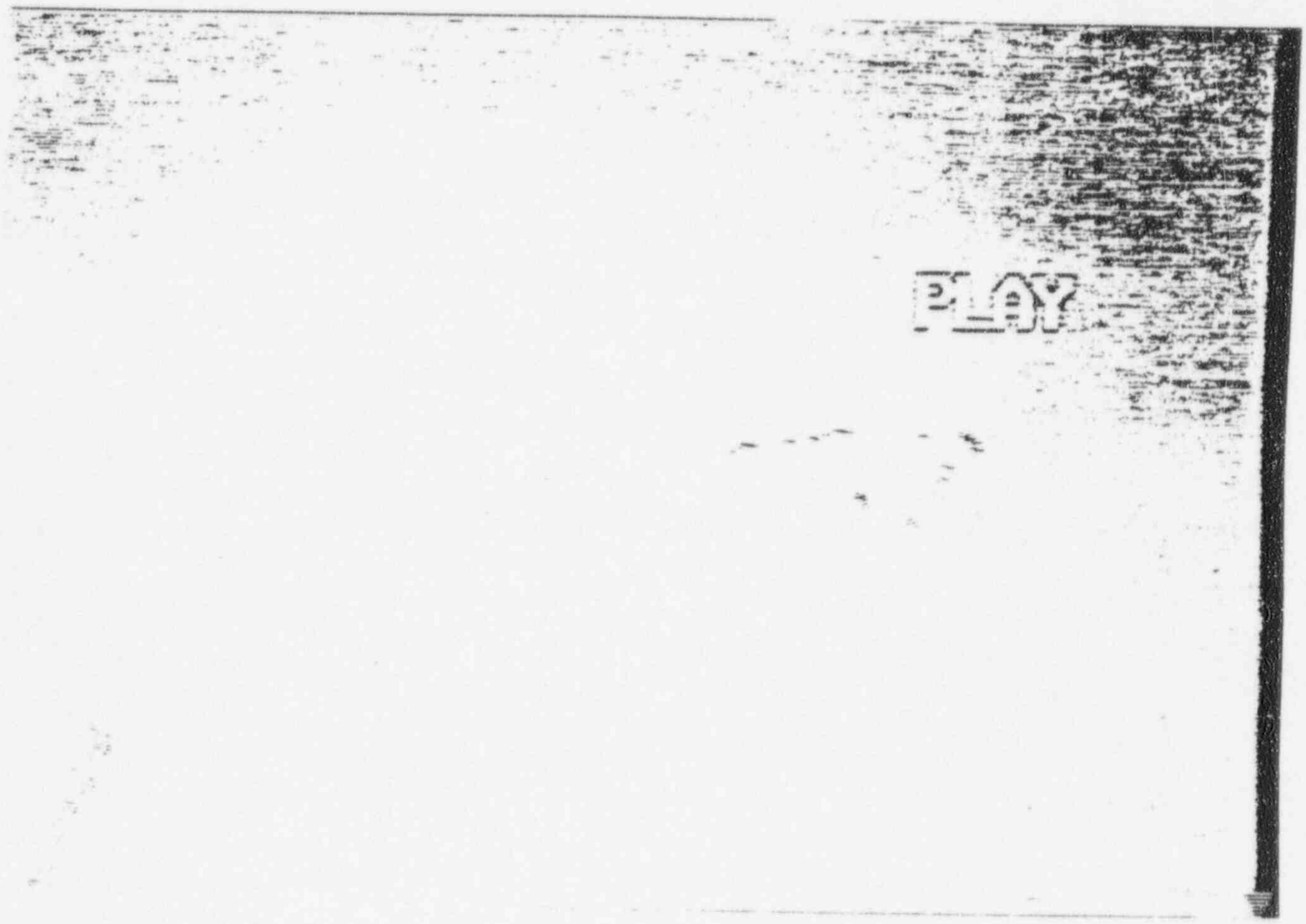

Figure 2.2-21. Close-up view of "corn flake" type corrosion deposit (approximately 4x magnification).

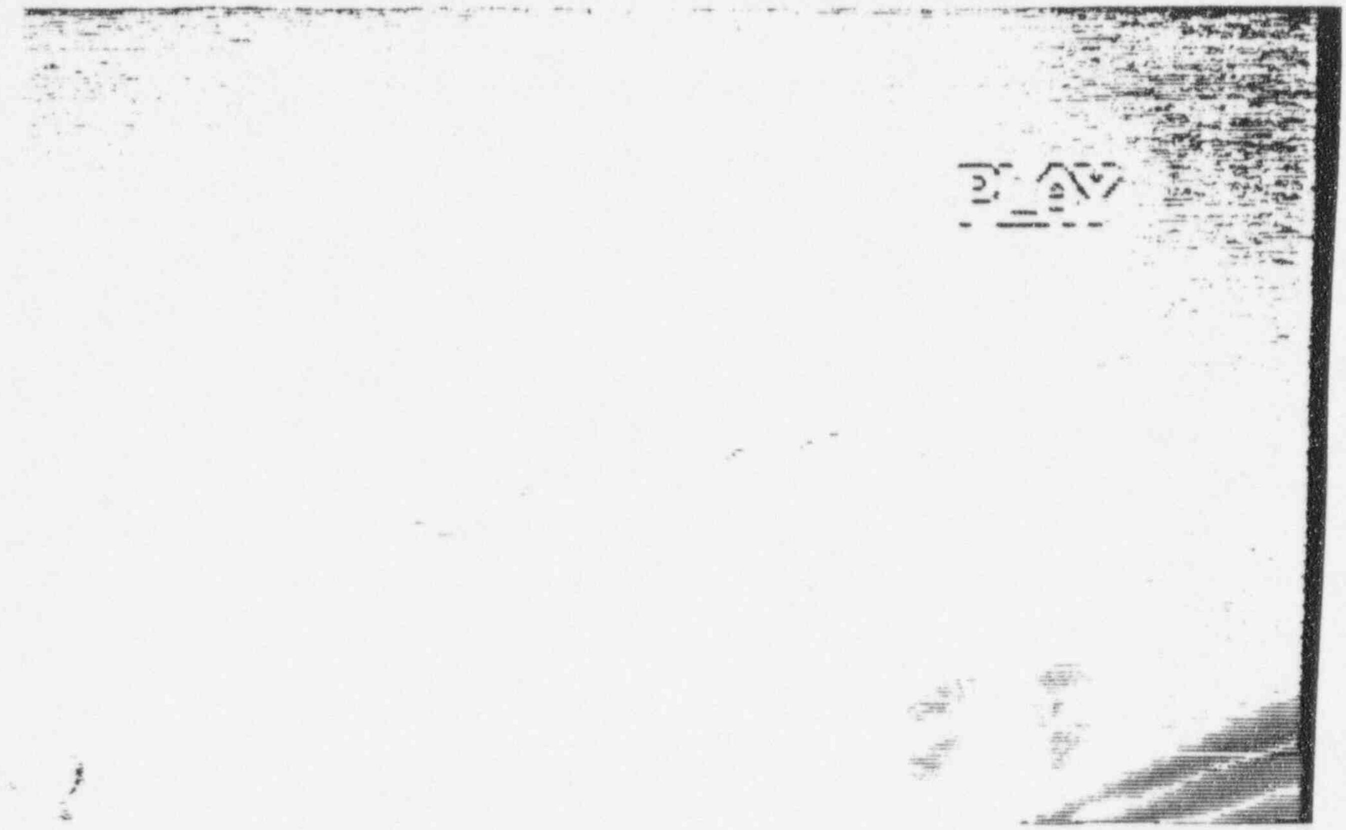

Figure 2.2-22. Removal of "corn flake" corrosion deposit. Step 1.

Figure 2.2-23. Removal of "corn flake" corrosion deposit. Step 2.

Figure 2.2-24. Removal of "corn flake" corrosion deposit. Step 3.

Figure 2.2-25. Removal of "corn flake" corrosion deposit. Step 4. Note nearly complete removal of deposit, and dark oxide of nozzle surface beneath deposit.

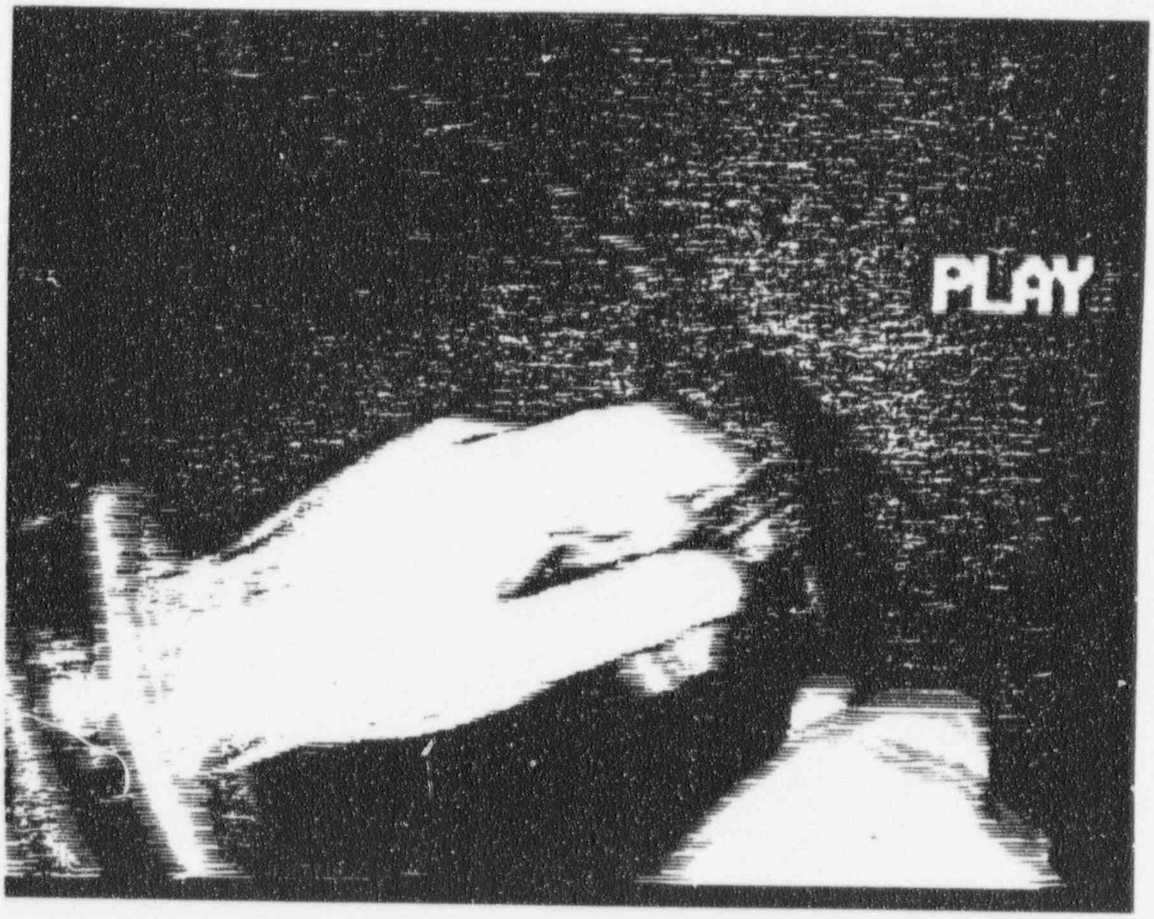

Figure 2.2-26. Sample collection of "corn flake" corrosion deposit.

2.3 Microbiological Concerns

Some microbiological species have established themselves on surfaces within the plant. These microbes were introduced when the water quality was low, and may not be appreciably affected by the restoration of good water quality. They will continue to exhibit predictable metabolic processes at the rates normal for the ambient conditions present in the plant.

2.3.1 Benchscale Testing

There are known chemical combinations that work successfully at destroying microbes without causing damage to the reactor internals and systems. After bench testing and assessment by a team of chemists, microbiologists and materials engineers for materials and fuels compatibility, one or a combination of those chemicals may be recommended.

The results of the corrosion characterization plan described in Section 2.2.4 were evaluated by GE for the following:

- Assess the current condition of possible corrosion degradation.
- Assess the potential for future degradation by microbiologically related corrosion activity.
- Assess the effectiveness of mitigating actions.

Benchscale Test Results

The following proved effective in removing the biofouling of the water and on metal surfaces:

[[redacted]]

The following proved effective in treating MIC related micro-organisms:

[[redacted]]

2.3.2 Near-Term Assessment

Based on laboratory tests to date, it is possible that slime forming microbes could establish microbial communities which will shelter species capable of corrosion activity against steel surfaces. These deposits will serve as a continuing source of microbiological contamination throughout the plant, with cells sloughing from surfaces and redepositing, especially in areas with complex surfaces, such as valves and nozzles.

All inspections performed to date indicate that there is no microbiologically induced corrosion nor have thriving communities been found. Since it is anticipated that the plant will be restarted in the near future, there is low probability that damage will occur to reactor components. However, short-term risks, if any, will remain localized to those surfaces not under high temperatures and pressures, such as the storage tanks.

2.3.3 Long-Term Assessment

Restoration of the plant to normal operating temperatures and pressures will eradicate most of the microbial activity subjected to these temperatures and pressures. However, it is possible that the biological processes could recur during the next outage. Experience to date indicates a slow morphology and should present no problems during a normal 60-day outage.

Additionally, some damage may occur in low pressure and low temperature systems during operation, especially valves and nozzles.

3.0 Fermi Safety Evaluation

3.1 Safety Assessment

The concern generated by the exposure to contaminated water (high chloride, high sulfate, and high pH) is two-fold:

- The primary concern is that the event has made austenitic (stainless steel and Alloy 600) components wetted by the contaminated water susceptible to stress corrosion cracking (SCC).

- The secondary concern is that exposure to the contaminated water will promote microbiologically induced corrosion (MIC) of austenitic (stainless steel and Alloy 600) and low alloy steel (LAS) and carbon steel components.

Although the primary emphasis in this review is the potential for stress corrosion cracking, the potential for long-term microbiologically induced corrosion (MIC) is also a concern. Therefore, both concerns are addressed in this evaluation.

Stress Corrosion Cracking

Comparison of the Fermi 2 water transient with previous water chemistry transients at other BWRs shows that the near-term impact of the Fermi 2 event substantially less severe than previous transients from a SCC viewpoint. It has been postulated that the high pH of the contaminated water during and following the Fermi 2 event substantially reduced the probability for SCC. Nevertheless, in-vessel visual inspection (IVVI) and ultrasonic testing (UT) of the reactor internals have detected several incidents of crack indications attributed to stress corrosion in other BWRs (see Section 3.3.2).

Microbiologically Induced Corrosion (MIC)

Deposits have been observed at the water line of the stainless steel clad RPV shell and on the unclad blend radius of the feedwater nozzle. Sampling of the deposits at the feedwater nozzle has confirmed the presence of microbiological species. Examination of surfaces directly underlying these deposits has been performed. Neither the ID of the RPV shell clad with stainless steel or the unclad inside diameter surface of the low alloy steel [redacted] feedwater nozzle shows any evidence of corrosive attack. Based on these examinations, it is concluded that degradation due to MIC activity is not a short-term (e.g., restart) safety concern.

Based on the apparent slow growth of micro-organisms, there is no short-term concern for significant microbiological activity or MIC. It is expected that operation at the high temperatures associated with BWR normal operation will eliminate or significantly reduce the number of viable micro-organisms. However, this beneficial effect will not carry over to those low temperature systems which experienced the water chemistry transient. For such systems, the risk of corrosion is expected to increase with time. Therefore, it is recommended that Fermi 2 adopt a plan for monitoring potentially susceptible systems to assure no unanticipated blooming of micro-organisms or potential degradation due to MIC. Implementation of such a monitoring plan will minimize the long term impact of microbiological activity.

3.1.1 Reactor Pressure Vessel

The Fermi 2 RPV consists of 14 major components, as shown Table 3.1-1. Of these, 9 are wetted by reactor water (as indicated by asterisk *). To date, extensive IVVI of the Fermi 2 RPV components has disclosed no evidence of cracking or localized pitting corrosion. DECo has committed to reinspection of these areas during the next major refueling outage. Based on the foregoing, there is no unresolved safety concern for the Fermi 2 RPV which would prevent reactor restart.

3.1.2 Reactor Internals

3.1.2.1 LPRM Detectors

Local power range monitors (LPRMs) are safety-related components. Two of the LPRM detectors (of the original creviced design) failed (presumably by SCC) during the intrusion. Consequently, all the original creviced design LPRMs strings (two failed LPRMs plus an additional 27 LPRMs) have been replaced with a new non-creviced design.

3.1.2.2 Shroud Head Bolts

The shroud head bolts (SHBs) are not classified as safety-related components. Ultrasonic testing (UT) of SHBs following the transient showed 16 SHBs with indications >10%. For Fermi 2, only 20 of a total of 48 SHBs are required for structural integrity. All 16 SHBs with indications >10% plus one additional SHB (due to mechanical difficulties) have been replaced.

3.1.2.3 Core Shroud Crack Indications

Two small indications (< 2-inch in combined length) were found adjacent to weld H2 during the recent inspection of the Fermi 2 shroud. The indications were axially oriented (perpendicular to H2). Reference 55 provides the screening criteria for the evaluation of detected indications. In addition, Reference 56 provides additional guidance on the evaluation of detected indications. Based on the results of Ref.erence 55, the allowable through-wall flaw lengths were determined to be:

- Allowable Circumferential Flaws: 100 inches
- Allowable Axial Flaws: 70 inches

The observed indications are negligible compared to the allowable through-wall flaw size. Thus, the integrity of the Fermi 2 shroud with the observed indication is assured.

In addition, the Reference 56 document proposes an acceptance standard which states that indications less than 15 inches in length are acceptable and do not require further evaluation. The

Fermi 2 indications would satisfy this acceptance standard and, thus, the indications are acceptable.

It is prudent to assume that there can be some impact on SCC propensity of reactor internals in the future. Inspection to establish a baseline condition of the most susceptible components for comparison during future refueling outages, along with augmented inspections of these components, has been performed.

3.1.3 Related Reactor Pressure Boundary Systems

The related reactor pressure boundary and the Emergency Core Cooling Systems were reviewed to determine systems or components which are potentially affected by the intrusion event. The results of this review and related information provided by DECo are summarized in Table 3.1-2.

3.1.4 Control Rod Drives (CRD)

Six CRDs were inspected to establish an assessment of the current conditions and to evaluate the extent of degradation due to the circulation water intrusion and any related idle water condition. The CRDs are fabricated from many individual pieces that, when assembled together, result in mechanical crevices. Crevices can promote accelerated corrosion and, under very specific ranges of tensile stress and environmental conditions, can accelerate stress corrosion crack initiation in the BWR environment. Pitting can be defined as a localized attack in which only small areas of the metal surface are attacked while the remainder is largely unaffected. Many of the CRD individual pieces have [redacted] surfaces. Pitting of the [redacted] surfaces can lead to general degradation of the [redacted] case and possible stress corrosion crack initiation.

The Fermi 2 CRDs exhibited noticeable corrosion pitting of th[redacted] surfaces of the index and piston tubes. During reactor operation, none of these [redacted] components is subjected to significant sustained stresses. Hence, crack initiation at these pitting corrosion or crevice corrosion sites is not expected as long as the autocatalytic corrosion processes are minimized by flushing. The daily CRD exercising (i.e., movement) performed at Fermi 2 during the outage (and periodic exercising during reactor operation) is clearly beneficial in minimizing the autocatalytic corrosion process. The detail assessment of Fermi 2 CRDs as the result of the incident is given in Reference 58.

The result of the assessment can be summarized as follows:

- The CRD scram function will not be adversely affected by the observed corrosion condition. However, continued corrosion degradation may result in excessive seal degradation and leakage which would lead to early CRD refurbishment or replacement.

- In the highly unlikely case where a failure (i.e., through-wall crack or complete severance) of the index tube or piston tube occurs, the CRD will remain insertable. The weekly surveillance testing which normally detects any failed parts will provide assurance of the integrity of the CRD components.

- The collet retainer tube (CRT) has very low mechanical loading and the probability of complete failure is extremely remote. Cracks in the CRT similar to those at Fermi 2 have been noted at many operating BWRs and the cracking phenomenon is believed not to have been influenced by the inc.dent. The plant Technical Specification requirements provide early detection of failures during weekly surveillance testing and limit the number of inoperable control rods.

3.1.5 Neutron Monitoring System (NMS)

The NMS includes the LPRM detectors, IRM (Intermediate Range Monitor) detectors and the SRM (Source Range Monitor) detectors. The original creviced design LPRM detectors have been replaced (see section 3.1.2.1). The SRM and IRM detectors are housed in dry tubes and, therefore, have not been wetted by the contaminated water. There were no crack indications identified in the dry tubes in the RF04 inspection. Furthermore, these dry tubes are under compressive stress conditions once the reactor pressure vessel is pressurized. Therefore, there is reason to believe that the SRM and the IRM detectors will not be effected by this incident.

Table 3.1-1

Fermi 2 RPV Components

Attachment Welds*
Top Head (Unclad)
Bottom Head*
Closure Studs
Nozzles & Safe Ends
Recirculation Inlet*
Recirculation Outlet*
Feedwater Nozzle*
Steam Outlet
Jet Pump Assembly and Instrument*
Core Spray*
CRD Penetrations*
RPV Shell (SS ID Clad)*
RPV Flange
RPV Support Skirt

*Wetted by reactor water

Table 3.1-2 (Continued)

Fermi 2 Potentially Impacted Systems

System	Intrusion Impact	Mitigation Activities	Safety Consequence
HPCI	System exposed to high conductivity water for a short time only.	System maintained in dry lay-up. CST suction line flushed.	System performance is not impacted. Surveillance testing will assure degradation has not occurred.
RCIC	System exposed to high conductivity water for a short time only.	System maintained in dry lay-up. CST suction line flushed.	System performance is not impacted and the RCIC System is not relied upon in safety analyses. Surveillance testing will assure that degradation has not occurred.
RHR	Entire RHR system potentially affected - Shutdown cooling (SDC) maintained in operation.	Divisions 1 and 2 drained and refilled.	Operation during the outage provides a basis that the system performance has not been impacted. Surveillance testing will assure that degradation has not occurred.
Core Spray	System not operated.	System drained and refilled.	System performance is not impacted by intrusion. Surveillance testing will assure that degradation has not occurred.
SLCS	System not operated.	Discharge line flushed.	System performance is not impacted by intrusion. Surveillance testing will assure that degradation has not occurred.
Suppression Pool	System potentially contaminated.	Desludged and cleanup performed using temporary demineralizers.	

Table 3.1-3

Fermi 2 Potentially Impacted Systems

(Other Systems)

System	Intrusion Impact	Mitigation Activities	Safety Consequence
Condensate Storage	System potentially contaminated.	Cleaned and refilled.	This system is not relied upon in plant safety analyses. Mitigative measures are appropriate for plant performance objectives.
Condensate & Feedwater	Entire system exposed to high conductivity water.	System drained and refilled with P11 water. Stainless steel components received additional cleaning.	This system is not relied upon in plant safety analyses. Mitigative measures are appropriate for plant performance objectives.

3.2 Safety Evaluation Findings

3.2.1 Probability of Occurrence

After the incident and cleanup:

- **Will the probability of occurrence or the consequences of an accident previously evaluated in the safety analysis report be increased?**

- **Will the probability of occurrence or the consequences of a malfunction of equipment important to safety previously evaluated in the safety analysis report be increased?**

There are three types of accidents evaluated in the Safety Analysis Report (SAR): (1) loss-of-coolant accidents (LOCA); (2) fuel handling accident; and (3) rod drop accident.

A bounding licensing basis LOCA assumes a sudden 360° severance of either the recirculation system piping or main steam line piping inside (or main steam line outside) of the containment. This postulated 360° severance assumption was not based on the quality of the piping material (the primary reactor pressure boundary), the reactor system peak pressure level, realistic precursors which may lead to pipe wall cracks or the adequacy of the leak detection system. The probability of a LOCA (not discussed explicitly in the SAR) does depend on all the above mentioned variables. The variables of piping material, the reactor system peak pressure level and the leak detection system adequacy remain constant after the incident; however, the incident does impact potential cracking precursors. These potential cracking precursors will likely reduce the time period prior to the potential initiation of IGSCC. However, because of industry understanding of "leak before break" phenomenon, operator sensitization to this incident through training programs, improved inspections and planned preventive and detection measures, it can be concluded that any change in probability of a LOCA before and after the intrusion incident is negligible. The HPCI, RCIC, and RHR Systems are not affected.

The consequences of a postulated licensing basis LOCA as covered in the SAR will not be changed because the radiological doses were computed based on NRC non-mechanistic requirements for leakage through the isolation valves, bypass leakage and Standby Gas Treatment System efficiencies.

The incident does not change the probability nor the consequences of a fuel handling accident described in the SAR, because this incident did not affect the fuel handling equipment, tools and sensing equipment used during reactor refueling operations.

The incident also should not change the probability of a rod drop accident (RDA) because the RDA already requires a high worth control rod to be stuck in the core area and for it to drop at the limiting speed. The incident certainly cannot increase the control rod worth nor increase the drop speed; therefore, there is no change in probability or consequence from this incident.

Whether the incident would affect the fuel or fuel behavior is an operational issue and does not affect the results in the SAR because the bounding SAR radiological consequence is based on Regulatory Guide 1.3 (TID-14844), which assumes a partially melted core.

This incident could have reduced the time period prior to initiation of IGSCC for some of the reactor internals and the primary reactor pressure boundary components that could not be thoroughly cleaned or were not replaced after the incident. However, industry experience has demonstrated that the time period to potential initiation of IGSCC is quite long and is assessed to be considerably longer than the next plant operating cycle. This experience, along with sensitization and training of inspection personnel, will help the Detroit Edison Company to anticipate and detect the onset of IGSCC and, coupled with a thorough In-service Inspection (ISI) program, initiate delaying measures against the onset of IGSCC. Therefore, it has been assessed that the malfunction probability of the reactor internals and system components will not be changed in the next operating cycle. In fact, because of operator sensitization during inspections and increased reactor internals cracking mitigation knowledge from the industry and other BWRs, Detroit Edison would be better able to manage IGSCC concerns as the Fermi 2 continues operation.

The degraded performance potential from the corrosive deposits found on some of the CRD components is judged to be an operational and not a safety concern. Such corrosion deposits would not prevent a scram. Furthermore , scram and CRD performance is periodically tested according to the Technical Specifications (Tech Spec) requirements and CRD System performance parameters also are monitored. Therefore, CRD System performance will not be compromised and the Technical Specifications scram time requirements will not be changed.

Thus, it can be concluded that the malfunction of equipment important to safety previously evaluated in the SAR will not be increased as a result of this incident.

3.2.2 Probability of New Safety Concerns

After the incident and cleanup:

- **Will a possibility of an accident of a different type than any evaluated previously in the safety analysis report be created?**
- **Will a possibility of a malfunction of a different type than any evaluated previously in the safety analysis report be created?**

An accident which may challenge safe shutdown of the plant and compromise the safety of the public is an extremely low probability event. Examples of an accident are the breach of the reactor pressure boundary (i.e., LOCAs), positive reactivity insertion (i.e., rod drop) and radiological releases inside the secondary containment (i.e., fuel handling mishaps). The water intrusion incident can, at worst, accelerate the IGSCC process for susceptible components, but such susceptibility and the affect would occur on a long-term basis. While sample deposits in the reactor vessel have been microbiologically examined and no sulfur reducing micro-organisms have been found, susceptible components to MIC also would be affected on a long-term basis which can be detected during planned inspections. The potential damage from these processes would be bounded by the design basis LOCA evaluation, which includes all types of reactor coolant pressure boundary leakage or sev rance has been included. The incident would not create any different types of accidents.

The consequences of malfunction of all active components such as pumps, valves and instrumentation that are of safety significance has already been considered in the safety analysis (single failure criterion). The consequences from malfunction of an individual passive component within the reactor pressure boundary are bounded by those from the design basis LOCA. It is important to realize that the malfunction symptom of a passive component such as any inside the reactor vessel as the result of the incident would be progressive and detectable during periodic inspections before complete failure. The incident does not introduce a malfunction of equipment that previously has not been considered. Rather, the incident potentially would accelerate the IGSCC process to the degree that inspections may reveal component degradation prior to what might otherwise be expected. Therefore, an accident or malfunction of a different type will not be created.

3.2.3 Margin of Safety

- **After the incident and cleanup, will the margin of safety as defined in the basis for any technical specifications be reduced?**

Although individual safety parameter performance may change slightly (as the result of the incident), as long as the monitoring instrumentation indications and the surveillance results are acceptable, the margin between the safety analysis result and the Tech Spec setpoints will not change. As an example, parts of a CRD could be degraded on a long-term basis due to the incident, but if the degradation does not affect the CRD safety function and the CRD is still able to meet Tech Spec scram time requirements, then there is no loss in the margin of safety. Also, there are Tech Spec requirements on the minimum number, as well as locations of operable LPRMs in each APRM channel. Similar operability requirements also are applicable to the IRMs, the SRMs, the HPCI, the RCIC, and the RHR Systems.. These requirements are there to assure that the margin of safety is not reduced. Therefore, the margin of safety is not reduced.

4.0 Recommendations

The water intrusion incident in December 1993 at Fermi 2 resulted in the injection of contaminated high conductivity water into the reactor and associated support systems. This contaminated high pH water was high in chlorides, sulfate, and organics. The exposure of surfaces wetted by these contaminants has raised two concerns:

- The primary concern is that the components (stainless steel and Alloy 600) wetted by the contaminated water are more susceptible to stress corrosion cracking (SCC).

- A secondary concern is that exposure to the contaminated water will promote microbiologically induced corrosion (MIC) of austenitic (stainless steel and Alloy 600) and low alloy steel (LAS) or carbon steel components.

The reactor pressure vessel, reactor internals, control rod drives, neutron monitoring system, reactor pressure boundary and emergency core cooling systems have been reviewed to determine what startup, near-term and long-term actions are recommended to monitor or mitigate potential future degradation of these systems and components.

Startup chemistry guidelines, in general, follow the 1993 BWR Water Chemistry Guidelines. Fermi 2 specific guidelines have been established for condensate/feedwater and reactor water during startup, hot standby, power operation and cold shutdown. Limits for various auxiliary systems are also provided.

Application of the [redacted] model to Fermi 2 components predicts that, if initiated, stress corrosion cracks wetted by contaminated water will propagate at a rate of roughly twice that for normal BWR water. Fermi 2 is already performing augmented inspections of numerous components and systems in conformance with various NRC IE bulletins and GE and EPRI recommendations. For those components and systems judged to be most susceptible to SCC which are not presently included under existing augmented inspection programs, it is recommended that DECo develop inspection criteria over the duration of the next cycle.

Based on the apparent slow growth of micro-organisms from the organic contaminants introduced at Fermi 2 during the chemistry transient, there is no short-term concern for significant microbiological activity or MIC (microbiologically induced corrosion). It is expected that operation at the high temperatures associated with BWR normal operation will eliminate or significantly reduce the number of viable micro-organisms. However, this beneficial effect will not carry over to those low temperature systems which experienced the water chemistry transient. For such systems, the risk of corrosion is expected to increase with time. Therefore, it is recommended that Fermi 2 adopt a plan for monitoring potentially susceptible systems to assure no unanticipated blooming of micro-organisms or potential degradation due to MIC.

4.1 Startup Chemistry Recommendations

4.1.1 EPRI Guideline Values

To the extent possible, Detroit Edison should fully utilize the chemistry limits established in the 1993 EPRI BWR Water Chemistry Guidelines (Ref 50) for all systems for the balance of the refueling outage, during the startup, which includes any periods of hot standby operation, and ultimately the power ascension phase. If there are administrative limits that are more restrictive than the values indicated in the EPRI Guidelines, these should take precedence.

Guideline limits have been established for condensate/feedwater, and reactor water during periods of cold shutdown, startup/hot standby and power operation. Limits for various auxiliary systems, such as storage tanks, are provided. In all systems, there are recommended values for critical chemistry parameters prior to startup. Three Action Levels are identified which recommend corrective action and strategy, depending on the extent of any chemistry parameter that is not within specification. In order of increasing severity, the corrective action recommended for three Action Levels are indicated below, cited directly from Reference 50.

4.1.1.1 Action Level 1 Value

The Action Level 1 value of a parameter represents the level above which data or engineering judgment indicates that long-term system reliability may be threatened, thereby warranting an improvement of operating practices. Actions if a parameter exceeds the Action Level 1 value include:

- Corrective action should be taken to reduce the parameter below the Action Level as soon as practical.
- If the parameter has not been reduced below the Action Level 1 value within 96 operating hours, a review shall be performed and a program and schedule for implementing corrective measures submitted to management for review and approval. Such a program may require equipment addition or modification over a long time period.

Each plant should formalize a management awareness program for prolonged off-normal water chemistry conditions. This should include a mechanism for informing appropriate levels of management of the existence of the condition, the implications, and the possible corrective measures over the short and long term.

4.1.1.2 Action Level 2 Value

The Action Level 2 value of a parameter represents the level above which data or engineering judgment indicates that significant degradation of the system may occur in the short term, thereby warranting a prompt correction of the abnormal condition. Actions if a parameter exceeds the Action Level 2 value include:

- As soon as practical, corrective action should be initiated to reduce the parameter below the Action Level 2 value.

- If a parameter has not been reduced below the Action Level 2 value within 24 hours, an orderly unit shutdown should be initiated and the plant should be brought to cold shutdown as rapidly as operating conditions permit.

- Following a unit shutdown caused by exceeding an Action Level 2 value, a review of the incident should be performed and appropriate measures taken before the unit is restarted.

4.1.1.3 Action Level 3 Value

The Action Level 3 value of a parameter represents the level above which data or engineering judgment indicate that it is inadvisable to continue to operate the plant. If an Action Level 3 value is exceeded:

- An orderly unit shutdown should be initiated immediately with the reduction of coolant temperature to <200°F as rapidly as operating conditions permit.

- Following a unit shutdown caused by exceeding an Action Level 3 value, a review of the incident should be performed and appropriate corrective measures taken before the unit is restarted.

4.1.2 System Flushing

Many systems that were in contact with the diluted circulation water have already been flushed, with additional flushing in progress or scheduled. There are no EPRI Guideline values established for system flushing. However, some chemistry guidelines for flushing were established in April 1994 by mutual agreement between the Fermi 2 Water Management Group and GE. These were an effluent conductivity for the water exiting the flushed system of less than 2 μS/cm, with chloride and sulfate concentrations less than 20 ppb each. These guidelines were met for flushing and refilling operations prior to startup to minimize the ingress of impurities into the reactor.

4.1.3 Auxiliary Systems Water Quality

All auxiliary systems with a potential cross-tie to the reactor should be maintained as free of chemical impurities as practical. Minimizing impurity ingress to the reactor water and/or condensate systems will aid in maintaining reactor water parameters within the recommended values and maximize run times of the Reactor Water Cleanup and Condensate Polishing Systems. In anticipation of many water transfers to and from these auxiliary systems prior to startup, it is also important to maintain each system at appropriate levels, in addition to the adherence to chemistry limits.

The limits identified in Table 4.1-1 should also be applied to the Fermi 2 Condensate Return Tank when the tank is refilled after cleaning. The last data available to GE indicated that all parameters were within specification for the Condensate Storage Tank. Water quality in this tank should be maintained throughout the balance of the outage and into the startup, to the extent practical. Water quality of the reactor water in common with the spent fuel pool is significantly better than the indicated Guidelines values. Water quality of the two systems should be maintained when the two systems are separated with the closure of the refueling floodgates. Maintaining good water quality will require maximum availability of the Reactor Water Cleanup and Fuel Pool Cleanup Systems.

4.1.4 Reactor Water During Cold Shutdown

Separate limits are defined for the reactor vessel water during cold shutdown (reactor temperature ≤200 °F) when isolated from the spent fuel pool. The controlling parameters as defined by the EPRI Guidelines are conductivity, chloride, and sulfate concentrations at the levels indicated in Table 4.1-4.

It would be highly desirable to have all three parameters below the indicated values prior to startup. There may be considerable hideout/return chemistry observed during the initial heatup. The lower the values for chloride and sulfate prior to startup, the more margin there is to tolerate these anticipated excursions. The minimum value for reactor water conductivity will be on the order of 0.8 μS/cm until heatup commences, which will strip most of the dissolved carbon dioxide from the system, and, in the absence of further ingress, lower the conductivity. As indicated above, the current reactor water chemistry for the cold shutdown condition is excellent, with both chloride and sulfate concentrations less than 5 ppb.

4.1.5 Startup Preparations

Most items in the remaining sections have been thoroughly addressed in the preliminary draft of the Fermi 2 Startup Chemistry Plan (Ref. 57). This document has been reviewed with suggestions forwarded to the chemistry group. Due to the length of the outage, a considerable inventory of both soluble and insoluble corrosion products may be available for release to the system. To minimize the input during the restart of Fermi 2, the following recommendations for startup preparations should be considered at least two weeks prior to the anticipated startup. Many of these items may impact the critical path scheduling, and should be factored into the overall outage planning schedule.

- To the extent possible, the restoration of the Radwaste Treatment System should be complete.

- Verify that the phase separator tank levels are minimized and available to receive backwashed precoats from the Condensate Treatment System and Reactor Water Cleanup System during the plant startup. A sizable number of backwashes can be anticipated prior to and during startup.

- Verify that both the Condensate System and Reactor Water Cleanup Systems are fully operable. This includes cleaning of any resin traps or strainers downstream of any given demineralizer. Any scheduled septa replacements or cleanings should be factored to the startup sequence.

- After cleanliness of the condenser/hotwell has been verified, flood the condenser to cover the tubes. Hydrostatic leak tests should be performed, and any leaky tubes plugged. After tube plugging operations (if any) are complete, lower the water level to normal operating level by returning condensate to the Condensate Storage Tank or Condensate Return Tank after passing through a condensate filter demineralizer or suitable portable demineralizer system.

- In anticipation of more frequent chemistry measurements during the startup, verify that all chemistry laboratory analysis equipment is calibrated and fully operational. Verify that process chemistry instrumentation within the plant are operational and within calibration.

4.1.6 Prevacuum Operations

Condensate/Feedwater System

While there is no hardened timetable for these operations, it is suggested that prevacuum flushing of the Condensate/Feedwater System be performed at least one week prior to the anticipated startup. There are no EPRI Guideline values for the Condensate/Feedwater System during periods of cold shutdown. However, it would be highly desirable to meet the following specifications for the condensate used in this flushing: Conductivity ≤ 1.0 μS/cm, with chloride sulfate concentrations each less than 20 ppb.

- Place two or three condensate filter demineralizers in service at 3500 gpm each, using the equivalent mixture precoat formulation specified by the chemistry supervisor. It may be desirable to increase the precoat loading on the septa to 0.3 lb/ft^2 (unless there are historical bridging concerns with this loading) to provide additional ion exchange capacity for the flushing operations.

- Route the initial flow from the Condensate System effluent to the Condensate Storage Tank until the level of the hotwell/condenser has been lowered to its normal operating level.

- After the normal water level has been established in the hotwell, route flow from the condensate filter demineralizers through all heaters, up to and including high pressure feedwater heaters back to the hotwell. It may be more effective to initially flush each heater string sequentially (higher linear flow velocity) before parallel flushing

- Analyze samples of water from the influent to the condensate filter demineralizers (CDI), effluent from the condensate filter demineralizers (CDE), and final feedwater (FFW) at least every 4 hours or at a greater frequency if specified by the Chemistry Supervisor. Measure the conductivity of each stream at 25°C (77°F), and chloride and sulfate concentrations. It is also recommended that periodic measurements of insoluble iron concentrations in each stream be conducted to track the effectiveness of the flushing operations. Utilization of in-line turbidimeters as a trend indicator for particulate concentrations may be beneficial to indicate the proper time to sample these streams for iron.

Reactor Water Cleanup System

It is assumed that the Reactor Water Cleanup System will be operating at full capacity for at least one week prior to the anticipated startup.

- Analyze samples of Reactor Water Cleanup System Influent (RCI) and effluents (RCEA and RCEB) at least every 8 hours or at a greater frequency if specified by the Chemistry Supervisor. Measure conductivity, chloride, sulfate, silica, calcium and magnesium.

4.1.7 Vacuum Operations

EPRI Guideline values for controlling chemistry parameters have been established for hot standby/startup modes (reactor temperature > 200°F, reactor power ≤ 10%) for both the condensate/feedwater systems and the reactor water. These Guideline values are indicated in Tables 4.1-5 and 4.1-6. All parameter values are indicated after condenser vacuum has been established with the steam jet air ejectors.

4.1.7.1 Condensate Feedwater System Recirculation

- Establish condenser vacuum using reactor steam.

- After vacuum has been established and stabilized, remove the condensate filter demineralizers previously used for the prevacuum recirculation. Put two freshly precoated filter demineralizers in service as directed by the Chemistry Supervisor.

- Gradually place additional condensate filter demineralizers into service and increase recirculation flow through the feedwater system back to the hotwell until approximately 20,000 gpm is obtained.

- Increase the sampling frequency for CDI, CDE and FFW at a frequency specified by the Chemistry Supervisor.

- Put freshly precoated condensate filter demineralizers in service to maintain the following conditions for the CDE sample: Conductivity ≤ 0.06 μS/cm, with chloride, sulfate, calcium, and magnesium concentrations less than 1 ppb each.

- Continue recirculation to maintain the following conditions in the FFW sample: Conductivity ≤ 0.065 μS/cm, with chloride, sulfate, calcium and magnesium concentrations less than 1 ppb each.

4.1.7.2 Vacuum Operation--Reactor Water Cleanup System

- After reactor water temperature reaches 500°F, increase sampling frequency for RCI, RCEA, and RCEB to every 2 hours or greater frequency if specified by the Chemistry Supervisor.

- Put Freshly precoated Reactor Water Cleanup filter demineralizers in service to maintain the conditions listed in Table 4.1-7.

4.1.8 Power Ascension

For operation above 10% power, the suggested EPRI Guideline values for reactor water are indicated in Table 4.1-8.

Hold points in the startup program have been established at various power levels. It is recommended that each Action Level 2 value in Table 4.1-8 be included as a limitation for power ascension. If any one of the three Action Level 2 values is exceeded, additional power increases should not be performed, allowing the Reactor Water Cleanup System to purify the coolant to acceptable levels. Daily measurements of chloride and sulfate are sufficient when the concentrations are below the Action Level 1 values.

The impact of organics on startup chemistry should be addressed. While there are no EPRI Guideline values for reactor water organics, it may be prudent to establish upper TOC limits for continued power ascension. In anticipation of the ingress of organics during startup, an upper limit as a consideration for additional power increases should be established. Because the thermal and radiolytic decomposition of most organics produces some conductive species, TOC concentrations above 100 ppb may likely result in elevated reactor water conductivity above the EPRI Guidelines Action Level 2 value. Re-dissolution of some calcium and magnesium salts may occur during the power ascension program. As an additional control on these release rates, it is recommended that the concentration of both ions be maintained below 20 ppb as an additional holding parameter for power increases.

The restart of the Fermi 2 reactor may be influenced by hideout-return of many chemical species, despite comprehensive system flushing and good water quality prior to heatup. It would be prudent to have on-line chemistry monitoring of the reactor water to provide guidance on the power ascension process to determine hold points if off-chemistry conditions exist. Continuous monitoring of monovalent and divalent cations, anions and organic acids is recommended. GE can provide assistance in this area if it is desired.

Also, GE recommends additional monitoring for organics at Fermi 2 using the technology of [redacted] This technique affords the identification for thousands of specific organic compounds, with detection limits at the part per billion level. These analyses may be performed at the GE Corporate Research and Development Laboratory in Schenectady, New York. At some point prior to startup, DECo may wish to analyze Condensate Storage Tank water (when recharged), Condensate Return Tank water, the Condenser Hotwell, Suppression Pool, and the reactor water to assess the nature of the impurities in these systems, and the need for additional treatment, in the event it is necessary.

EPRI Guideline values for condensate/feedwater during power operation are shown in Table 4.1-9. If the water quality of the plant auxiliary systems is maintained within the EPRI Guideline values, and the pre-vacuum and vacuum flushing is adequate, there should be no difficulties maintaining the water exiting the condensate treatment system and ultimately the final feedwater below the Action Level 1 values for each parameter. At approximately 65% power, forward pumping of the heater drains to blend with the polished condensate can commence. Since this system has been stagnant for some time, it is recommended that these drains be recirculated to the hotwell prior to pumping forward. The use of in-line turbidimeters to trend the particulate concentrations in these drains may be beneficial to determine when they may be pumped forward.

The responses taken in the event of an Action Level 2 excursion require some preplanning and engineering judgment. [redacted] For every possible scenario, continuous trending of the key parameters is essential. No operating decisions should be based on a single analysis. If a strong upward trend is observed prior to exceeding the Action Level 2 values, consideration should be given to delaying the power ascension or initiating those evolutions that may further degrade the water quality.

At the first observation of an Action Level 2 excursion, power should be held constant. It is important to identify source terms for the excursion, whether they originate from the condensate/feedwater system, or if in vessel generation, such as resin breakdown, organic decomposition or hideout/return is controlling. Some judgment must be input to the situation, with respect to the peak concentrations and trends after the Action Level 2 value is exceeded.

If RWCU is operating at full capacity, the RWCU half-time is on the order of two hours at low-power operation. The allows some scientific predictions as to when chemistry conditions will be restored. If trends indicate that the chemistry will recover below Action Level 2 values within the 24 hour window, then it is probably safe to resume the power ascension when the Action Level 2 value is cleared. If it appears the 24-hour window for an Action Level 2 will be exceeded for a few hours, it may be prudent to reduce power prior to the clock expiration to allow more effective RWCU treatment. It is a judgment call whether a rapid cold shutdown is more damaging than exceeding the 24-hour window by a few hours.

Table 4.1-1

Diagnostic Parameters for Demineralized Water Storage Tanks (DWST), Condensate Storage Tanks (CST)and Radwaste Sample Tanks for Recycle (RWST)

Diagnostic Parameter	Frequency of Measurement		Recommended Limit
	DWST/CST	RWST	
Conductivity (μS/cm)	Daily	Each Batch	≤1.0
Chloride (ppb)	Daily	Each Batch	≤20
Sulfate (ppb)	Daily	Each Batch	≤20
Silica (ppb)	Weekly *	Each Batch	≤50
TOC (ppb)	Weekly *	Each Batch	≤200
Post UV Anions	Weekly	Each Batch	Plant Specific

*Unless continuously monitored. Daily when water added to tank in the last 24 hours. Increased frequencies are recommended if chemical ingress is detected or suspected.

Table 4.1-2

Diagnostic Parameters for Torus/Pressure Suppression Pool

Diagnostic Parameter	Measurement Frequency *	Recommended Limit
Conductivity (μS/cm)	Quarterly	≤5.0
Chloride (ppb)	Quarterly	≤200
Sulfate (ppb)	Quarterly	≤200
TOC (ppb)	Quarterly	≤1000

(*) Increased frequencies are recommended if chemical ingress is detected or suspected.

Table 4.1-3

Diagnostic Parameters for Spent Fuel Pool

Diagnostic Parameter	Measurement Frequency	Recommended Limit
Conductivity (μS/cm)	Daily	≤2.0
Chloride (ppb)	Weekly	≤100
Sulfate (ppb)	Weekly	≤100
TOC (ppb)	Weekly	≤400

Table 4.1-4

Chemistry Guidelines--Reactor Water--Cold Shutdown

Control Parameter	Action Level 1	2	3	Value Prior to Startup
Conductivity (µS/cm)	>2.0	---	---	≤1.0
Chloride (ppb)	>100	---	---	≤100
Sulfate (ppb)	>100	---	---	≤100

Table 4.1-5

Chemistry Guidelines--Feedwater/Condensate--Startup/Hot Standby

Control Parameter	Measurement Frequency	Action Level 1	2	3	Value Prior to Startup
FFW Conductivity (µS/cm)	Continuously	>0.15	---	---	---
FFW Corrosion Products (ppb)	Continuously	>100	---		---
CDI Conductivity (µS/cm)	Continuously	---	---	>10	---
CDE Dissolved Oxygen (ppb)	Continuously	>200	---	--	>200

Table 4.1-6

Chemistry Guidelines--Reactor Water--Startup/Hot Standby (c)

Control Parameter	Measurement Frequency	Action Level 1	2	3	Value Prior to Power Op.
Conductivity (µS/cm)	Continuously	---	>1.0	>5.0	≤1.0
Chloride (ppb)	Daily (a)	---	>100	>200	≤20
Sulfate (ppb)	Daily (a)	---	>100	>200	≤20
Dissolved Oxygen (ppb)	Continuously	>300 (b)	---	---	---

(a) If the conductivity exceeds a plant-established target value indicative of elevated anionic concentrations (a suggested value is 0.3 µS/cm), these measurements should be made more frequently

(b) Dissolved oxygen must be less than 300 ppb before reactor water temperature is increased above 140°C, and must be maintained below this level at higher temperatures

(c) It is suggested that the chemistry limits provided in this table be restricted to startup/hot standby periods of 24 hours. After 24 hours, power operation values should be instituted.

Table 4.1-7

Suggested Chemistry Parameters Prior to Startup

Sample	RCI	RCEA and RCEB
Conductivity (μS/cm)	≤ 0.3	≤ 0.09
Chloride (ppb)	≤ 20	≤ 2
Sulfate (ppb)	≤ 20	≤ 2
Silica (ppb)	≤ 50	≤ 5
Calcium	≤ 10	≤ 1
Magnesium	≤ 10	≤ 1

Table 4.1-8

Chemistry Guidelines--Reactor Water--Power Operation

Control Parameter	Measurement Frequency	Action Level			Median Value
		1	2	3	
Conductivity (μS/cm)	Continuously	>0.30	>1.0	>5.0	0.11
Chloride (ppb)	Daily	>5	>20	>100	1
Sulfate (ppb)	Daily	>5	>20	>100	2

Table 4.1-9

Chemistry Guidelines--Reactor Feedwater/Condensate--Power Operation

Control Parameter	Measurement Frequency	Action Level			Median Value
		1	2	3	
FFW Conductivity (μS/cm)	Continuously	>0.07	---	---	0.06
CDI Conductivity (μS/cm)	Continuously	>0.10	---	>10	---
FFW Total Iron (PPB)	Integrated	>5	---	---	~1
FFW Oxygen (PPB)	Continuously	<15, >200	---	---	30
CDE Oxygen (PPB)	Continuously	<15, >200	---	---	

4.2 Inspections

The [redacted] model predicts that for Fermi 2, stress corrosion cracks in components wetted by contaminated water as a result of the chemistry transient will propagate at a rate roughly twice that projected for the same components in normal BWR water. Therefore, some augmented inspection of high susceptibility components is prudent.

Fermi 2 is already performing augmented inspections of numerous components and systems to comply with various NRC IE Notices and Regulatory Guides, plus a wide range of GE SILs, RICSILs and other recommendations (Tables 4.2-1 and 4.2-2). These augmented inspections are judged to be adequate to monitor potential degradation due to stress corrosion. For those components and systems judged to be susceptible to SCC which are not presently included under existing inspection programs, it is recommended that DECo develop criteria for inspection over the next reactor cycle.

Table 4.2-1

RF04 SECTION XI SCHEDULED EXAMINATIONS
and
Additional Augmented Examinations
(Excluding IVVI)

Class 1 - RPV and RPV Nozzle Welds and Components Examined:

Description	Quantity Examined	NDE Method	ASME Section XI	Augmented Exam	Augmented Reason
RPV Feedwater Nozzle Welds					NUREG-0619 Feedwater Nozzle Inner Radius and Nozzle Inner Bore (A, B, D Nozzles)
Inner Radius	(3)	UT	Yes*	Yes	
Inner Bore Regions	(3)	UT	Yes*	Yes	
Dissimilar Metal Welds					
Nozzle to Safe-end	(3)	UT/PT	Yes	No	GL 88-01 Category B, NUREG-0313
Safe-end to Safe-end extension					
Nozzle to Safe-end	(1)	UT	Yes*	Yes	UT only 101-304E due to 12/25/93 Water Transient. This weld was previously inspected.

Table 4.2-1 (Continued)

RF04 SECTION XI SCHEDULED EXAMINATIONS
and
Additional Augmented Examinations
(Excluding IVVI)

Class 1 - Piping Welds Examined:

Description	Quantity Examined	NDE Method	ASME Section XI	Augmented Exam	Augmented Reason
Piping Welds					
B31-Recirc	(11 Total)	PT/UT			GL 88-01
	(5)		Yes	Yes	Category B, NUREG-0313,
	(1)		Yes	No	Rev 2,
	(5)		No	Yes	GL 88-01 Category B, NUREG-0313, Rev 2
E11-RHR	(4)	MT/PT/UT	Yes	No	
B21-CS	(1)	PT/UT	Yes	No	
B41-HPCI	(1)	MT/UT	Yes	No	
G33-RWCU	(5 Total)	PT/UT			
	(4)		Yes	No	
	(1)		No	Yes	GL88-01 Category B, NUREG-0313, Rev 2
N21-FW	(6)	PT/MT/UT	Yes	No	

Table 4.2-1 (Continued)

RF04 SECTION XI SCHEDULED EXAMINATIONS
and
Additional Augmented Examinations
(Excluding IVVI)

Class 1 - Piping Welds Examined:

Description	Quantity Examined	NDE Method	ASME Section XI	Augmented Exam	Augmented Reason
Piping Lugs					
B21-Main Steam	(4)	MT	Yes	No	
E11-RHR	(6)	PT	Yes	No	
E21-CS	(8)	MT	Yes	No	
N21-FW	(4)	PT	Yes	No	
CRD Housings					
C11-CRD	(2)	PT	Yes	No	

Table 4.2-1 (Continued)

RF04 SECTION XI SCHEDULED EXAMINATIONS
and
Additional Augmented Examinations
(Excluding IVVI)

Class 2 - Piping Welds Examined:

Description	Quantity Examined	NDE Method	ASME Section XI	Augmented Exam	Augmented Reason
Piping Lugs					
E11-RHR	(26)	MT/PT	Yes	No	N/A
E21-CS	(2)	MT	Yes	No	N/A
Pipe Welds					
C41-SLC	(2)	PT	Yes	No	N/A
11-RHR	(11)	MT/UT**	Yes	No	N/A
E21-CS	(2)	MT	Yes	No	N/A
E41-HPCI	(5)	MT/PT/UT**	Yes	No	N/A
N30-MS	(2)	MT/UT**	Yes	No	N/A
T48-CGC	(2)	MT	Yes	No	N/A
G42-FPCCU	(1)	MT	Yes	No	N/A

Non-Class - Piping Welds Examined:

Pipe Welds					
Condensate	(4)	UT	No	Yes	GL 88-01 Category D NUREG-0313, Rev 2

* No credit taken for ASME Section XI ISI/NDE Program
** MT and UT required on circumferential butt welds > 1/2" wall thickness

Table 4.2-2

IN-VESSEL VISUAL EXAMINATIONS

RF04 Section XI Scheduled Examinations
and
Additional Augmented Examinations

VT Visual Examinations (VT- 3) Except as Noted:

Description	Percent Examined	ASME Section XI	Augmented Exam	Augmented Reason
Shroud (VT-1)				
Enhanced Technique				
Outside Surface				
360° around H-1 through H-7 welds to maximum • extent possible	100% (accessible areas)	Yes/Partial	Yes/Full VT	SIL 572, Rev. 1 RICSIL 054, Rev.1 RICSIL 068, IE Notice 93-079
Inside Surface				
360° around H-2 through H-4 welds to maximum extent possible	100%	Yes/Partial	Yes/Full VT (accessible areas)	SIL 572, Rev. 1 RICSIL 054, Rev.1 RICSIL 068, IE Notice 93-079
Support Welds				
(VT-3)	100% (accessible areas)	Yes/Partial	Yes/Full VT (accessible areas)	
Feedwater Nozzles (6)				
Unclad Nozzle Bore Area	100%	Yes	Yes	NUREG-0619
Spargers (6)	100%	Yes	Yes	
Sparger Brackets (6)	100%	Yes	No	

Table 4.2-2 (Continued)
IN-VESSEL VISUAL EXAMINATIONS

RF04 Section XI Scheduled Examinations
and
Additional Augmented Examinations

VT Visual Examinations (VT- 3) Except as Noted:

Description	Percent Examined	ASME Section XI	Augmented Exam	Augmented Reason
Core Spray Nozzles (2)				
Spargers (accessible areas)	~100%	Yes	Yes	SIL 289, Supplement 1 IE Bulletin 80-13
Core Spray Internal Piping (accessible areas)	~100%	Yes	Yes	SIL 289, Supplement 1 IE Bulletin 80-13
Piping Brackets (accessible areas)	~100%	Yes	No	
Top Guide (6 locations)				
Hold downs	~100% (Top surfaces only)	Yes	No	
Beam Alignment	~3%	Yes	No	
Beam cracking	~3%	Yes	Yes	SIL 554 RICSIL 059

Table 4.2-2 (Continued)
IN-VESSEL VISUAL EXAMINATIONS

RF04 Section XI Scheduled Examinations
and
Additional Augmented Examinations

VT Visual Examinations (VT- 3) Except as Noted:

Description	Percent Examined	ASME Section XI	Augmented Exam	Augmented Reason
Jet Pumps				
Jet Pump Assembilies (20)	100%	Yes	Yes	SIL 465, Supplement 1
Instrumentation lines and brackets (as accessible)	~100%	Yes	Yes	SIL 420
Jet pump riser arms (20) (VT-1)	100%	Yes	Yes	SIL 551
Jet pump restrainer screws (20)	100%	Yes	Yes	SIL 574
Jet Pump Hold-down Beams				
Perform UT and ET baseline inspection in warehouse.	100%	No	Yes (100%)	SIL 330, Supplements 1 & 2 RICSIL 065 IE Bulletin 80-09
Perform UT and visual inspection following installation	100%	Visual	Yes (UT/VT) (100%)	SIL 330, Supplements 1 & 2 RICSIL 065 IE Bulletin 80-09

Table 4.2-2 (Continued)
IN-VESSEL VISUAL EXAMINATIONS

RF04 Section XI Scheduled Examinations
and
Additional Augmented Examinations

VT Visual Examinations (VT- 3) Except as Noted:

Description	Percent Examined	ASME Section XI	Augmented Exam	Augmented Reason
Incore Dry Tubes (4 SRM/8 IRM) Examine upper 18-24 inches	100% of available locations	No	Yes	SIL 409 Inspections recommended by GE.
RPV Bottom Head Inspect RPV bottom head at 2 locations	~10%	No	Yes	Inspection recommended by GE.
Control Rod Blades Inspect 2 of 20 original CRBs	10%	No	Yes	Inspection recommended by GE.
RPV Cladding Perform visual inspection of RPV cladding and feedwater nozzle corrosion deposits	2%	Yes	Yes	Sampling dive per GE recommendations including visual inspection.

4.3 Microbiologics

Based upon the inspections performed to date within the reactor pressure vessel and observations of other systems opened for maintenance during RF04, there does not appear to be any significant microbial communities at this time. Nor is there any evidence of any MIC. Further, the high temperatures, pressures and radiation fields that will exist within the reactor during operation will eliminate or significantly reduce the number of viable micro-organisms. However, these beneficial temperatures and pressures will not exist throughout the other systems which experienced the transient.

Based on the apparently slow growth rate of these micro-organisms and the actions taken to date to improve water quality (flushes, drain and fills, chemical cleanings, etc.), there is little concern about returning the plant to service. Given sufficient time, however, some components not subject to high temperatures and pressures could experience corrosion. These would include storage tanks and other slow water turnover components and complex surfaces such as valves. It is therefore recommended that a plan of monitoring and surveillance of low temperature and pressure plant systems be instituted to ensure no unexpected blooming of biologics.

In addition to the use of [redacted] which DECo currently uses, DECo should consider using [redacted] test kits. Taking samples from stainless steel/carbon steel, low temperature/low pressure systems and low flow pumps/valves upon inspections/maintenance/or repair, view each kit after the first and second day, then weekly thereafter.

DECo should be alert to the risk of corrosion damage due to the presence of micro-organisms increasing with time. Tests have shown [redacted]

In the event that evidence suggests increased biological activity or actual corrosive damage due to micro-organisms is detected, a pilot test program to determine the effectiveness of treatments should be performed. In this phase, a plant system which shows significant MIC bacterial activity could be isolated and subjected to a chemical treatment that has been shown to be benign to plant materials.

Fortunately, test results indicated that the easiest of the MIC bacteria to eliminate were the [redacted] These are the most destructive of the MIC bacteria and cause the most rapid corrosion damage, especially in stainless steel. Test results indicate that utilizing [redacted] was sufficient to kill the [redacted] species found in Lake Erie water.

4.4 Other Systems

During the months following the December event, DECo personnel conducted extensive draining and flushing of interfacing systems to remove trace amounts of chloride and sulfate impurities. Some activities relevant to the other plant systems are summarized in Table 3.1-3.

In addition, visual inspections of the plant systems, especially those with stainless steel system welds which operated continuously with high conductivity water, were conducted for evidence of corrosion. Stagnant systems which did not operate or which could not be flushed, may continue to have increased risk of localized corrosion in the piping and welds. Some follow-on inspection may be appropriate as part of the routine plant in-service inspection.

No corrosion related issues are considered a safety concern at this time.

5.0 References

1) "Millstone Nuclear Power Station Unit 1, Special Report, Chloride Intrusion Incident," NEDC-10691, December 1972.

2) J. W. Bagg et al, "Chemical and Radiochemical Analysis Results from the Duane Arnold Energy Center Startup Test Program", NEDE-13405, March 21, 1975.

3) W. J. Shack et al, "Environmentally Assisted Cracking in Light Water Reactors: Annual Report October 1983 - September 1984," NUREG/CR-4287, ANL-85-33, June 1985.

4) W. J. Shack et al, "Environmentally Assisted Cracking in Light Water Reactors: Semiannual Report April - September 1985," NUREG/CR-4667, ANL-86-31, June 1986.

5) W. E. Ruther et al, "Effect of Temperature and Ionic Impurities at Very Low Concentrations on Stress Corrosion Cracking of Type 304 Stainless Steel," paper #102, NACE Corrosion 85, Boston, March 25, 1985.

6) L. G. Ljungberg et al, "The Effects of Sulfate on Environmental Cracking in BWRs Under Constant Load or Fatigue," paper #617, NACE Corrosion 89, New Orleans, April 17, 1989.

7) M. E. Indig et al, "The Role of Water Purity on Stress Corrosion Cracking," proceedings of the International Symposium on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, NACE, Houston, 1983.

8) S. Syoji et al, Hitachi, private communication, May 1979.

9) B. M. Gordon, "The Effect of Chloride and Oxygen on the Stress Corrosion Cracking of Stainless Steel: Review of Literature," Materials Performance, Vol. 19, No. 4, p. 29-38, April 1980.

10) H. S. Tong and D. J. Swartz, "Stress Corrosion Cracking and Electrochemical Behavior of AISI 304 Stainless Steel in Chloride-Containing Sulfate Solutions," J. Electrochemical Soc., Vol. 127, No. 1, p. 31-36, January 1980.

11) A. Poznansky and D. J. Duquette, "Stress Corrosion Cracking of Annealed and Sensitized Type 304 Stainless Steel in Deaerated Chloride/Sulfate Solutions," Corrosion, 39, No. 11, p. 425-431, November 1983.

12) J. K. Kee and Z. Szklarska-Smialowska, "Stress Corrosion Cracking of Sensitized AISI 304 Stainless Steel in Aqueous Chloride Solutions Containing Sulfur Species at 50 through 200°C," Corrosion, 44, No. 8, p. 560-565, August 1988.

13) G. Cragnolino et al, "Stress Corrosion Cracking of Sensitized Type 304 Stainless Steel in Sulfate and Chloride Solutions at 250°C and 100°C," Corrosion, 37, No. 6, p. 312-320, June 1981.

14) L. F. Lin et al, "Stress Corrosion Cracking of Sensitized Type 304 Stainless Steel in High Temperature Chloride Solutions," Corrosion, 37 No. 11, p. 616-627, November 1981

15) G. Cragnolino and D. D. MacDonald, "Intergranular Stress Corrosion Cracking of Austenitic Stainless Steel at Temperatures Below 100°C - A Review," Corrosion, 38, No. 8, p. 406-424, August 1982.

16) F. P. Ford and M. Silverman, "The Prediction of Stress Corrosion Cracking of Sensitized Type 304 Stainless Steel in 0.01 M Na_2SO_4 at 97°C," Corrosion, 36, No. 10, p. 558-565, October 1980.

17) G. Herbsleb, "The Stress Corrosion Cracking of Sensitized Austenitic Stainless Steels and Nickel-Base Alloys," Corrosion Science, 20, 1980.

18) M. E. Indig, "Controlled Potential Simulation of Deaerated and Non-Deaerated Start Up," paper # 40, Proceedings of EPRI Seminar on Countermeasures for BWR pipe cracking, WS79-174, Vol. 3, Palo Alto, January 1980.

19) J. W. Frey and R. W. Staehle, "Effect of Temperature on the Stress Corrosion Cracking of Iron-Nickel-Chromium Alloys," paper presented at Corrosion 67, Los Angeles, March 16, 1967.

20) S. A. Wilson letter to W. L. Walker, "Analysis of Stress Corrosion Results," VNC DA Review, October 16, 1969.

21) K. Tanno et al, "Intergranular Stress Corrosion Cracking of Sensitized Type 304 Stainless Steel in Sodium Sulfate at Approximately 100°C," Corrosion, 49, No. 4, p. 319-326, April 1993.

22) B. M. Gordon, "Effects of Anionic Impurities and Oxygen on the Stress Corrosion Cracking of Type 304 Stainless Steel in Low Temperature (<205°C) Environments," unpublished, March 26, 1992.

23) H. R. Copson and G. Economy, "Effect of Some Environmental Conditions on the Stress Corrosion Behavior of Ni-Cr-Fe Alloys in Pressurized Water," presented at Power Conference, Lausanne, published in Corrosion, Vol. 24, No. 3, p. 55-65, March 1968.

24) M. Honda et al, "Stress Corrosion Cracking of Stainless Alloys in Alkaline Sulfide Solutions," Corrosion, 48, No. 10, p. 822-829, October 1992.

25) P. L. Andresen, "Effects of Specific Anion Impurities on Environmental Cracking of Austenitic Materials in 288°C Water," paper presented at the Fifth Inter. Symp. on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, Monterey, CA, August 25, 1991, proceedings of same, ANS, La Grange, IL, p. 209-217, 1992.

26) S. H. Shim and Z. Szklarska-Smialowska, "Effect of Fluid Flow on Stress Corrosion Cracking of AISI 304 Stainless Steel in Pure Water and 0.01 M Na2S04 Solutions Differing in pH," Corrosion, 43, No. 5, p. 286-290, May 1987.

27) L. R. Scharfstein and W. F. Brindley, "Chloride Stress Corrosion Cracking of Austenitic Stainless Steel - Effect of Temperature and pH," paper presented NACE Corrosion 58, San Francisco, CA, March 17, 1958, published in Corrosion, Vol. 14., No. 12, p. 588-592, December 1958.

28) J. C. Griess and G. F. Creek, "Design Considerations of Reactor Containment Systems -Part X - The SCC of Type 304 and 316 Stainless Steel in Boric Acid Solutions," ORNL-TM-2412 Part X, May 1971.

29) H. P. Leckie and H. H. Uhlig, "Environmental Factors Affecting the Critical Potential for Pitting in 18-8 Stainless Steel," Jour. Electro. Chem. Soc., Vol. 113, No. 12, p. 1262, December 1966.

30) B. M. Gordon, "Alternate Materials Program Severe Pitting Tests," WAPD-SGA(MC)-841, September 1974.

31) G. L. Licina, "Sourcebook for Microbiologically Influenced Corrosion in Nuclear Power Plants," EPRI NP-5580, Palo Alto, CA, 1988.

32) R. E. Tatnall, "Fundamentals of Bacteria Induced Corrosion," paper #129, NACE Corrosion 81, Toronto, ONT, April 1981, published in Materials Performance, Vol. 20, No. 9, p. 32-38, September 1981.

33) D. H. Pope et al, "Microbiologically Influenced Corrosion of Industrial Alloys," paper presented at NACE Corrosion 83, Anaheim, CA, April 1983, published in Materials Performance, Vol. 23, No. 4, p. 14-18, April 1984.

34) B. M. Gordon, "Severe Transients in BWRs," unpublished data.

35) R. Carnahan and J. C. Cutt, "Millstone Point 1 Isolation Condenser and Shutdown Cooling System Piping Cracks," NEDE-25400, Class III, May 1981.

36) "Edwin I. Hatch Nuclear Plant, Unit 1, Coolant Chemistry Transient Safety Analysis," NEDO-22134, May 1982.

37) J. Doyle, "Technical Report 94-01, GE LPRMs and Dry Tubes Installed in Fermi 2," January 7, 1994.

38) "Incore Dry Tube Cracks," SIL No. 409, Revision 1, July 31, 1986.

39) L. C. Wimpee, "Life of Type 304 Stainless Steel Dry Tubes Subjected to Fast Neutron Irradiation," Sensor Products Engineering Memo, Number 792-89-01, May 31, 1991.

40) RICSIL No. 002, "Crevice Corrosion Cracking of Advanced Test Control Rod", April 1986.

41) NEDE-31392P, "Crevice Corrosion Cracking of Boiling Water Reactor Control Rods", GE Proprietary Information, August 1987.

42) SIL No. 139 Revised Supplement 1, "CRD Collet Retainer Tube Inspection Reports", April 29, 1977.

43) SIL No. 157, Revision 2, "Control Blade Lifetime", September 1981.

44) C. S. O'Toole, "Harmful Effects of Resin on Alloy 600 Pipe Tests", PMET 81-688-27, March 1981.

45) P. L. Andresen, I. P. Vasatis and F. P. Ford, "Behavior of Short Cracks in Stainless Steel at 288°C", Paper 495 presented at Corrosion 90, NACE, Las Vegas, April 1990.

46) SIL No. 579, "Crevice Corrosion Cracking in Duralife 120 and 140 Control Rods," May 5, 1994.

47) R. N. Ikemoto, Test Plan and Procedures, "Fermi 2 Reactor Site EOC-4 Fuel Inspection," April 1994.

48) R. N. Ikemoto, "Fermi 2 EOC-4 Irradiated Fuel Inspection Exit Report," May 1994.

49) "BWR Water Chemistry Guidelines--1993 Revision. Normal and Hydrogen Water Chemistry". EPRI Document No. TR-103515, February 1994.

50) "BWR Water Chemistry Guidelines--1993 Revision. Normal and Hydrogen Water Chemistry". EPRI Document No. TR-103515, Project 2493, Final Report, February 1994.

51) S. E. Garcia, "Fermi 2 EOC-4 Fuel Deposit Report," to be issued.

52) GE Report GE-NE 523-A53-0494, "Evaluation and Screening Criteria for the Fermi 2 Shroud," April 1994.

53) GE Report, GE-NE 523-148-1193, "BWR Core Shroud Evaluation," Prepared for the BWR Owners Group, April 1994.

54) GE Report GE-NE C1100297-02, "Fermi 2 Circulation Water Transient CRD Safety Evaluation Analysis," draft report dated July 1994, E. Gibo.

55) GE Report GE-NE 523-A53-0494, "Evaluation and Screening Criteria for the Fermi 2 Shroud, April 1994.

56) GE Report, GE-NE-523-148-1193, "BWR Core Shroud Evaluation," Prepared for the BWR Owners Group, April 1994.

57) S. Bartman, "Startup Chemistry Plan--Preliminary Draft", July 13, 1994.

58) GE Report, GE-NE C1100297-01, Rev. 1, "Enrico Fermi 2 CRD Material Evaluation," July 1994

GE Nuclear Energy

GE Proprietary Information

NEDC-32320D
September 1994

Enrico Fermi 2
Materials and Fuels Evaluation
Final Report — Appendices

Volume 2

Prepared for
Detroit Edison Company

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Appendix 1

Plant Data

FERMI 2 REACTOR WATER

DATE	TIME	POWER	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON	COND	CHLORIDE	SULFATE	NITRATE	SILICA	D.O.	TOC	Na	Ca
		%				(μS/CM)	(μS/CM)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppm)
12/22/93	15 55	93	1	50		0.092									
12/23/93	1 30	93	1	50	6.8	0.090	0.089	1	2.8	1.6	142	94			
12/[illegible]93	8 40	93	1	50		0.090									
12/23/93	16 12	93	1	50		0.090									
12/24/93	0 40	93	1	50	6.7	0.090	0.090	1	2.6	1.4	150	98			
12/24/93	7 40	93	1	50		0.090									
12/24/93	15 25	93	1	50		0.089									
12/25/93	0 10	93	1	50	6.9	0.089	0.09	1	2.1	1.4	160	97			
12/25/93	7 40	93	1			0.090									
12/25/93	13 25						10								
12/25/93	18 10	0	3	37	9.8		61.4	5772	5786	598					
12/25/93	20 10	0	3	37	10.3		70	4591	6199	497					
12/25/93	22 10	0	3	37	10.2		89	4925	6233	656					
12/26/93	0 10	0	3	37	10.2		95	3868	4845	472					
12/26/93	2 05	0	3	37	10.1		102	5200	6749	669					
12/26/93	4 10	0	3	50	10.4		103.5	5580	5730	699	1740		58		
12/26/93	6 10	0	3	50	10.4		107	6326	6177	490					
12/26/93	8 10	0	3	50	10.4		150	6420	6180	900					
12/26/93	10 10	0	3	50	10.5		138	9780	7200	960					
12/26/93	12 10	0	3	50	10.5		150	7800	7560	780					
12/26/93	14 10	0	3	50	10.6		162	86[illegible]	8040	960					
12/26/93	16 10	0	3	50	10.5		172	[illegible]780	8940	1260					
12/26/93	18 10	0	3	50	10.6		179	12267	10742	1332					
12/26/93	20 10	0	3	50	10.6		182	11497	10554	1423					

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
12/26/93	20:55	0	3	42A			114								
12/26/93	22:05	0	3	50	10.6		146	10525	10189	629					
12/27/93	0:10	0	4	50	10.4		138	10288	9492	479	529				
12/27/93	2:10	0	4	50	10.4		137								
12/27/93	6:10	0	4	50	10.3		128	9804	7967	98					
12/27/93	12:10	0	4	50	10.4		120	10200	8280	480					
12/27/93	14:20	0	4	50			117.8								
12/27/93	18:10	0	4	50	10.3		115	10500	8119	770					
12/27/93	21:52	0	4	50			118								
12/28/93	0:10	0	4	50	10.2		114	11345		626	440				16
12/28/93	6:10	0	4	50	10.3		112	10070	6123	479					
12/28/93	11:10	0	4	50	10.3		115	10114	5949	503				5120	
12/28/93	17:10	0	4	50	10.2		100.6	10400	5250	455				####	20
12/29/93	0:10	0	4	50	10.2		113	10430	5500	460	540			4416	
12/29/93	6:10	0	4	50	10.3		113	10008	5125	341					
12/30/93	13:10	0	4	50	10.1		106	9200	4600	500					
12/30/93	20:10	0	4	50	9.9		103	9590	5500	680			79		
12/31/93	3:10	0	4	50	9.9		105	9590	6000	683	420			6300	
12/31/93	10:10	0	4	50	9.9		104	9400	4500	683					
12/31/93	17:10	0	4	50	9.7		104	9170	4500	680					
1/1/94	0:10	0	4	50	9.7		102.4	9091	4400	592	470			6072	
1/1/94	7:10	0	4	50	9.8		102	9300	4500	680					
1/1/94	14:10	0	4	50	10.1		103	9200	4500	680					
1/1/94	21:10	0	4	50	9.8		101	7000	4500	680					
1/2/94	4:10	0	4	50	9.8		101	9174	4350	546	348			5865	

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
1/2/94	11:10	0	4	50	9.9		101	9200	4300	680					
1/2/94	18:10	0	4	50	9.7		100	8800	4500	680					
1/3/94	1:10	0	4	50	9.9		101	9200	4500	650	406			5500	
1/3/94	8:10	0	4	50	9.8		101	8540	4000	544					
1/3/94	15:10	0	4	50	9.8		100	8549	4500	566					
1/3/94	22:10	0	4	50	9.9		99	8600	4600	610	426			5600	
1/4/94	5:10	0	4	50	9.9		99	8500	4500	522	417			5600	
1/4/94	12:10	0	4	50	9.7		99	8757	4375	544					
1/4/94	19:10	0	4	50	9.8		98	8500	4200	500					
1/5/94	2:10	0	4	50	9.7		97	8800	4300	560	452				
1/5/94	9:10	0	4	50	9.8		98	8757	5200	622				5400	
1/5/94	16:10	0	4	50	9.9		98	8300	4300	435				5800	
1/5/94	23:10	0	4	50	9.9		96	8500	4300	520	404			5800	
1/6/94	6:10	0	4	50	9.8		96	8340	4150	440					
1/6/94	13:05	0	4	50	9.7		96.6	8340	4785	425				5780	
1/6/94	20:10	0	4	50	9.8		97	8300	4600	650					
1/7/94	3:10	0	4	50	9.9		95	8300	4300	440	410			5800	
1/7/94	10:10	0	4	50	9.9		95.3	8130	4550	435				5800	
1/7/94	17:10	0	4	50	9.9		95.3	8340	4000	435				5800	
1/8/94	0:10	0	4	50	9.8		95	8340	4500	650	380			5500	
1/8/94	7:10	0	4	50	9.8		94.5	8300	4000	435					
1/8/94	14:10	0	4	50	9.9		94.2	8340	4250	435					
1/8/94	21:10	0	4	50	9.9		95	8350	4200	520				5600	
1/9/94	4:10	0	4	42a	9.8		92	8300	4200	480	399			5500	
1/9/94	11:10	0	4	42a	9.8		94	8123	4375	544					

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
1/9/94	18:10	0	4	42a	9.8		94	8236	4000	479					
1/10/94	1:10	0	4	42a	9.9		93	8000	4000	440	380			5300	
1/10/94	15:10	0	4	42a	9.8		93	8400	3904	400					
1/10/94	22:10	0	4	42a	9.9		87	7200	3560	200				5050	
1/11/94	5:10	0	4	42a	9.9		86	7040	3610	280				4870	
1/11/94	11:00	0	4	50	9.8		87	7000	3660	400					
1/11/94	18:00	0	4	42a	9.9		85	6800	3660	400					
1/11/94	22:30	0	4	42a	9.9		86	6800	3610	240	334			4655	
1/12/94	5:30	0	4	42a	9.9		72	6280	2590	240	277			4290	
1/12/94	12:30	0	4	42a	9.8		68	6000	2200	400				4210	
1/13/94	16:30	0	4	42A	9.7		69.3	5800	2440	400					
1/13/94	23:30	0	4	42A	9.3		68	5200	1952	400	240			3738	
1/14/94	6:30	0	4	42A	9.4		68	5200	2200	400					
1/14/94	13:30	0	4	42A	9.5		69.1	5360	2489	400				3738	
1/14/94	20:30	0	4	42A	9.6		68	5200	2300	400					
1/15/94	3:30	0	4	42A	9.6		69	5200	2200	400	324			3738	
1/15/94	10:30	0	4	42A	9.5		69	5200	2200						
1/15/94	17:30	0	4	42A	9.6		69.7	5400	2300	455					
1/16/94	0:30	0	4	42A	9.6		70	5570	2460	455	302			3580	
1/16/94	7:30	0	4	42A	9.6		70	5264	2360	455					
1/16/94	14:30	0	4	42A	9.6		65	5000	2257	364					
1/16/94	21:30	0	4	42A	9.7		65	4870	2260	360				3200	
1/17/94	4:30	0	4	42A	9.7		66	4610	2050	320	173			3040	
1/17/94	11:30	0	4	42A	9.5		61	4260	2050	320					
1/17/94	18:30	0	4	42A	9.4		47	2915	1385	273					

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
1/18/94	1:30	0	4	42A	9.5		37	2580	1030	300	101			1400	
1/18/94	8:30	0	4	42A	9.3		30	1349	693	114					
1/18/94	15:30	0	4	42A	9.2		24.3	957	539	93					
1/18/94	22:30	0	4	42A	9.2		24	748	520	19					
1/19/94	5:30	0	4	42A	9.3		21	746	524	51	48				
1/19/94	12:30	0	4	42A	9.5		18.2	588	395	39					
1/19/94	19:30	0	4	42A	9.4	16.5	16.5	390	280	29				300	
1/20/94	2:30	0	4	42A	9.3	14.9	14.9	265	300	43	44			226	
1/20/94	9:30	0	4	42A	9.2	12.9	12.7	185	225	19					
1/20/94	16:30	0	4	42A	9.2	11.4	11.2	197	170	18					
1/20/94	23:30	0	4	42A	9.2	10	10	109	125	6	32			78	
1/21/94	6:30	0	4	42A	9.2	9.4	9.4	100	99	5					
1/21/94	9:50	0	4	42A		9.2	9.1								
1/21/94	8:30	0	4	RHR B SUCT			63	3480	5027	501					
1/21/94	13:30	0	4	42A	9.0	8.52	8.42	35.7	78.6	5.42					
1/21/94	20:30	0	4	42A	9.0	7.99	7.84	32.1	56.6	3.9					
1/22/94	3:30	0	4	42A	8.9	7.35	7.2	24	54	3.5	24			70.6	
1/22/94	10:30	0	4	42A	9.0	7.08	6.81	18.1	25.4	2.8				72	
1/22/94	17:30	0	4	42A	8.9	6.5	6.3	8.7	31.8	2.1					
1/23/94	0:30	0	4	42A	8.9	6.02	5.98	5.3	27.8	1.8	22			21.2	
1/23/94	7:30	0	4	42A	8.8	5.6	5.4	6.8	23.2	1.8					
1/23/94	14:30	0	4	42A	8.8	5.3	5.2	5.4	19.2	1.6					
1/23/94	21:30	0	4	42A	8.8	5.2	4.91	4.6	17	1.4					
1/24/94	4:30	0	4	42A	8.8	4.89	4.8	3.5	14.3	1.3	20			6.3	
1/24/94	11:30	0	4	42A	8.8	4.65	4.56	3.2	13.1	1.4					

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
1/24/94	18:30	0	4	42A	8.8	4.56	4.38	3.1	11.8	1.1					
1/25/94	1:30	0	4	42A	8.8	5.98	5.91	22.8	102.2	5.4	28			16.5	
1/25/94	8:30	0	4	42A	8.8	5.32	5.18	18.2	73.9	4.4					
1/25/94	22:30	0	4	42A	8.8	4.64	4.52	11.1	47.2	2.6					
1/26/94	4:30	0	4	42A	8.7	4.33	4.3	8.8	30.7	2	14			21	
1/26/94	11:30	0	4	42A	8.5	3.91	3.8	7.7	27.7	1.8					
1/26/94	18:30	0	4	42B	8.5	5.6	6.6	256	290	23					
1/26/94	22:20	0	4	42B	8.7	7.3	7.4	320	210	26					
1/27/94	3:30	0	4	42B	8.5	8.1	8.04	326	158	30	46			225	
1/27/94	11:30	0	4	42B	8.7	8.98	8.9	115.1	116.3	28.7					
1/27/94	18:00	0	4	42B		9	9.6	164	120	27					
1/27/94	20:50	0	4	42B		9.7	9.8								
1/28/94	1:25	0	4	42B	8.9	9	9	151	156	14	88			48	
1/28/94	9:25	0	4	42B	8.6	6.88	6.86	132	96	18					
1/28/94	17:25	0	4	42B	8.5	5.59	5.53	136.6	105.3	14.9					
1/29/94	1:25	0	4	42B	8.3	4.63	4.5	110	70	10	33				
1/29/94	9:25	0	4	42B	8.4	3.98	3.94	96	81	9.3				36	
1/29/94	17:25	0	4	42B	8.4	3.33	3.31	95.4	60	6.9					
1/30/94	1:25	0	4	42B	8.2	3	2.74	39.8	77	6.5	50			18.1	
1/30/94	9:25	0	4	42B	8.2	2.69	2.62	60	52	5.1					
1/30/94	17:25	0	4	42B	8.1	2.61	2.6	60	66	5.7					
1/31/94	1:25	0	4	42B	8.1	2.49	2.65	30.2	64.4	4.3	23			21.2	
1/31/94	9:30	0	4	42B	8.1	2.36	2.3	26.5	54.6	3.4					
1/31/94	16:30	0	4	42B	8.1	2.14	2.26	28.1	64.1	3.8					
2/1/94	1:40	0	4	42B	8.1	2.05	2.1	24	49.7	3.1	29			21.4	

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
2/1/94	9:40	0	4	42B	8.2		2.22	46.8	54.9	4.2					
2/1/94	15:30	0	4	42B	8.3		2.02	21.4	47.1	2.8					
2/2/94	0:00	0	4	42B	8.1	1.99	2.02	25	60.1	3.7	44			21.6	
2/2/94	8:00	0	4	42B	8.2		1.98	25	64.3	4.2					
2/2/94	16:00	0	4	42B	8.2		1.87	19.3	42.8	2.7					
2/3/94	0:00	0	4	42B	8.0	2.17	2.12	28.8	73.9	6.2	60				
2/3/94	8:00	0	4	42B	7.8	1.99	1.97	24.6	58.1	4.5				36.5	
2/3/94	16:00	0	4	42B	7.9	1.99	1.93	32.3	58.1	5.1					
2/4/94	0:00	0	4	42B	7.4	1.86	1.85	57	52	4.5	49			47.5	
2/4/94	8:00	0	4	42B	7.2		1.72	43.8	61.5	4.6					
2/4/94	16:00	0	4	42B	7.2		1.62	48.6	44.4	4.5					
2/5/94	0:00	0	4	42B	7.4	1.65	1.68	60	57.6	5.4	52			49.5	
2/5/94	8:00	0	4	42B	7.2		1.55	34.2	50.2	4.6					
2/5/94	16:00	0	4	42B	7.2		1.61	36.5	46.5	4					
2/6/94	0:01	0	4	42B	7.7	1.5	1.6	30	53.9	4.8	58			29.5	
2/6/94	12:00	0	4	42B	7.1		1.59	23.6	55.1	5					
2/7/94	0:00	0	4	42B	7.2	1.5	1.5	32.2	65.5	5.7	46			47.5	
2/7/94	12:00	0	4	42B	7.1		1.32	23	39.3	4.2					
2/8/94	0:00	0	4	42B	6.9	1.33	1.32	25.3	48.8	5.1	41			35.6	
2/8/94	12:00	0	4	42B			1.39								
2/9/94	12:00	0	4	42B	7.1	1.25	1.24	34.3	33	5.1					
2/10/94	0:00	0	4	42B	7.0	1.36	1.29	42	45	9	26			38	
2/10/94	13:00	0	4	42B			1.39								
2/11/94	0:00	0	4	42B	7.1	1.14	1.13	22	29	4.3	40			20	
2/11/94	12:20	0	4	42B	7.1	1.32	1.27	40.3	42.9	6.9					

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
2/12/94	0:00	0	4	42B	6.9	1.28	1.24	42	43	6	43			21	
2/12/94	23:00	0	4	42B		1.27	1.26								
2/13/94	8:45	0	4	42B	7.2	1.1	1.07	21.4	37.9	5.2	24			16	
2/14/94	3:45	0	4	42B	7.4	1.22	1.19	23.9	54	6.5	28			21	
2/15/94	2:45	0	4	42B	7.4	1.04	1.03	23.2	32.8	5.3	56			26.4	
2/16/94	1:45	0	4	42B	7.3	1.17	1.14	24.8	49.8	6.3	29			54.5	
2/17/94	0:45	0	4	42B	6.8	1.04	1.01	22	40	5.4	30			52	
2/17/94	23:45	0	4	42B	6.8	0.91	0.9	18	36	4.5	31			50	
2/18/94	6:00	0	4	42B		1.05	1.08								
2/19/94	5:00	0	4	42B	7.0	1	1.04	23	41	5.4	32			39.6	
2/20/94	4:00	0	4	42B	7.1	0.87	0.88	19.9	32	4.7	33			17.8	
2/21/94	3:00	0	4	42B	7.2	0.97	0.97	20.9	29.3	4.1	15			16.5	
2/22/94	2:00	0	4	42B	7.1	1.14	1.13	27.2	52.6	6.5	17			39.6	
2/23/94	1:00	0	4	42B	6.5	0.92	0.91	30.7	31.2	6.2	11			21.4	
2/23/94	4:30	0	4	50		0.8	0.81								
2/24/94	3:30	0	4	50	8.0	1.5	1.44	21	28	3	21				
2/24/94	10:00	0	4	50		0.81	0.78								
2/24/94	12:00	0	4	50			0.96								
2/25/94	2:30	0	4	50	6.9	0.62	0.6	12.1	12.5	2.4	14			8	
2/25/94	13:12	0	4	50			0.67								
2/25/94	14:10	0	4	50			1.06								
2/26/94	1:20	0	4	50	6.6	1.79	1.73	32.7	80.2	7.7	33			18.7	
2/27/94	0:20	0	4	50	6.5	1.48	1.43	34.6	43.7	5.5	36			63.6	
2/27/94	5:40	0	4	50		1.6	1.6							59.5	
2/28/94	1:10	0	4	50	6.5	1.85	1.82	58.8	59.2	7.1	97			72.2	

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
2/28/94	1:40	0	4	50		1.84	1.89								
3/1/94	0:55	0	4	50	6.2	2.1	2.27	90.8	58	9.2	230				
3/1/94	3:30	0	4	50		2.17	2.32								
3/1/94	12:25	0	4	50		2.32	2.44	103.8	51	7.8					
3/1/94	20:25	0	4	50		2.5	2.63	136.5	55.8	10.8					
3/2/94	2:30	0	4	50	6.2	2.41	2.52	132.2	42.8	9.6	186				
3/2/94	10:30	0	4	50		2.48	2.61	109.1	38.1	6.7					
3/2/94	18:23	0	4	50			2.75	144.1	60.3	12					
3/3/94	1:30	0	4	50	6.3	2.34	2.92	149.8	45.2	9	113				
3/3/94	9:30	0	4	50		2.81	3.11	133	46.7	7.6					
3/3/94	18:00	0	4	50		2.95	3.27	138.9	47.8	8.3					
3/4/94	0:30	0	4	50	6.3	3.03	3.33	166	62.4	10.1	127				
3/4/94	0:50	0	4	50			3.4	84	51	9.5					
3/4/94	16:30	0	4	50			3.4	145.2	43.2	9.8					
3/4/94	23:30	0	4	50	6.4	3.4	3.6	143	40	10	126				
3/5/94	6:30	0	4	50		3.6	3.8	148	38	10.8					
3/5/94	8:45	0	4	50		3.55	3.82								
3/5/94	14:30	0	4	50	6.5	3.63	3.7	152.4	34.6	10.8					
3/5/94	17:32	0	4	50			3.3	144	36.9	4.8					
3/5/94	22:30	0	4	50		2.9	2.9	129	42.3	10.9					
3/6/94	8:30	0	4	50	6.6	2.5	2.5	68	52	11	92				
3/6/94	13:40	0	4	50		2.2	2.2	63	53	9.8					
3/6/94	21:30	0	4	50		1.9	1.9	59	55	9					
3/7/94	5:15	0	4	50	6.6	1.67	1.66	64.8	43.2	7.7	48				
3/8/94	0:55	0	4	50	6.4	1.29	1.26	45.8	42.5	6.5	38				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
3/8/94	4:10	0	4	50		1.25	1.24								
3/9/94	0:20	0	4	50	6.6	1.11	1.29	42.2	42.5	5	27				
3/9/94	3:10	0	4	50		1.13	1.15								
3/10/94	2:10	0	4	50	6.5	1.51	1.5	55	79	5.5	35				
3/10/94	2:40	0	4	50			1.52								
3/10/94	9:45	0	4	50			1.56	65.9	80.6	4.8					
3/11/94	1:10	0	4	50	6.9	1.56	1.54	67	80.5	2.1	24				
3/11/94	2:45	0	4	50				61	75	7.2					
3/12/94	0:10	0	4	50	6.6	1.46	1.41	51	74	7.4	32				
3/12/94	23:10	0	4	50			1.39								
3/13/94	5:00	0	4	50	6.4	1.44	1.4	50	74	8	40				
3/14/94	1:20	0	4	50	6.5	1.48	1.44	51.2	74.6	9	29				
3/15/94	5:00	0	4	50	6.5	1.56	1.52	53.2	77.4	9.8	18				
3/16/94	2:00	0	4	50	6.6	1.56	1.53	54.2	77.2	10.5	19				
3/17/94	1:00	0	4	50	6.8	1.44	1.41	56	68	9.9	17				
3/18/94	0:01	0	4	50	6.8	1.22	1.18	48.5	48.4	9.1	33				
3/19/94	3:35	0	4	42B	6.5	1.16	1.13	42.6	38.1	9.3	33				
3/20/94	2:35	0	4	42B	6.7	1.22	1.2	41.7	32.8	14.4	53				
3/20/94	15:15	0	4	42B		1.29	1.27	44.2	30.9	14.5					
3/21/94	1:35	0	4	42B	6.7	1.21	1.19	41	42.2	24.2	40				
3/22/94	0:35	0	4	50	6.8	0.42	0.41	10.2	6.3	5.3	13				
3/22/94	23:35	0	4	50	6.5	0.23	0.23	4.2	3.3	3	<5				
3/23/94	22:35	0	4	50		0.25									
3/24/94	4:40	0	4	50	6.8	0.29	0.27	5.6	3.6	1.9	17				
3/25/94	3:40	0	4	50	6.8	0.27	0.26	4.8	5.1	1.7	20				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
3/26/94	2:40	0	4	50	7.0		0.25	5	5.2	1.7	21				
3/27/94	1:40	0	4	50	6.9		0.26	5.1	5.1	1.8	20				
3/28/94	0:40	0	4	50	6.8		0.29	5.4	6.1	1.6	5				
3/29/94	5:20	0	4	50			0.27								
3/30/94	4:15	0	4	50	6.9		0.29	5.2	6.4	1.6	7				
3/31/94	3:15	0	4	50	6.9		0.35	8.1	8.5	2	12				
4/1/94	2:15	0	4	50	6.9		0.39	9.9	10.8	2.2	21				
4/2/94	1:15	0	4	50	6.6		0.44	10.9	10.7	2.3	27				
4/3/94	0:15	0	4	50	6.5		0.504	11.7	10.1	2.4	75				
4/4/94	3:50	0	4	50	6.4		0.63	17.5	12.9	2.5	60				
4/5/94	2:50	0	4	50	6.4		0.7	19.6	15.1	3	68				
4/6/94	1:50	0	4	50	6.5		0.49	16	15.1	2.6	9				
4/7/94	0:45	0	4	50	6.3		0.47	16.1	14.4	2.8	20				
4/8/94	1:30	0	4	50	6.2	0.52	0.52	14.8	13.3	2.7	40				
4/9/94	0:40	0	4	50	6.3	0.64	0.64	13.7	11.1	2.6	59				
4/10/94	2:05	0	4	50	6.2	0.67	0.66	7.9	4	1.5	57				
4/11/94	0:05	0	4	50	6.0	0.66	0.65	3.2	1.7	1	45				
4/12/94	0:05	0	4	50	6.0	0.64	0.64	3.3	1	1.2	53				
4/13/94	0:10	0	4	50	5.9	0.62	0.62	4	1	1.2	49				
4/14/94	3:25	0	4	50	6.0	0.61	0.61	9.1	4.2	1.9	36				
4/15/94	1:05	0	4	50	6.1	0.7	0.7	15.2	6.4	2.7	36				
4/16/94	0:02	0	5	50	6.0	0.74	0.74	12.6	4.5	2.8	30				
4/17/94	1:35	0	5	42a	6.2	0.71	0.72	12.4	2.2	3.2	30				
4/18/94	0:50	0	5	42a	6.0	0.95	0.95	22	19.5	5.2	25		91		
4/19/94	1:20	0	5	50	5.9	0.69	0.7	5.5	7	2.7	193		36		

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D O (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
4/20/94	1:15	0	5	50	5.9	0.75	0.75	3.6	3.5	1.4	298				
4/21/94	1:10	0	5	50	5.9	0.77	0.77	4	3.6	1.4	275				
4/22/94	1:45	0	5	50	5.9	0.69	0.67	3.8	3.1	1.1	241				
4/23/94	1:25	0	5	50	5.9	0.77	0.77	4.9	3.8	1.2	295				
4/24/94	0:45	0	5	50	5.8	0.8	0.78	5.8	4.5	1.3	148				
4/25/94	1:45	0	5	50	5.8	0.76	0.76	6	4.2	1.2	285				
4/26/94	0:35	0	5	50	6.0	0.79	0.79	8.3	6	1.7	240				
4/27/94	0:50	0	5	50	5.9	0.75	0.75	13.1	10.5	2.4	185				
4/28/94	1:15	0	5	50	6.1	0.715	0.723	23.4	19.5	3.7	60				
4/29/94	2:40	0	5	50	6.3	0.65	0.64	13.7	11.4	2.1	89				
4/30/94	0:01	0	5	50	6.0	0.84	0.83	14.1	36.9	1.2	98				
5/1/94	0:35	0	5	50	5.9	0.86	0.86	11	23.8	1	69				
5/2/94	1:15	0	5	50	5.8	0.86	0.86	6.8	13.1	1	132		37		
5/3/94	0:15	0	5	50	5.8	0.86	0.87	6.1	11.3	1	129				
5/4/94	1:35	0	5	50	5.7	0.86	0.86	5.3	6.9	1	127				
5/5/94	0:40	0	5	50	5.7	0.86	0.85	4.8	4.3	1	144				
5/6/94	1:45	0	5	50	5.7	0.85	0.84	4.3	3	1	134				
5/7/94	0:45	0	5	50	5.7	0.87	0.87	4.1	1	1	111				
5/8/94	0:25	0	5	50	5.8	0.87	0.87	4	1	1	114				
5/9/94	0:40	0	5	50	5.8	0.86	0.86	4.1	1	1	143		20		
5/10/94	1:00	0	5	50	6.0	0.86	0.86	4.6	1	1	155				
5/11/94	0:35	0	5	50	5.8	0.86	0.86	4.6	1	1	156				
5/12/94	1:20	0	5	50	5.8	0.85	0.85	4.6	1	1	178				
5/13/94	0:50	0	5	50	5.7	0.84	0.84	4.8	1	1	183				
5/14/94	0:15	0	5	50	5.8	0.83	0.83	4.5	1	1	180				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
5/15/94	0:45	0	5	50	5.7	0.84	0.83	4.6	1	1	190				
5/16/94	0:30	0	5	50	5.8	0.84	0.84	4.7	1	1	215		20		
5/17/94	0:55	0	5	50	5.7	0.83	0.83	4.8	1	1	188				
5/18/94	0:05	0	5	50	5.7	0.83	0.83	4.1	1	1	0				
5/19/94	1:20	0	5	50	5.8	0.83	0.83	4.4	1	1	0				
5/20/94	1:40	0	5	50	5.8	0.83	0.82	4.3	1	1	228				
5/21/94	0:25	0	5	50	5.8	0.83	0.81	4.4	1	1	229				
5/22/94	1:10	0	5	50	5.9	0.82	0.8	4.3	1	1	226				
5/23/94	1:10	0	5	50	5.9	0.82	0.81	3.9	1	1	234				
5/24/94	0:40	0	5	FP	6.0		0.75	1	1	1	265				
5/25/94	22:40	0	5	FP	5.8		0.75	1	1	1	290				
5/26/94	21:40	0	5	FP	5.9		0.75	1	1	1	280				
5/27/94	20:40	0	5	FP	5.8		0.77	1	1	1	270				
5/28/94	19:40	0	5	FP	6.0		0.75	1.1	1	1	289				
5/29/94	18:30	0	5	FP	6.0		0.81	1	1	1	285				
5/30/94	17:30	0	5	FP	6.1		0.81	1.1	1.3	1	282				
5/31/94	16:40	0	5	FP	6.0		0.82	1	1	1	280				
6/1/94	15:40	0	5	FP	5.9		0.81	2.3	2.1	1	232				
6/2/94	14:40	0	5	FP	5.9		0.79	2	1.5	1	254				
6/3/94	13:40	0	5	FP	6.0		0.72	1.9	1.1	1	246				
6/4/94	12:40	0	5	FP	5.9		0.7	1.6	1	1	235				
6/5/94	11:40	0	5	FP	5.9		0.65	1.2	1	1	169				
6/6/94	10:30	0	5	FP	5.9		0.67	1	1	1	243		20		
6/7/94	9:30	0	5	FP	5.8		0.7	1	1	1	242				
6/8/94	8:30	0	5	FP	6.0		0.78	1.3	1	1	257				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
6/9/94	6:40	0	5	FP	6.0		0.72	1.3	1	1	240				
6/10/94	5:30	0	5	FP	5.9		0.79	1.3	1	1	242				
6/11/94	4:30	0	5	FP	5.9		0.71	1.2	1	1	221				
6/12/94	3:30	0	5	FP	6.3		0.68	1.8	1.2	1.1	255				
6/13/94	2:30	0	5	FP	5.9		0.71	1	1	1	241		20		
6/14/94	1:30	0	5	FP	5.8		0.72	1	1	1	220				
6/15/94	0:30	0	5	FP	5.9		0.71	1.2	1	1	214				
6/16/94	22:30	0	5	FP	6.0		0.71	1.2	1	1	250				
6/17/94	21:30	0	5	FP	6.2		0.72	1.2	1	1	222				
6/18/94	20:30	0	5	FP	5.8		0.71	1	1	1	231				
6/19/94	19:30	0	5	FP	6.1		0.69	1	1	1.1	227				
6/20/94	17:52	0	5	FP	5.8		0.68	1.2	1.1	1	228				
6/21/94	16:20	0	5	FP	5.9		0.7	1	1	1	180				
6/22/94	15:20	0	5	FP	5.9		0.69	1.2	1.1	1	221				
6/23/94	14:20	0	5	FP	6.2		0.65	1	3.3	1	149				
6/24/94	13:15	0	5	FP	5.8		0.68	1.2	2.2	1	191				
6/25/94	12:15	0	5	FP	5.9		0.69	1.2	1	1	208				
6/26/94	11:20	0	5	FP	6.0		0.7	1	1	1	195				
6/27/94	10:15	0	5	FP	6.0		0.75	1	2.2	1	180		20		
6/28/94	9:15	0	5	FP	5.9		0.79	1	1	1	147				
6/29/94	8:15	0	5	FP	6.0		0.71	1	1	1	87				
6/30/94	7:15	0	5	FP	6.0		0.72	1	1	1	150		20		
7/1/94	6:15	0	5	FP	6.3		0.72	1	1	1	185				
7/2/94	5:15	0	5	FP	6.5		0.8	1.3	1	1	184				
7/3/94	4:15	0	5	FP	6.3		0.76	1.1	1.2	1	140				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
7/4/94	3:15	0	5	FP	6.0		0.78	1.3	1	1	183				
7/5/94	2:15	0	5	FP	6.3		0.79	1.1	1	1	202				
7/6/94	1:15	0	5	FP	6.1		0.8	1.2	1	1	180				
7/7/94	0:20	0	5	FP	6.4		0.81	1.2	1.2	1	194				
7/8/94	22:15	0	5	FP	6.4		0.81	1.2	1	1	185				
7/9/94	21:15	0	5	FP	6.1		0.79	1.2	1	1.3	210				
7/10/94	19:50	0	5	FP	6.0		0.79	1.1	1	1	181				
7/11/94	16:15	0	5	FP	6.0		0.8	1.1	1	1	195		20		
7/12/94	15:15	0	5	FP	6.1		0.79	1.1	1	1	190				
7/13/94	14:15	0	5	FP	6.1		0.8	1.2	1	1	209		20		
7/14/94	13:15	0	5	FP	6.1		0.8	1.1	1	1	215				
7/15/94	12:15	0	5	FP	6.1		0.8	1.1	1	1	231		21		
7/16/94	11:15	0	5	FP	6.1		0.81	1.1	1	1	213				
7/17/94	10:15	0	5	FP	6.1		0.8	1	1	1	234		20		
7/18/94	9:15	0	5	FP	6.1		0.8	1	1	1	240		37		
7/19/94	8:15	0	5	FP	6.1		0.81	1.2	1	1	238		20		
7/20/94	7:15	0	5	FP	6.0		0.82	1.2	1	1	236				
7/21/94	5:30	0	5	FP	6.2		0.85	1.2	1	1	243				
7/22/94	4:30	0	5	FP	6.0		0.8	1.2	1	1	234				
7/23/94	3:30	0	5	FP	6.4		0.8	1.1	1.2	1	236				
7/24/94	2:30	0	5	FP	6.3		0.76	1.1	1.1	1	206				
7/25/94	1:30	0	5	FP	6.3		0.79	1	1	1	246		42		
7/26/94	0:30	0	5	FP	6.4		0.79	1	1	1	249				
7/27/94	22:30	0	5	FP	6.4		0.76	1	1.6	1	220				
7/28/94	21:30	0	5	FP	6.1		0.81	1	1.8	1	227				

FERMI 2 REACTOR WATER

DATE	TIME	POWER %	MODE	SAMPLE SOURCE	pH	CONDUCTIVITY COND BY MON (µS/CM)	COND (µS/CM)	CHLORIDE (ppb)	SULFATE (ppb)	NITRATE (ppb)	SILICA (ppb)	D.O. (ppb)	TOC (ppb)	Na (ppb)	Ca (ppm)
7/29/94	20:30	0	5	FP	6.1		0.79	1	1	1	247				
7/30/94	19:30	0	5	FP	6.3		0.79	1	1	1	228				
7/31/94	18:30	0	5	FP	6.2		0.79	1	1	1	215				
8/1/94	17:30	0	5	FP	6.2		0.78	1	1		251				
8/2/94		0	5	FP											
8/3/94		0	5	FP											
8/4/94		0	5	FP											
8/5/94		0	5	FP											
8/6/94		0	5	FP											
8/7/94	11:30	0	5	FP	6.0		0.83	1	1		255				
8/8/94		0	5	FP											
8/9/94		0	5	FP											
8/10/94		0	5	FP											
8/11/94		0	5	FP											
8/12/94		0	5	FP											
8/13/94		0	5	FP											
8/14/94		0	5	FP											
8/15/94	3:30	0	5	FP	6.2		0.72	1	1		238				
8/16/94		0	5	FP											
8/17/94															

FERMI FUEL POOL WATER

DATE	TIME	SAMPLE SOURCE	pH	ONDUCTIVITY (µS/cm)	SUSPENDED SOLIDS (ppb)	SiO2 (ppb)	CHLORIDE (ppb)	SULFATE (ppb)	TOC (ppb)
12/6/93	9:30	FP	6.0	0.91	<10	898	<1	<1	
12/13/93	17:00	FP	6.1	0.88	<10	600	2	2	
12/15/93	5:55	FP		0.86		1080			
12/17/93	3:05	FP		0.92		1060			
12/20/93	3:50	FP	6.5	0.94	<10	1040	<1	<1	
12/21/93	8:40	FP		0.78		680			
12/27/93	0:05	FP	6.9	0.93	<10	744	21	20	
1/3/94	1:10	FP	6.3	1.02	<10	853	24	10	
1/10/94	0:30	FP	6.3	0.80	<10	966	6	2	
1/16/94	14:45	FP	6.2	0.85	10				45
1/17/94	4:40	FP	6.0	0.89	<10	869	22	13	<20
1/17/94	10:15	FP		0.81	10				33
1/18/94	13:50	FP	5.9	0.85	10				<20
1/19/94	5:45	FP	6.3	0.88	10				<20
1/20/94	2:45	FP	6.1	0.88	<10				33
1/22/94	1:10	FP	6.5	0.82	<10				49
1/23/94	0:15	FP	6.2	0.83	10				<20
1/24/94	3:20	FP	6.2	0.87	<10	514	23	10	40
1/25/94	1:50	FP	6.2	0.86	<10				<20
1/26/94	1:45	FP	6.3	0.89	25				<20
1/27/94	3:40	FP	6.2	0.90	100	635	36	19	<20
1/28/94	1:40	FP	6.2	0.83	25				<20
1/29/94	1:40	FP	6.1	0.90	50				87
1/30/94	3:15	FP	6.1	0.87	25				<20
1/31/94	1:50	FP	6.7	1.18	35	488	48	49	36
2/7/94	4:00	FP	6.8	2.00	100	920	93	118	38
2/8/94	4:40	FP	6.8	3.30	600		193	259	84
2/9/94	3:00	FP	6.4	2.40	100		118	139	63
2/10/94	0:00	FP	6.6	2.80	100		151	150	55
2/10/94	23:40	FP	6.5	2.50	25		140	148	42
2/12/94	0:15	FP	6.3	2.50	10		192	198	30
2/13/94	1:30	FP	6.4	2.50	100		140	164	23
2/14/94	3:55	FP	6.5	2.40	500	749	140	154	36
2/15/94	2:55	FP	6.5	2.50	100		141	181	48
2/16/94	1:55	FP	6.5	2.50	500		139	181	43
2/17/94	0:50	FP	6.6	2.80	150		210	225	45
2/17/94	23:50	FP	6.8	2.80	500		153	165	42
2/18/94	10:30	FP	6.7	2.90	250		140	189	40
2/19/94	0:10	FP	6.5	2.80	100		200	200	47
2/20/94	1:40	FP	6.6	2.60	250		161	191	32
2/21/94	2:50	FP	6.6	2.70	250	875	123	139	26
2/21/94	16:20	FP	7.0	1.10	100		46	39	
2/22/94	2:10	FP	6.6	0.84	200	601	21	16	28
2/23/94	1:10	FP	6.5	0.79	75	606	9	1	25
2/24/94	0:50	FP	6.6	0.85	100	620	11	1	<20
2/25/94	2:40	FP	6.6	0.84	100	600	15	1	<20

FERMI FUEL POOL WATER

DATE	TIME	SAMPLE SOURCE	pH	CONDUCTIVITY (µS/cm)	SUSPENDED SOLIDS (ppb)	SiO2 (ppb)	CHLORIDE (ppb)	SULFATE (ppb)	TOC (ppb)
2/26/94	0:10	FP	6.5	0.80	50	980	8	<1	<20
2/27/94	0:10	FP	6.4	0.88	100	860	6	4	56
2/28/94	1:00	FP	6.5	0.88	150	722	9	4	22
3/1/94	1:05	FP	6.3	0.90	<10	531	10	3	<20
3/2/94	3:20	FP	6.0	0.89	250	953	8	4	<20
3/3/94	1:20	FP	6.0	0.96	35	941	8	2	<20
3/4/94	0:15	FP	6.4	0.89	<10	930	8	1	<20
3/4/94	23:15	FP	6.1	0.88	<10	868	9	2	<20
3/6/94	5:15	FP	6.0	0.88	10	980	10	3	<20
3/6/94	21:15	FP	6.1	0.38	10	870	8	1	<20
3/8/94	0:30	FP	6.3	0.89	100	945	8	1	37
3/9/94	0:05	FP	5.9	0.94	50	920	9	1	36
3/10/94	2:15	FP	5.8	0.87	10	990	9	<1	54
3/11/94	1:00	FP	6.2	0.88	50	910	8	1	29
3/12/94	0:01	FP	5.8	0.85	<10	810	8	<1	47
3/13/94	1:00	FP	6.1	0.85	<10	920	8	2	55
3/14/94	4:10	FP	6.1	0.90	25	910	8	2	24
3/15/94	2:50	FP	6.2	0.89	50	1058	9	2	25
3/16/94	1:50	FP	6.1	0.89	50	1011	8	1	30
3/17/94	0:50	FP	6.1	0.84	25	921	9	<1	21
3/18/94	0:10	FP	6.2	0.83	10	880	9	<1	28
3/21/94	1:30	FP	6.2	0.85	25	1000	9	1	75
3/22/94	14:38	FP			<10				35
3/22/94	23:25	FP	6.6	0.71	10	472	3	1	23
3/24/94	17:00	FP			<10				
3/26/94	8:40	FP			10				

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/25/93	13:30	550	550	540	520			1030
12/25/93	13:45	555	555	540	522			1030
12/25/93	14:00	555	555	540	525			1002
12/25/93	14:15	555	555	546	520			1070
12/25/93	14:30	550	550	540	520			1000
12/25/93	14:45	540	540	535	515			930
12/25/93	15:00	525	525	533	495			760
12/25/93	15:15	515	520	530	490			720
12/25/93	15:30	510	510	525	480			700
12/25/93	15:45	492	492	518	475			620
12/25/93	16:00	492	492	515	470			610
12/25/93	16:15	472	472	510	465			515
12/25/93	16:30	460	460	505	450			490
12/25/93	16:45	480	480	500	470			600
12/25/93	17:00	470	470	500	455			520
12/25/93	17:15	470	470	495	450			505
12/25/93	17:30	490	490	490	460			580
12/25/93	17:45	470	470	487	450			490
12/25/93	18:00	460	460	485	440			450
12/25/93	18:15	435	435	480	430			370
12/25/93	18:30	450	450	475	425			410
12/25/93	18:45	440	440	470	420			370
12/25/93	19:00	440	440	470	415			360
12/25/93	19:15	420	420	460	400			320
12/25/93	19:30	410	410	460	390			260
12/25/93	19:45	405	405	455	390			260
12/25/93	20:00	385	385	450	370			205
12/25/93	20:15	390	390	445	375			205
12/25/93	20:30	365	365	440	350			160
12/25/93	20:45	370	370	435	360			170
12/25/93	21:00	355	355	430	340			140
12/25/93	21:15	355	355	425	330			140
12/25/93	21:30	350	350	420	305			130
12/25/93	21:45	345	345	420	290			130

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/25/93	22:00	345	345	410	270			125
12/25/93	22:15	350	350	410	260			130
12/25/93	22:30	345	345	405	250			130
12/25/93	22:45	350	350	405	245			130
12/25/93	23:00	345	345	405	245			130
12/25/93	23:15	350	350	390	345			130
12/25/93	23:30	345	345	390	335			130
12/25/93	23:45	350	350	385	345			130
12/25/93	0:00	345	345	380	340			140
12/26/93	0:15	350	350	380	345			140
12/26/93	0:30	345	345	380	340			120
12/26/93	0:45	345	345	375	340			120
12/26/93	1:00	345	345	370	340			140
12/26/93	1:15	345	345	370	340			130
12/26/93	1:30	345	345	370	340			130
12/26/93	1:45	345	345	365	335			130
12/26/93	2:00	345	345	365	335			130
12/26/93	2:15	345	345	360	335			120
12/26/93	2:30	345	345	360	335			130
12/26/93	2:45	350	350	360	340			140
12/26/93	3:00	350	350	355	340			140
12/26/93	3:15	340	340	355	335			120
12/26/93	3:30	345	345	355	345			140
12/26/93	3:45	345	345	350	340			130
12/26/93	4:00	335	335	350	330			110
12/26/93	4:15	325	325	350	320			100
12/26/93	4:30	315	315	345	315			80
12/26/93	4:45	310	310	340	305			80
12/26/93	5:00	300	300	335	300			60
12/26/93	5:15	305	305	335	305			70
12/26/93	5:30	310	310	335	310			80
12/26/93	5:45	320	320	330	320			70
12/26/93	6:00	330	330	330	330			100
12/26/93	6:15	330	330	330	330			1[illegible]0

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/26/93	6:30	330	330	330	330			110
12/26/93	6:45	335	335	330	330			100
12/26/93	7:00	340	340	330	335			120
12/26/93	7:15	350	350	330	340			130
12/26/93	7:30	350	350	330	340			120
12/26/93	7:45	350	350	330	340			120
12/26/93	8:00	341	341	332	340			130
12/26/93	8:15	340	340	332	338			130
12/26/93	8:30	340	340	332	338			120
12/26/93	8:45	340	340	332	335			110
12/26/93	9:00	346	346	332	341			130
12/26/93	9:15	341	341	332	335			110
12/26/93	9:30	341	340	332	338			130
12/26/93	9:45	345	345	332	339			130
12/26/93	10:00	335	335	331	332			120
12/26/93	10:15	348	348	331	343			130
12/26/93	10:30	340	340	331	335			120
12/26/93	10:45	342	342	331	340			130
12/26/93	11:00	341	341	331	336			120
12/26/93	11:15	335	335	330	335			120
12/26/93	11:30	346	346	331	341			130
12/26/93	11:45	335	335	331	332			120
12/26/93	12:00	340	340	331	342			130
12/26/93	12:15	345	345	330	340			130
12/26/93	12:30	337	337	331	335			120
12/26/93	12:45	340	340	331	335			120
12/26/93	13:00	339	339	331	335			120
12/26/93	13:15	346	346	331	341			130
12/26/93	13:30	339	339	331	334			110
12/26/93	13:45	348	348	331	341			130
12/26/93	14:00	339	339	331	334			120
12/26/93	14:15	339	339	331	338			120
12/26/93	14:30	347	347	331	344			130
12/26/93	14:45	338	338	331	335			110

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/26/93	15:00	340	338	331	338			130
12/26/93	15:15	340	338	330	338			115
12/26/93	15:30	340	338	330	338			125
12/26/93	15:45	340	338	330	338			140
12/26/93	16:00	340	338	330	338			115
12/26/93	16:15	340	338	330	338			128
12/26/93	16:30	340	338	330	338			140
12/26/93	16:45	337	335	330	334			120
12/26/93	17:00	341	338	330	337			130
12/26/93	17:15	332	332	330	330			107
12/26/93	17:30	325	325	330	320			95
12/26/93	17:45	315	315	325	310			80
12/26/93	18:00	310	305	325	305			75
12/26/93	18:15	315	310	322	315			85
12/26/93	18:30	320	320	320	320			95
12/26/93	18:45	325	325	320	320			95
12/26/93	19:00	325	320	320	295			85
12/26/93	19:15	315	310	317	257			80
12/26/93	19:30	315	305	312	238			75
12/26/93	19:45	310	300	311	222			80
12/26/93	20:00	292	297	310	209			85
12/26/93	20:15	275	283	310	275			70
12/26/93	20:30	290	289	310	290			60
12/26/93	20:45	290	273	308	272			58
12/26/93	21:00	271	252	300	255			47
12/26/93	21:15	253	240	299	243			37
12/26/93	21:30	240	230	297	232			33
12/26/93	21:45	230	215	295	216			25
12/26/93	22:00	219	209	290	208			20
12/26/93	22:15	210	204	287	201			15
12/26/93	22:30	208	197	285	196			13
12/26/93	22:45	201	180	282	180			9
12/26/93	23:00	192	170	280	167			7
12/26/93	23:15	181	161	280	160			6

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/28/93	0:30			175	152	155		
12/28/93	1:30			172	150	153		
12/28/93	2:30			170	145	150		
12/28/93	3:30			168	145	149		
12/28/93	4:30			165	145	149		
12/28/93	5:30			165	145	149		
12/28/93	6:30			165	145	149		
12/28/93	7:30			161	145	149		
12/28/93	8:30			160	145	149		
12/28/93	9:30			158	145	148		
12/28/93	10:30			158	143	148		
12/28/93	11:30			157	142	148		
12/28/93	12:30			156	141	147		
12/28/93	13:30			153	140	146		
12/28/93	14:30			153	141	145		
12/28/93	15:30			153	145	145		
12/28/93	16:30			152	146	145		
12/28/93	17:30			152	156	154		
12/28/93	18:30			151	152	156		
12/28/93	19:30			148	148	151		
12/28/93	20:30			146	150	150		
12/28/93	21:30			145	150	149		
12/28/93	22:30			144	147	148		
12/28/93	23:30			141	145	149		
12/29/93	0:30			142	147	150		
12/29/93	1:00			142	150	150		
12/29/93	2:00			142	150	150		
12/29/93	3:00			140	150	153		
12/29/93	4:00			140	149	152		
12/29/93	5:00			140	146	151		
12/29/93	6:00			141	146	150		
12/29/93	7:00			139	145	150		
12/29/93	8:00			139	148	150		
12/29/93	9:00			139	145	150		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/29/93	10:00			139	148	147		
12/29/93	11:00			137	140	140		
12/29/93	12:00			136	132	136		
12/29/93	13:00			132	125	128		
12/29/93	14:00			130	120	122		
12/29/93	15:00			130	120	120		
12/29/93	16:00			130	117	117		
12/29/93	17:00			130	117	117		
12/29/93	18:00			130	114	114		
12/29/93	19:00			127	113	113		
12/29/93	20:00			125	113	111		
12/29/93	21:00			125	112	110		
12/29/93	22:00			123	107	108		
12/29/93	23:00			122	107	108		
12/30/93	0:00			122	105	107		
12/30/93	1:00			121	105	105		
12/30/93	2:00			121	110	105		
12/30/93	3:00			120	110	108		
12/30/93	4:00			119	109	109		
12/30/93	5:00			119	105	109		
12/30/93	6:00			119	103	109		
12/30/93	7:00			119	103	109		
12/30/93	8:00			119	103	109		
12/30/93	9:00			119	103	109		
12/30/93	10:00			119	103	109		
12/30/93	11:00			118	103	109		
12/30/93	12:00			119	103	109		
12/30/93	13:00			115	103	109		
12/30/93	14:00			115	103	109		
12/30/93	15:00			115	103	109		
12/30/93	16:00			115	103	109		
12/30/93	17:00			112	103	108		
12/30/93	18:00			112	103	108		
12/30/93	19:00			112	103	108		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
12/30/93	20:00			112	103	108		
12/30/93	21:00			110	103	108		
12/30/93	22:00			110	102	108		
12/30/93	23:00			109	102	107		
12/30/93	0:00			109	102	105		
12/31/93	1:00			110	102	105		
12/31/93	2:00			110	102	105		
12/31/93	3:00			110	102	106		
12/31/93	4:00			110	102	105		
12/31/93	5:00			108	100	105		
12/31/93	6:00			108	100	105		
12/31/93	7:00			108	100	105		
12/31/93	8:00			108	101	103		
12/31/93	9:00			108	102	102		
12/31/93	10:00			108	102	102		
12/31/93	11:00			106	102	102		
12/31/93	12:00			108	105	103		
12/31/93	13:00			108	103	103		
12/31/93	14:00			106	104	104		
12/31/93	15:00			108	105	105		
12/31/93	16:00			105	105	105		
12/31/93	17:00			105	105	105		
12/31/93	18:00			105	105	105		
12/31/93	19:00			105	105	105		
12/31/93	20:00			105	105	105		
12/31/93	21:00			105	106	106		
12/31/93	22:00			104	105	106		
12/31/93	23:00			105	105	106		
1/1/94	0:00			105	105	105		
1/1/94	1:00			105	105	105		
1/1/94	2:00			105	105	105		
1/1/94	3:00			105	105	105		
1/1/94	4:00			105	105	105		
1/1/94	5:00			105	105	105		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
1/1/94	6:00			105	105	106		
1/1/94	7:00			105	105	106		
1/1/94	8:00			105	105	106		
1/1/94	9:00			104	105	106		
1/1/94	10:00			104	105	106		
1/1/94	11:00			104	105	106		
1/1/94	12:00			105	105	106		
1/1/94	13:00			104	105	106		
1/1/94	14:00			105	105	106		
1/1/94	15:00			105	105	106		
1/1/94	16:00			105	105	106		
1/1/94	17:00			105	105	106		
1/1/94	18:00			105	105	106		
1/1/94	19:00			105	105	106		
1/1/94	20:00			105	105	106		
1/1/94	21:00			105	105	106		
1/1/94	22:00			105	105	106		
1/1/94	23:00			105	105	106		
1/1/94	0:00			105	105	106		
1/2/94	1:00			105	105	106		
1/2/94	2:00			105	105	106		
1/2/94	3:00			105	105	106		
1/2/94	4:00			105	105	106		
1/2/94	5:00			105	105	106		
1/2/94	6:00			106	106	107		
1/2/94	7:00			106	106	107		
1/2/94	8:00			106	106	107		
1/2/94	9:00			106	106	107		
1/2/94	10:00			106	106	107		
1/2/94	11:00			106	106	107		
1/2/94	12:00			105	106	107		
1/2/94	13:00			105	106	107		
1/2/94	14:00			105	106	107		
1/2/94	15:00			105	106	107		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
1/2/94	16:00			105	106	107		
1/2/94	17:00			105	106	106		
1/2/94	18:00			105	105	106		
1/2/94	19:00			105	105	106		
1/2/94	20:00			105	105	106		
1/2/94	21:00			105	104	105		
1/2/94	22:00			104	104	105		
1/2/94	23:00			103	102	109		
1/3/94	0:00			102	101	103		
1/3/94	1:00			102	102	102		
1/3/94	2:00			102	103	102		
1/3/94	3:00			102	103	103		
1/3/94	4:00			102	103	104		
1/3/94	5:00			102	103	104		
1/3/94	6:00			102	103	104		
1/3/94	7:00			102	103	104		
1/3/94	8:00			102	103	104		
1/3/94	9:00			100	102	104		
1/3/94	10:00			100	102	104		
1/3/94	11:00			100	103	104		
1/3/94	12:00			100	103	104		
1/3/94	13:00			100	103	104		
1/3/94	14:00			99	103	104		
1/3/94	15:00			99	103	105		
1/3/94	16:00			99	104	105		
1/3/94	17:00			99	104	105		
1/3/94	18:00			99	104	105		
1/3/94	19:00			99	103	105		
1/3/94	20:00			99	103	105		
1/3/94	21:00			99	104	105		
1/3/94	22:00			99	104	105		
1/3/94	23:00			99	104	105		
1/4/94	0:00			100	105	106		
1/4/94	1:00			100	105	107		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
1/4/94	2:00			100	106	107		
1/4/94	3:00			100	107	107		
1/4/94	4:00			100	107	107		
1/4/94	5:00			100	107	107		
1/4/94	6:00			100	106	107		
1/4/94	7:00			100	106	107		
1/4/94	8:00			100	107	107		
1/4/94	9:00			100	106	107		
1/4/94	10:00			100	106	107		
1/4/94	11:00			100	106	107		
1/4/94	12:00			100	106	107		
1/4/94	13:00			100	106	107		
1/4/94	14:00			100	106	107		
1/4/94	15:00			100	106	107		
1/4/94	16:00			100	106	107		
1/4/94	17:00			100	106	107		
1/4/94	18:00			100	106	107		
1/4/94	19:00			100	105	107		
1/4/94	20:00			100	105	107		
1/4/94	21:00			100	105	106		
1/4/94	22:00			99	105	106		
1/4/94	23:00			100	105	106		
1/5/94	8:00			100	102	106		
1/5/94	16:00			100	100	104		
1/6/94	8:00			100	100	105		
1/6/94	16:00			100	101	105		
1/7/94	8:00			100	101	104		
1/7/94	16:00			100	105	105		
1/8/94	8:00			100	103	106		
1/8/94	16:00			100	101	105		
1/9/94	8:00			100		105		
1/9/94	16:00			100		109		
1/10/94	8:00			101	101	109		
1/10/94	13:00			101	102	105		

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
1/11/94	8:00			100	102	102		
1/11/94	16:00			100	110	105		
1/12/94	8:00			101	105	102		
1/12/94	16:00			100	104	102		
1/13/94	8:00			100	105	101		
1/13/94	16:00			100	105	101		
1/14/94	8:00			99	105	101		
1/14/94	16:00			98	101	99		
1/15/94	8:00			94	110	104		
1/15/94	16:00			94	100	101		
1/16/94	8:00			93	103	100		
1/16/94	16:00			92	104	101		
1/17/94	8:00							
1/17/94	16:00							
1/18/94	8:00			94	104	100		
1/18/94	16:00			94	104	100		
1/19/94	8:00			92	103	103		
1/19/94	16:00			95	104	103		
1/20/94	8:00			95	104	99		
1/20/94	16:00			95	103	100		
1/21/94	8:00			100	104	101		
1/21/94	16:00			100	103	100		
1/22/94	8:00			100	105	101		
1/22/94	16:00			100	104	101		
1/23/94	8:00			100	103	102		
1/23/94	16:00			101	105	102		
1/24/94	8:00			100	105	101		
1/24/94	16:00			100	102	102		
1/25/94	8:00			100	104	102		
1/25/94	16:00			101	105	104		
1/26/94	8:00			99	102	100		
1/26/94	16:00			99	101	100		
1/27/94	8:00							
1/27/94	16:00							

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
1/28/94	8:00			100	104		105	
1/28/94	16:00			100	104		107	
1/29/94	8:00			100	103		104	
1/29/94	16:00			100	103		103	
1/30/94	8:00			99	101		102	
1/30/94	16:00			100	103		103	
1/31/94	8:00			98	105		105	
1/31/94	16:00			97	104		103	
2/1/94	8:00			95	108		107	
2/1/94	16:00			95	105		107	
2/2/94	8:00			95	105		105	
2/2/94	16:00			95	105		105	
2/3/94	8:00							
2/3/94	16:00							
2/4/94	8:00			91	102		102	
2/4/94	16:00			91	102		103	
2/5/94	8:00			91	105		107	
2/5/94	16:00			91	108		109	
2/6/94	8:00			92	104		105	
2/6/94	16:00			90	101		103	
2/7/94	8:00			90	103		102	
2/7/94	16:00			90	101		102	
2/8/94	8:00			91	106		108	
2/8/94	16:00			91	106		107	
2/9/94	8:00			92	105		105	
2/9/94	16:00			92	100		102	
2/10/94	8:00			92	105		105	
2/10/94	16:00			92	106		105	
2/11/94	8:00			92	108		108	
2/11/94	16:00			92	106		105	
2/12/94	8:00			94	103		103	
2/12/94	16:00			94	103		102	
2/13/94	8:00			93	102		103	
2/13/94	16:00			93	101		101	

FERMI-2 REACTOR TEMPERATURE

DATE	TIME	RECIRC LOOP A (°F)	RECIRC LOOP B (°F)	REACTOR VESSEL SHELL (°F)	REACTOR VESSEL BOTTOM DRAIN (°F)	RHR HX A INLET (°F)	RHR HX B INLET (°F)	REACTOR PRESSURE (PSIG)
2/14/94	8:00			93	102		102	
2/14/94	16:00			92	102		101	
2/15/94	8:00			93	103		103	
2/15/94	16:00			93	103		104	
2/16/94	8:00			93	105		103	
2/16/94	16:00			92	102		103	
2/17/94	8:00			91	102		102	
2/17/94	16:00			90	102		102	
2/18/94	8:00							
2/18/94	16:00							
2/19/94	8:00			92	105		104	
2/19/94	16:00			90	102		105	
2/20/94	8:00			94	102		102	
2/20/94	16:00			90	102		104	
2/21/94	8:00			92	105		105	
2/21/94	16:00			92	103		103	

Appendix 2

SHB Inspection Report &

SIL No. 433

GE Nuclear Energy

EXAMINATION SUMMARY SHEET

REPORT NO.: SHB94-R001

PROJECT: FERMI Unit 2 RF04	PROCEDURE: UT-FER-501V0 REV: 0 FRR: N/A N/A N/A
SYSTEM: RPV	N/A REV: N/A FRR: N/A N/A N/A
WELD NO.: SHROUD HEAD HOLD DOWN BOLT	
CONFIGURATION: BOLTS	N/A REV: N/A FRR: N/A N/A N/A
EXAMINER: JACOB BRIGGS LEVEL: III	NDE ☐ MT ☐ PT ■ UT ☐ VT
EXAMINER: N/A LEVEL: N/A	WELD TYPE: ☐ CIRCUMFERENTIAL ☐ LONGITUDINAL ■ OTHER BOLTS
EXAMINER: N/A LEVEL: N/A	
DATA SHEET NO.(S): SHB94-D001	CAL SHEET NO.(S): SHB94-C001

On Friday, May 20, 1994 personnel from GE Nuclear Energy performed an ultrasonic (UT) examination of all 48 shroud head hold down bolts attached to the steam separator for evidence of cracking.

Over the years, cracking has been detected in shroud head hold down bolting associated with Boiling Water Reactor (BWR). The cracking in these bolts (BWR 4's and earlier plants) has been confined to a creviced region created by a 304 stainless steel ring welded to an alloy 600 Inconel shaft. Typically, this cracking is IGSCC in natur[redacted]

The steam separator, because of radiation activation, is stored under water in a storage pool for shielding purposes when removed from the reactor pressure vessel. To examine the hold down bolting attached to the steam separator remote UT techniques are used. Forty-eight (48) bolts were examined from the refuel bridg[redacted]

EXAMINATION RESULTS:

All Forty-eight (48) shroud head hold down bolts attached to the Fermi Unit 2 Steam Separator were examined for evidence of cracking. Of these Forty-eight bolts, sixteen (16) exhibited evidence of cracking. The bolts which exhibited this evidence were # 2, 11, 12, 19, 20, 21, 22, 23, 24, 27, 31, 36, 39, 41, 47, and 48. See attached Data sheets for examination results.

■ EXAM COMPLETE ☐ PARTIALLY EXAMINED (EXPLAIN IN COMMENTS) ☐ EXAM COMPLETE IN COMBINATION WITH DATA SHEETS BELOW

RWP NO.: 94-1065

ADDITIONAL DATA SHEETS: N/A

COMPARED TO: ☐ PSI ■ ISI REPORT NO.(S): ☐ NO CHANGE

NO. OF RECORDABLE INDICATIONS: 16

TOTAL DOSE 0 MAN REM

EXAMINATION RESULTS: ☐ ACCEPTABLE ■ UNACCEPTABLE

NO. OF REPORTABLE INDICATIONS: 16

SUMMARY BY	LEVEL	DATE	REVIEWED BY	LEVEL	DATE
[signature]	III	5/20/94	[signature]	III	5-21-94
			REVIEWED BY [signature: M.C. Groth]	TITLE III	DATE 5-21-94

FORM UT-09 REV 1

GE Nuclear Energy

ULTRASONIC CALIBRATION DATA SHEET
(Shroud Head Hold Down Bolts)

SITE: FERMI UNIT: 2 REPORT NO.: SHB94-R001

PROJECT NO.: RF04 CALIBRATION SHEET NO.: SHB94-C001

PROCEDURE NO.: UT-FER-501V0 REVISION: 0 FRR: N/A

Instrument: KRAUTKRAMER (Manufacturer) USIP-11 (Model No) 21192-6639 (Serial No)

Search Unit: AEROTECH (Manufacturer) E03810 (Serial No) .50" (Size) 2.25 MHz (Freq) 0°L (Angle/Mode)

Cable: RG-59 (Type) 150' (Length) 0 (No. of Connectors)

Calibration Standard: LFK-069 (Serial No.) INCO-600 (Material) 12.75" (Thickness) AMBIENT °F (Temp)

Couplant: WATER (Type) N/A (Batch No) Thermometer: N/A (Serial No)

DAC

AMPLITUDE 100 90 80 70 60 50 40 30 20 10

[redacted]

SWEEP: 0 - 10 = 12

☐ DEPTH ☒ METAL PATH

INSTRUMENT SETTINGS

Gain [redacted]
Frequency
Range
Sweep
Delay
Filter

Rep. Rate [redacted]
Resolution
Sensitivity
Damping
Reject
Pulse Width

Jack ☒ R ☐ T

CALIBRATION VERIFICATION	TIME	SWEEP	AMPLITUDE
INITIAL CALIBRATION TIME	15:00	7.2	80
CALIBRATION CHECK	17:30	7.2	60
CALIBRATION CHECK	N/A	N/A	N/A

NOTCH RESPONSE

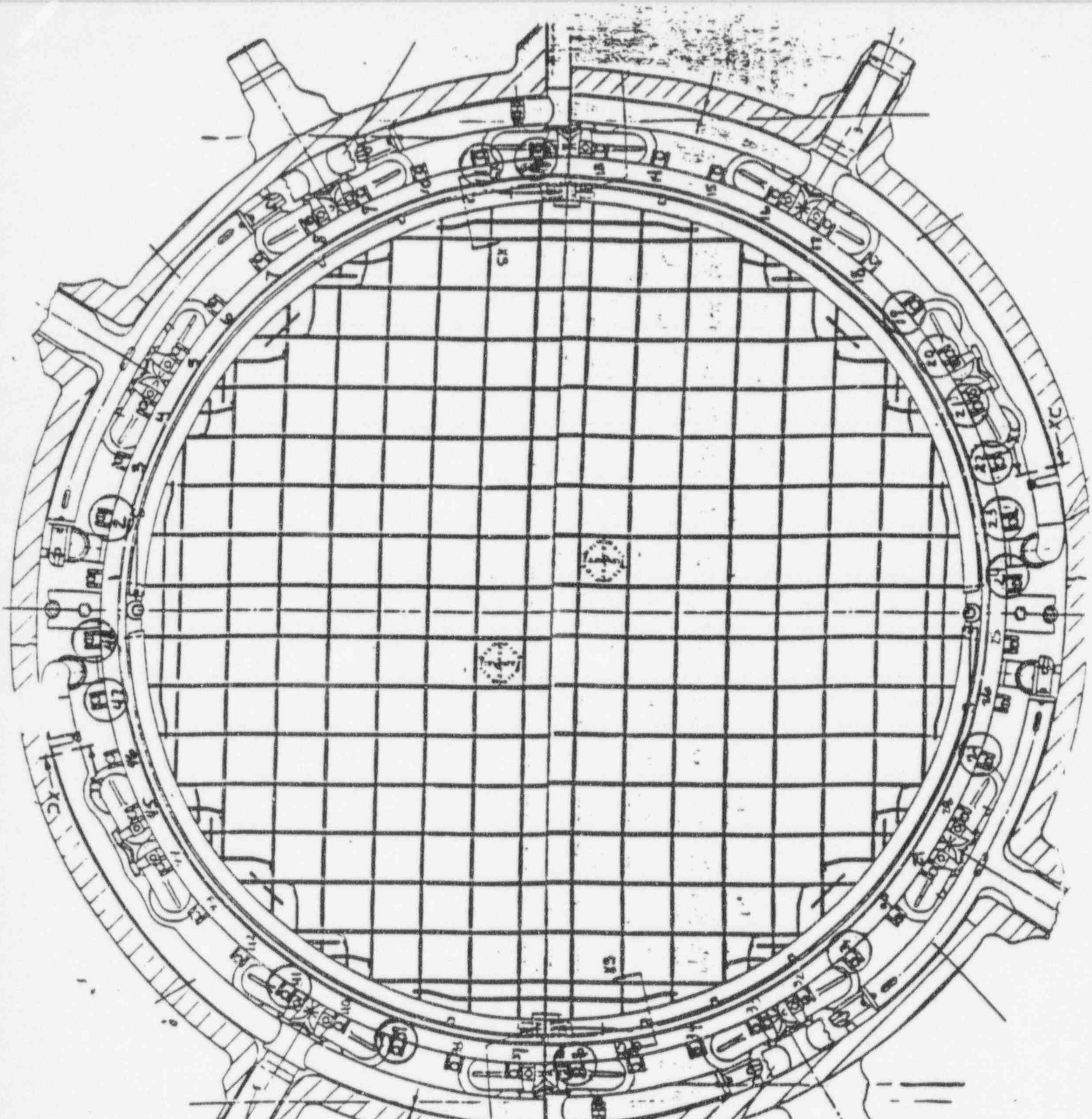
AMPLITUDE: 80 %

SWEEP: 7.2

COMMENTS:

[signature]	III	5/20/94					
EXAMINER	LEVEL	DATE	REVIEWED BY	DATE	ANII REVIEW BY	DATE	
[signature]	III	5-20-94					
GE REVIEWED BY	LEVEL	DATE	REVIEWED BY	DATE			

FORM UT-147 REV. 0



270°

Shroud head bolt failures

SIL No. 433
Supplement 1
September 15, 1993

SIL No. 433, issued February 7, 1986, informed GE BWR owners that cracking had occurred in the Inconel alloy 600 shaft in a creviced region of a shroud head bolt. Since then, several cracked shroud head bolts of the original design have been found in pre–BWR/6 plants. A complete failure of the shaft of one of the original design shroud head bolts occurred recently at a GE BWR/4. The failure location was different from that of the failure described in SIL No. 433. The purpose of this Supplement 1 to SIL No. 433 is to inform GE BWR owners of the recent failure.

Discussion

The failed bolt separated approximately 68 inches above the bottom of the bolt at the weld connection between the lower portion of the NiCrFe Inconel alloy 600 rod and the 304 stainless steel stud. The lower portion of the bolt—approximately 68 inches long, which includes the Inconel tee section, was found resting on a group of jet pump sensing lines in the annulus between the shroud and the vessel walls. The bolt tee section failed to disengage during unbolting after the upper segment of the bolt shaft had been rotated. This caused the lower bolt segment to separate when the shroud head was lifted. A visual inspection of the fractured surface indicated that essentially the entire cross section of the bolt was cracked before plant personnel attempted to untorque the bolt. As described in SIL No. 433, the cracked bolt was "captured" during operation. Because the bolt's tee section failed to disengage during unbolting, the lower bolt segment was torn from the shroud head bolt sleeve assembly and fell into the vessel annulus when the shroud head was lifted.

Although the cause of the cracking has not been identified positively, intergranular stress corrosion cracking (IGSCC) is suspected. In an outage at this plant in 1987, ultrasonic examination of the same shroud head bolt indicated a crack at a different location—in the base collar region. All shroud head bolts in this GE BWR/4 were the original bolts supplied during plant construction. Similar failures of original design shroud head bolts have been found in pre–BWR/6 plants since SIL No. 433 was issued.

The cause of the cracking described in SIL No. 433 was confirmed to be crevice-accelerated IGSCC. The cracking occurred in the creviced region between the shroud head bolt's stainless steel collar and the Inconel rod. In response to this occurrence, GE Nuclear Energy recommended in SIL No. 433 that owners of all pre–BWR/6 plants perform ultrasonic examination of the shroud head bolts the next time the bolts were accessible.

SIL No. 433 also informed GE BWR owners that GE had redesigned the shroud head bolt to eliminate the creviced condition in the Inconel collar. Other design changes reduce the probability of failure in other IGSCC-susceptible parts of the bolt. The new bolt design includes the following improvements:

[redacted]

[redacted]

Recommended actions

GE Nuclear Energy recommends that owners of pre-BWR/6s in which the original design shroud head bolts are still installed perform the following:

1. Revise the ultrasonic examination procedure to include the entire length of the bolt rather than limiting the inspection to the collar region.

2. At the first opportunity, ultrasonically examine the entire length of all original design shroud head bolts.

3. If any crack indications are found in the main shroud head bolt shaft, replace the damaged bolt with a bolt of the new design. If a new shroud head bolt is not available, GE can perform an evaluation to determine the feasibility of operating the plant with the cracked bolt removed until a new bolt is available.

4. If original design bolts with crack indications are being used or if original design bolts are being used that have not been examined ultrasonically in the past three years, visually verify that the bolt tee section is unlatched from the shroud lugs before removing the shroud head.

Implementation considerations

The purpose of the recommendations presented in this SIL is to locate any cracking in shroud head bolts so that the bolts may be replaced on a timely basis. There is no safety concern associated with a failure of these bolts, because a failed bolt will be captured during plant operation. A bolt can fall into the annulus during shroud head lifting only if the tee section remains latched to the shroud lugs. This can occur only during shutdown and, therefore, does not jeopardize plant safety. Not performing the recommended actions only increases the likelihood that a crack will not be detected and the chance that a crack may be discovered when it is not convenient to perform repairs. Failure of one or two shroud head bolts is not sufficient to allow differential pressure to lift the shroud head during plant operation.

In preparing these recommendations, GE has not considered all plant-unique conditions. GE recognizes that implementation at individual plants may vary as a result of many factors. Therefore, an analysis based on plant-unique considerations should be performed to determine both applicability and an appropriate course of action based on cost, benefits and risk.

To receive additional information on this subject or for assistance in implementing a recommendation, please contact your local GE Nuclear Energy service representative.

This SIL pertains only to GE BWRs. The conditions under which GE Nuclear Energy issues SILs are stated in SIL No. 001 Revision 2, the provisions of which are incorporated into this SIL by reference.

Product reference

1—Reactor Assembly

Technical source

Y. K. Jahanian

Issued by

J. G. Moore, Manager
Customer Service Communications
GE Nuclear Energy
175 Curtner Avenue, San Jose, CA 95125

NUCLEAR SERVICES | INFORMATION LETTER

NUCLEAR SYSTEMS & SERVICES OPERATIONS • SAN JOSE, CALIFORNIA

REC'D FEB 1 1986

February 7, 1986
File Tab B

SIL No. 433
Category 1

GENERAL ELECTRIC COMPANY
P. O. BOX 1118
MONROE, MI 48161

SHROUD HEAD BOLT CRACKS

Cracking of shroud head bolts (SHB) has been observed at four BWR/4's and one BWR/3. The cracking occurs in the NiCrFe alloy 600 shaft of the SHB in a creviced region formed by a 304 SS sleeve welded to the bolt shaft. The BWR/6 uses a shroud head stud design different than the BWR/2-5 design and is not susceptible to the failure mode addressed by this Service Information Letter (SIL). Complete failure of a SHB is normally detected during assembly following shroud head removal and replacement. Complete failure has only been observed at one plant. Cracking at other plants was found by ultrasonic examination (UT). The purpose of this Service Information Letter is to discuss the bolt cracks, bolt inspections and results, possible consequences of SHB failure and General Electric recommendations.

DISCUSSION

Design Description

The shroud head bolt is a bi-metallic device (See Figures 1 & 2) designed to allow remote assembly and disassembly that utilizes differential thermal expansion for loading of the shroud-to-shroud head flange joint. The SHB is a non-safety related component that is part of the non-safety related shroud head and separator assembly. The SHB is designed to keep the shroud head in place on the shroud during normal operation and during transient and accident conditions. The SHB's are loosened and unlatched each time the shroud head is removed from the vessel. The removal operation, using tooling specially designed for the purpose, allows the joint to be unloaded and the bolt disengaged from the shroud SHB lugs. When the SHB's are unloaded and disengaged, the shroud head and separator assembly can be removed from the reactor pressure vessel (RPV). Installation of the shroud head and separator assembly is performed using the same special tooling. During installation, the bolts are latched [redacted] and tightened to a torque of approximately [redacted] A broken bolt is not capable of developing [redacted] and it is in this way that a failed bolt is detected. Failure of the shroud head bolt does not result in loose parts. The lower part of the failed bolt cannot drop away from the sleeve and become loose because the alignment pin protrudes through the window in the sleeve and the broken segment is thus captured.

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Cracking Found By UT Examination

An ultrasonic examination (UT) procedure has been developed to examine SHB's. [redacted] In most cases, this examination method is capable of differentiating between severely cracked or separated bolts and those which are partially cracked.

Cracked SHB Examination Results

The fracture surface of one of the failed SHB's has been subjected to extensive metallurgical examination. The cause of failure has been confirmed to be crevice accelerated intergranular stress corrosion cracking (IGSCC). The failure location is shown on Figure 1 and is just above the connecting weld of the collar to the shaft, within the crevice formed between the SHB collar and the SHB shaft. All shroud head bolts used on BWR/2-5's are potentially susceptible to this type of cracking.

Other Considerations

[redacted] is one factor in predicting when cracks will initiate and grow. [redacted] is also a factor. However, [redacted] is the major factor that controls time to crack initiation and crack growth. Additional data is being obtained from on-going UT examination, review of existing data and some additional laboratory work. This on-going work will help determine the frequency of examinations that will assure maintaining the integrity of the shroud-to-shroud head flange joint. At this time, there is no known safety concern. However, if some bolts are found to be cracked in a given reactor, it should be expected that other bolts may also crack. Therefore, consideration should be given to replacement of creviced bolts to allow future operation without inspection of SHB's for cracks.

RECOMMENDATIONS

1. It is recommended that all BWR/2-5's perform a UT examination of all shroud head bolts the next time the reactor vessel head is removed and the shroud head and separator assembly is moved to the equipment storage pool.

2. All bolts that are found to be cracked should be replaced with new bolts that do not have a crevice.

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3. If cracked bolts cannot be replaced due to unavailability of spare bolts, they should remain in place until replacement bolts can be obtained. Some structural strength is retained until the time of complete severance of the bolts. Failed bolts do not result in lost parts.

4. If cracked bolts cannot be replaced or the bolt status is unknown, an evaluation should be performed to confirm that there are no safety concerns and to assess the potential risk of damage to reactor internals and Balance of Plant equipment.

Parts Availability

An improved design bolt [redacted] and other product improvements incorporated) is now available. These parts are carried in stock in limited quantities. If demand has used up existing stock, the factory delivery cycle is 28 weeks from receipt of order.

Please contact your local General Electric service representative for additional information.

Prepared by: R.E. Legate

Issued by: B.H. Eldridge

B.H. Eldridge, Manager
Service Information and Analysis

Product Reference:
B11 - Reactor Assembly

B11-D075 Fermi using Ass/PL 920D232G002, now obsolete.
Replacement is 112D3485G002
Checked 9/12/89

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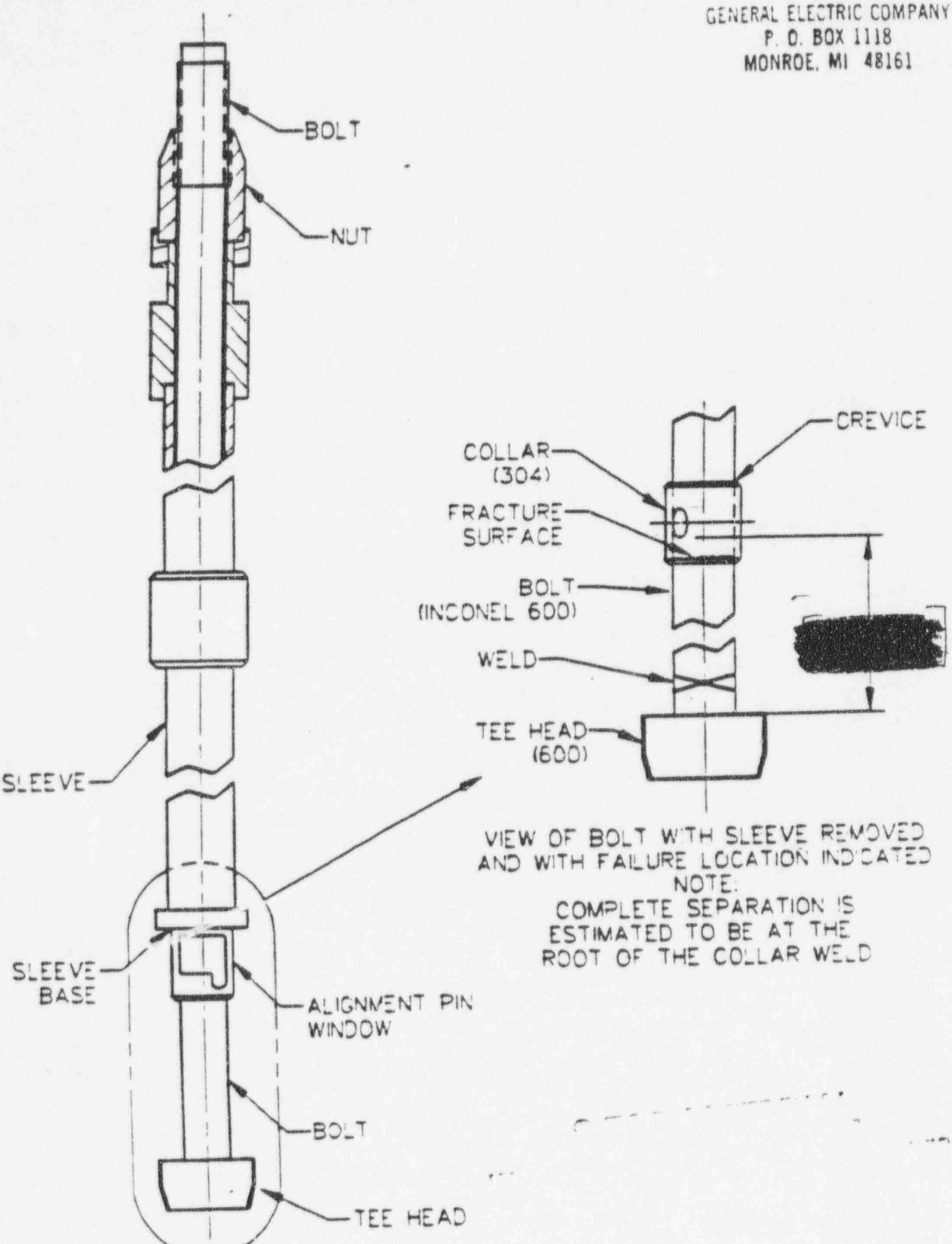

FIG. 1

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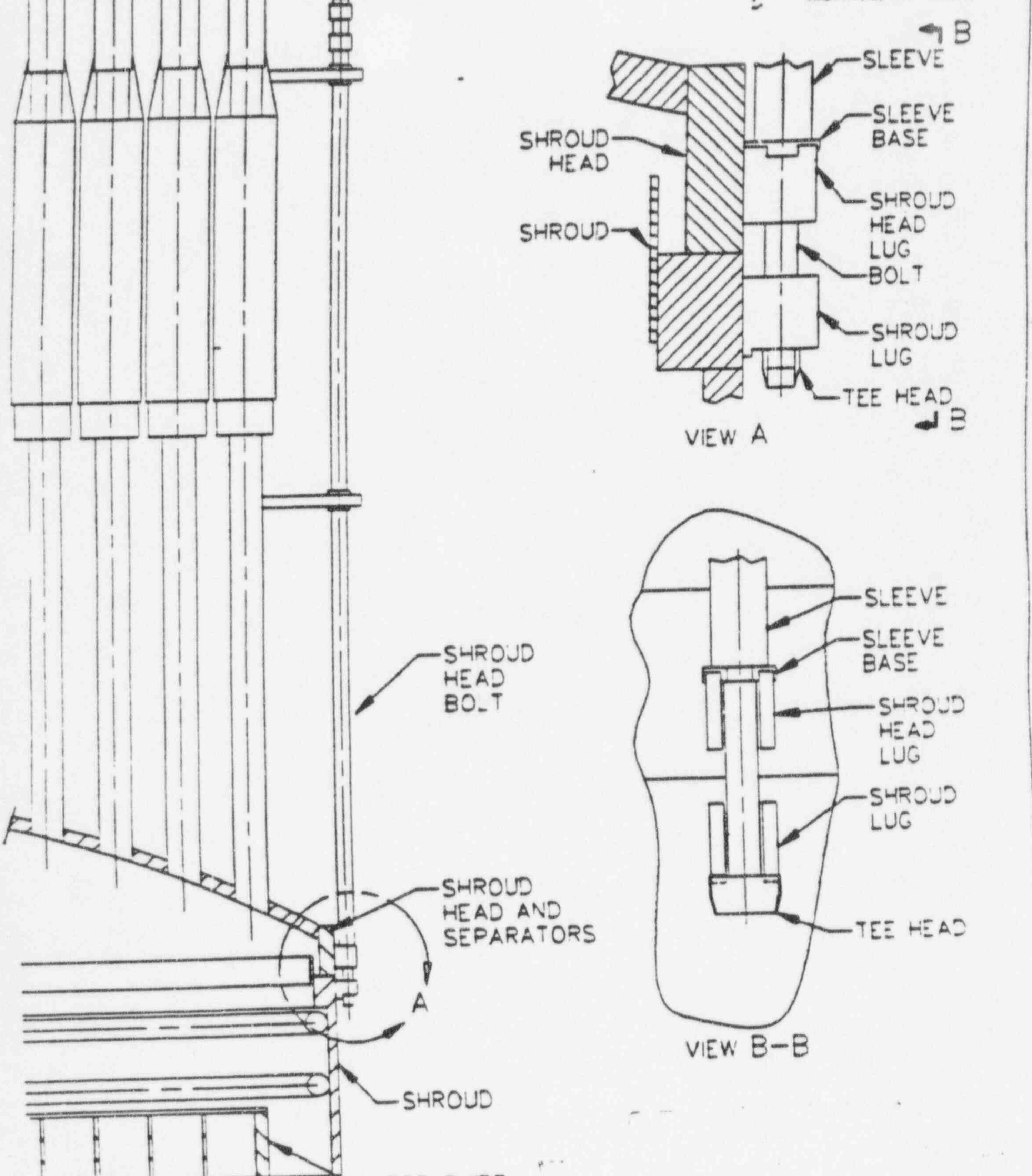


FIG. 2

Appendix 3

RPV Corrosion Evaluation Plan

GE Nuclear Energy
NEDC 32374A
Class 2
June 28, 1994

RPV Corrosion Evaluation Plan

Enrico Fermi 2
Materials and Fuels Evaluation Project

Prepared by: ______________________
R.R. Milian-Rodriguez
Project Manager, Materials and Fuel Evaluation Project

Approved by : ______________________
J.P. Higgins
Projects Manager, BWR Technology

Prepared for
Detroit Edison Company

1.0 SCOPE

The purpose of this plan is to support the Detroit Edison Company (DECo) in evaluating the impact of the water chemistry transient caused by the 25 December 1993 turbine/turbine generator-failure at the Enrico Fermi 2 plant. The chemistry transient ions that contributed to unusually high reactor water conductivity (182 uS/cm) were chloride (11-12 ppm), sulfate (10-11 ppm), and nitrate (1.2-1.4 ppm). Subsequent analyses of calcium (16-20 ppm as $CaCO_3$ or 8 ppm as Ca) and sodium (5-6 ppm) were reported after the transient maxima. High reactor water conductivity has been associated with accelerated corrosion phenomena.

1.1 BACKGROUND

As part of the Enrico Fermi 2 Materials and Fuels Evaluation (Second Interim Report NEDC-32320B) inspections are being performed on reactor internals. The identification of localized corrosion products on the reactor pressure vessel (RPV) clad and unclad surfaces, and a feedwater check valve, at Fermi 2, have raised concerns about the nature of the corrosion mechanism(s). Two visually distinct types of corrosion products have been observed.

The first type of corrosion product observed was a crusty, reddish brown colored "island" of corrosion products with a possible pit at or near the center. These "islands" or corroded areas were detected on the stainless steel cladded surfaces of the RPV in an area just below the main steam lines. The location and distribution of the corroded areas were consistent with the kind of corrosion activity associated with a water/air interface.

The second type of corrosion product observed was a crusty, white to tan colored "corn flake" build-up of corrosion products. The morphology was significantly different from the first type in that the shape was more linear than round. Distribution appeared to follow a "flow" pattern. Corrosion products were observed near the feedwater nozzle and sparger on the uncladded surface of the low alloy steel RPV. These indications were unique in appearance with no visible pit associated with the corrosion products.

It is important to attempt a determination of the mechanism(s) of both of the corrosion types observed on the RPV surfaces by characterization of corrosion products. For example, there are several mechanisms (including microbiologically induced corrosion [MIC]) that could produce subsurface cavities beneath the surface point of entry. The surface indications could be more serious than present visual inspections indicate. Conversely, the build up may be due to a localized breach in the RPV clad surface; the corrosion product composition would be characteristic of alloy steel oxidation with possible concentration of foreign ionic species resulting from the transient.

The follo‹‹ing is the GE recommended plan for the RPV corrosion evaluation.

2.0 INSPECTIONS

2.1 Visual Inspections

Visual inspections (VT) using a remote video camera were performed. Individual observers from both DECo and GE examined the video tape and found corrosion conditions to be uniform. After careful assessment of the video images, it was decided that visual inspection and corrosion sampling would be performed at azimuth 150. In addition, the video mapping was used to acquaint diving personnel with conditions present in the RPV.

2.2 Determination of Biological Activity

On June 2, 1994, DECo obtained a sample of the "corn flake" corrosion at the unclad feedwater nozzle. A[redacted]was utilized to attempt to locate and categorize any biologics present. On June 15, 1994, a representative from BTI and GE expert Beverly Ramsey, were present to evaluate th[redacted]nd to observe a preserved raw sample. Under microscopic examination, biological cell counts of approximately 10 - 100,000 cells/ml were observed. The[redacted] indicated the presence of aerobic, anaerobic and sulfate reducing organisms.

3.0 Corrosion Characterization Plan

Although the likelihood is small, there is concern that the corrosion activity on the RPV surface could affect the cladding integrity and eventually the structural integrity of the RPV wall. Exploratory inspection/surface dressing is highly recommended to assess the extent of the corrosion damage. Based on the results of the diver inspection and sampling, recommendations will be made for DECo's consideration as to the value of non-destructive examination (NDE) on the RPV in areas affected by corrosion activity. If no pitting is present, there will be no need for further NDE. If pitting corrosion is shallow, the need for limited NDE on a representative area will be evaluated. If the pitting is significant (exceeding the thickness of the cladding) or there is cracking, thorough NDE should be considered for a complete engineering assessment and disposition.

3.1 Exploratory Inspections

Exploratory inspections /surface dressing is recommended to further assess the extent of the corrosion damage. Using a diver equipped with hand, as well as air driven tools, perform localized exploratory examination (including superficial surface dressing) in various locations for each observed type of corrosion. As necessary, a small buffing wheel and/or burl tip tool may be used to characterize the deposits. Minimum material removal is to be stressed. Any qualitative observations noted by the diver should be documented. This includes the following:

- Depth of Penetration
- Extent
- Size
- Shape
- Color
- Location
- Density
- Texture/Friability

Detailed descriptions of each location should be documented (such as voice recording and/or written description). This portion of the procedure will have the highest priority. Capture debris released during exploratory inspections in accordance with the requirements described in Section 3.2.

3.1.1 "Corn flake" Corrosion

[redacted]

3.1.2 "Island" Corrosion

[redacted]

[redacted]

3.2 Corrosion Product Sampling

[redacted]

3.3 Water Sampling

[redacted]

[redacted]

4.0 Summary

Although MIC may not be a significant corrosion issue at this time, it is considered prudent to address the possibility of treating all contaminated systems. Nuclear MIC experience has shown that certain microbes can be irradiation and temperature resistant by going dormant and waiting for the right conditions for reproducing. It has been verified that there are viable microbes present in the reactor and reactor systems at Fermi 2.

A decision to implement a biological decontamination treatment will be based on GE and DECo review of such factors as the following:

- MIC bench tests to determine the candidate treatment solutions,
- compatibility of materials and fuel with candidate treatment solution,
- the extent of corrosion damage,
- the logistics of implementation prior to start-up.

There are known chemical combinations that work successfully at destroying microbes without causing damage to the reactor internals and systems. After bench testing and assessment by a team of chemists, microbiologists and materials engineers for materials and fuels compatibility, one or a combination of those chemicals may be recommended.

The results of the corrosion characterization plan described above will be analyzed and evaluated by General Electric Company to 1) assess the current condition of possible corrosion degradation, and 2) assess the potential for future degradation by microbiologically related corrosion activity, and 3) assess the effectiveness of mitigating actions.

Appendix 4

CRD Photos & Tables

Table 2
INSPECTION RESULTS OF FERMI 2 CRDS

Part Name	CRD 30-51 S/N4126 (5/12/94)	CRD 30-23 S/N 4092 (5/13/94)	CRD 26-15 S/N 3395 (5/14/94)	CRD 34-27 S/N 3324 (5/14/94)	CRD 26-39 S/N 4572 (5/16/94)	CRD 10-43 S/N 6177 (5/16/94)
Index Tube	S/N W3113 Wide spread of reddish brown corrosion deposits at notch 00, concentrated at the step. Evidence of chipped nitride at the corner of notch 00 in the vicinity of collet finger contact. Chipped nitride (~3/8") at notches 02, 04, and 06, apparently caused by mechanical impact with the collet fingers. No apparent corrosion products found at these locations. Very light corrosion activity along the entire OD length.	S/N W3182 Only slight reddish brown corrosion deposits observed at notch 00 in the areas of collet finger contact. Only slight evidence of chipping at the step. In general, very light corrosion activity observed along the length. Slight reddish brown stain observed at the top where the 6 collet fingers made contact while in the full-out overtravel position.	S/N W2072 Reddish brown corrosion deposits observed at notch 00 in the areas where the collet fingers resided. This included the corner and the flat area in the notch. One 1/4" region of chipped nitride noted at notch 02 and slight corrosion buildup observed at two locations of notch 46. Several reddish brown corrosion spots (1/16 to 1/8") observed on the ID surface.	S/N W3290 Moderate amount of reddish brown corrosion deposits at notch 00. The corrosion activity concentrated in the areas of nitride case chipping and regions of collet finger contact. Overall, very light corrosion activity along the entire length.	S/N 1877 Reddish brown corrosion deposits observed at notch 00 in the areas where the collet fingers resided. One 1/4" to 3/8" diameter pit noted just below the sloped surface of notch 02. Few and scattered areas of corrosion activity noted along the entire length.	S/N 6682 Reddish brown corrosion deposits observed at notch 00 in the areas where the collet fingers made contact. One chipped corner of approximately 1/4x1/2, 1/8x1/4 and 1/8x1/4 inches was noted at notches 02, 04 and 06, respectively. Very few, scattered and small regions of corrosion activity noted along the entire length.

Table 2 (cont) Inspection Results of Fermi 2 CRDs

Part Name	CRD 30-51 S/N4126 (5/12/94)	CRD 30-23 S/N 4092 (5/13/94)	CRD 26-15 S/N 3395 (5/14/94)	CRD 34-27 S/N 3324 (5/14/94)	CRD 26-39 S/N 4572 (5/16/94)	CRD 10-43 S/N 6177 (5/16/94)
Piston Tube	S/N KW269 Series of corrosion pits (~3/8 to 1/4") at two circumferential locations, approximately 4" and 12" from the piston tube top shoulder (spring washer). The locations appear to be where the drive piston internal seals reside when the CRD is positioned at 00. Small reddish brown corrosion deposits (~1/16" dia) lightly dispersed in an area approximately 3 feet below the piston tube top shoulder.	S/N KW2714 Numerous corrosion pits (~1/8") at two circumferential location, approximately 4" and 12" from the piston tube top shoulder. Appeared to be in the locations of the drive piston internal seals. A few reddish brown corrosion spots (~1/16" to 1/8") in the area 2 to 3 feet below the piston tube top shoulder. A few (3 to 4) were about 3/8" in diameter. Slight corrosion activity was observed at the lower end at the circumferential boundary of the nitride interface.	S/N W2521K Slight corrosion pits (1/16" to 1/8") noted in the circumferential area, approximately 3" to 4" below the piston tube top shoulder. Approximately 12 reddish brown corrosion spots, 1/8" to 3/8" diameter, were noted in the area about 2 1/2 feet below piston tube top shoulder. Few smaller corrosion spots were also noted in this area. The lower circumferential boundary of the nitride interface boundary was relatively free of corrosion activity. Approximately 3 1/2" above the piston head (above the nitride interface boundary), two relatively large corrosion pits were noted. The pits were about 1/4x1/2 and 3/16x1/4 and separated by about 1/4". A series of smaller corrosion spots, less than 1/16", formed a complete circumference at this location. This appears to be the area where the drive piston internal seals resides either at the fully withdrawn or overtravel position.	S/N W2485N Uniformly distributed corrosion in a circumferential area about 4" below the piston tube top shoulder. One 1/4" diameter and a few 1/8" corrosion spots were noted in an area 18" below the stop piston tube top shoulder. Two 1/4" corrosion spots were located about 3 feet below the top shoulder. No significant corrosion activity were observed at the lower end.	S/N W2287K Numerous corrosion pits were noted in the circumferential area, 4" below the piston tube top shoulder. There were about two 1/4" dia and seven 1/8" dia pits. In an area about 3 feet below the top shoulder, approximately twenty 1/16" to 1/8" dia corrosion spots were observed. All other areas were essentially free of corrosion activity.	S/N 4443J Numerous corrosion pits were noted in the circumferential area, 4" below the piston tube top shoulder. There were about one 1/2" dia and three 1/8" to 3/8" dia pits. Pittings of 1/8" dia were also noted in an area 8" and 18" below the piston tube shoulder. At the midspan, there were about four 1/4" dia pits. The lower end was essentially free of corrosion activity.

Table 2 (cont) Inspection Results of Fermi 2 CRDs

Part Name	CRD 30-51 S/N4126 (5/12/94)	CRD 30-23 S/N 4092 (5/13/94)	CRD 26-15 S/N 3395 (5/14/94)	CRD 34-27 S/N 3324 (5/14/94)	CRD 26-39 S/N 4572 (5/16/94)	CRD 10-43 S/N 6177 (5/16/94)
Seal and Bushings	All four sets of stop piston seals had one or two broken segments. No broken drive piston bridge/radial seals observed.	1 tab of the 4 sets of stop piston seals was broken. All other seals were intact.	All four sets of stop piston seals had one or two broken segments. No broken drive piston bridge/radial seals observed.	All four sets of stop piston seals had broken segments. Drive piston external and internal seals were all intact.	Several sets of stop piston seals had broken segments. Drive piston external and internal seals were all intact.	Several sets of stop piston seals had broken segments. Drive piston external and internal seals were all intact.
Seal Springs	There were no broken stop piston and outer drive piston C-springs, and garter springs. No cracks were observed.	Similar results as CRD 30-51.	Similar results as CRD 30-51.	Similar results as CRD 30-51.	Similar results as CRD 30-51.	Similar results as CRD 30-51.
Cylinder, Tube and Flange	No evidence of corrosion activity observed on either the external or internal surfaces, including the lower chrome plated surfaces. Liquid penetrant exam performed on 5/13/94 revealed a 9/16" linear indication in the area between the upper tube weld and shoulder.	No evidence of corrosion activity observed on either the external or internal surfaces, including the lower chrome plated surfaces. No linear indications reported in the collet retainer tube.	Similar results as CRD 30-23.	Similar results as CRD 30-23. Four ~5/8" diameter white deposits were noted on the upper OD end of the outer tube.	Similar results as CRD 30-23. A streak of white deposits were noted on the upper OD end of the outer tube.	Similar results as CRD 30-23. A dark brown, tightly adhering, discoloration was noted on the weld material at the outer tube to flange weld. It was reported (T. Shannon, W) that the discoloration was removed by scrubbing with Scotch Brite and denatured alcohol.
Collet Assembly	No significant corrosion activity observed on the collet piston or collet fingers. The spring tension of all the collet fingers was maintained after slight radial (outward) bend test	Similar results as CRD 30-51. No apparent pitting observed on the contact surfaces of the collet fingers. White deposits found on the collet fingers.	Similar results as CRD 30-51. No apparent pitting observed on the contact surfaces of the collet fingers. White deposits on a collet finger was remove by brisk rubbing.	Similar results as CRD 30-51.	Similar results as CRD 30-51. No apparent pitting observed on the contact surfaces of the collet fingers. White deposits found on the collet fingers.	Similar results as CRD 30-51.

Table 2 (cont) Inspection Results of Fermi 2 CRDs

Part Name	CRD 30-51 S/N4126 (5/12/94)	CRD 30-23 S/N 4092 (5/13/94)	CRD 26-15 S/N 3395 (5/14/94)	CRD 34-27 S/N 3324 (5/14/94)	CRD 26-39 S/N 4572 (5/16/94)	CRD 10-43 S/N 6177 (5/16/94)
Guide Cap	No apparent significant chipping or corrosion activity observed.	Similar results as CRD 30-51.	Similar results as CRD 30-51.	Similar results as CRD 30-51. In addition, a series of small corrosion pits was noted around the circumference of the top end.	Similar results as CRD 30-51.	Similar results as CRD 30-51. A series of small corrosion pits was noted around the circumference of the top end. One 1/8x1/16" chip nitride corner.
Spud	No evidence of corrosion activity noted. One finger was slightly deformed outward (finger gap ~11/32 vs nominal of 1/4 ").	No evidence of corrosion activity noted.	Similar results as CRD 30-23.	Similar results as CRD 30-23.	Similar results as CRD 30-23.	Similar results as CRD 30-23.

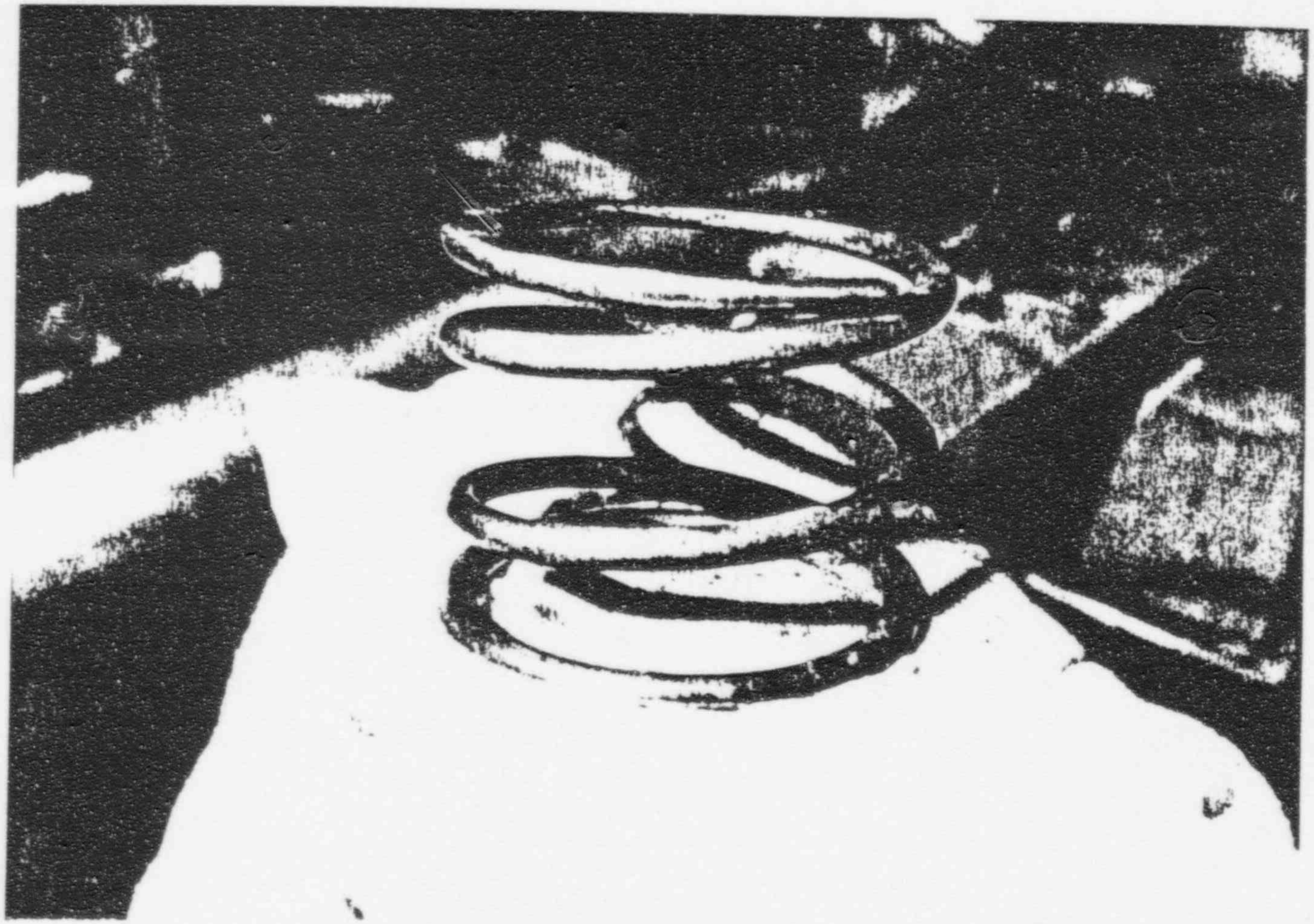


FIGURE: CRD 34-07 (S/N 4230)
Collet Spring

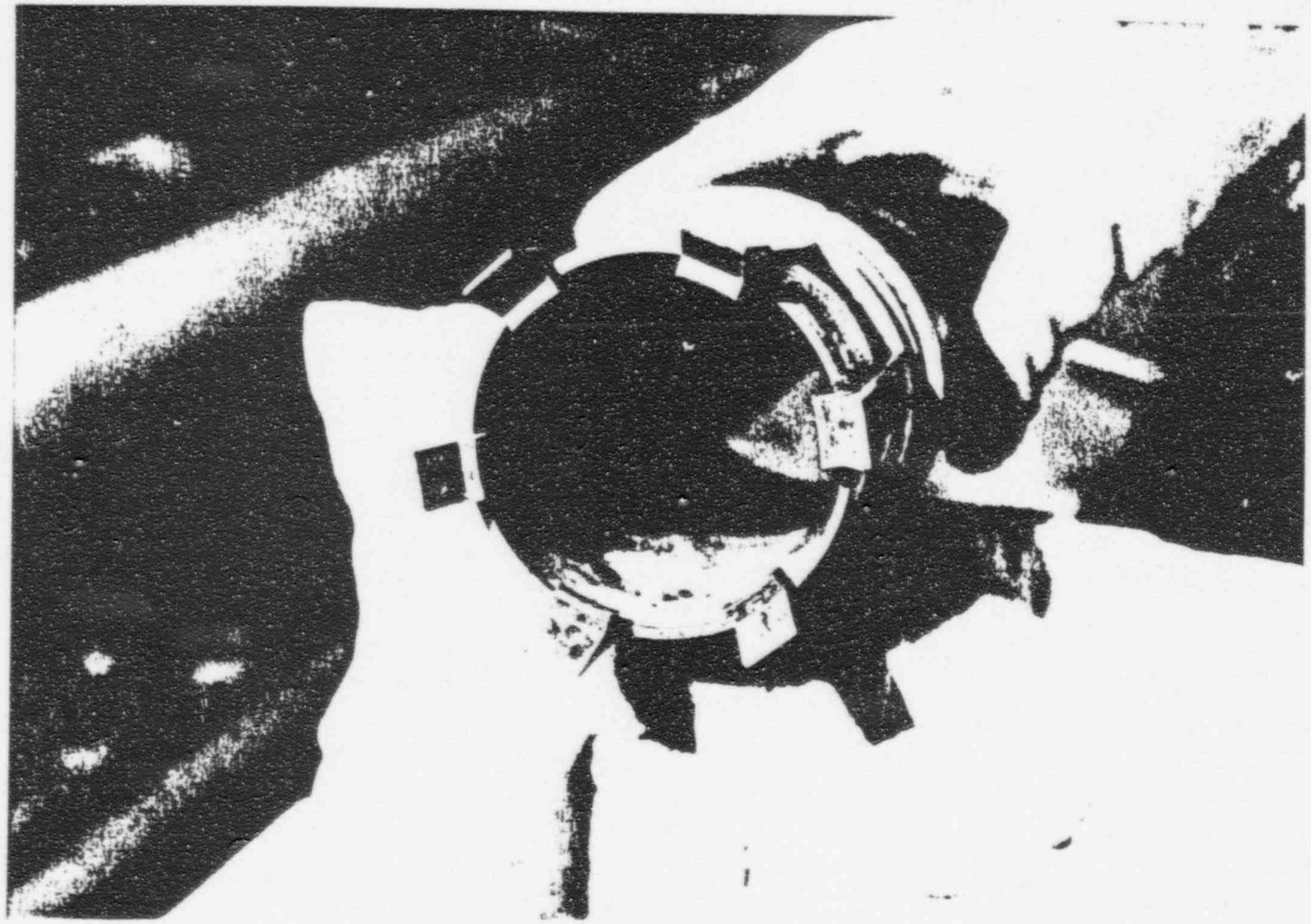


FIGURE: CRD 34-07 (S/N 4230)
Collet and Piston

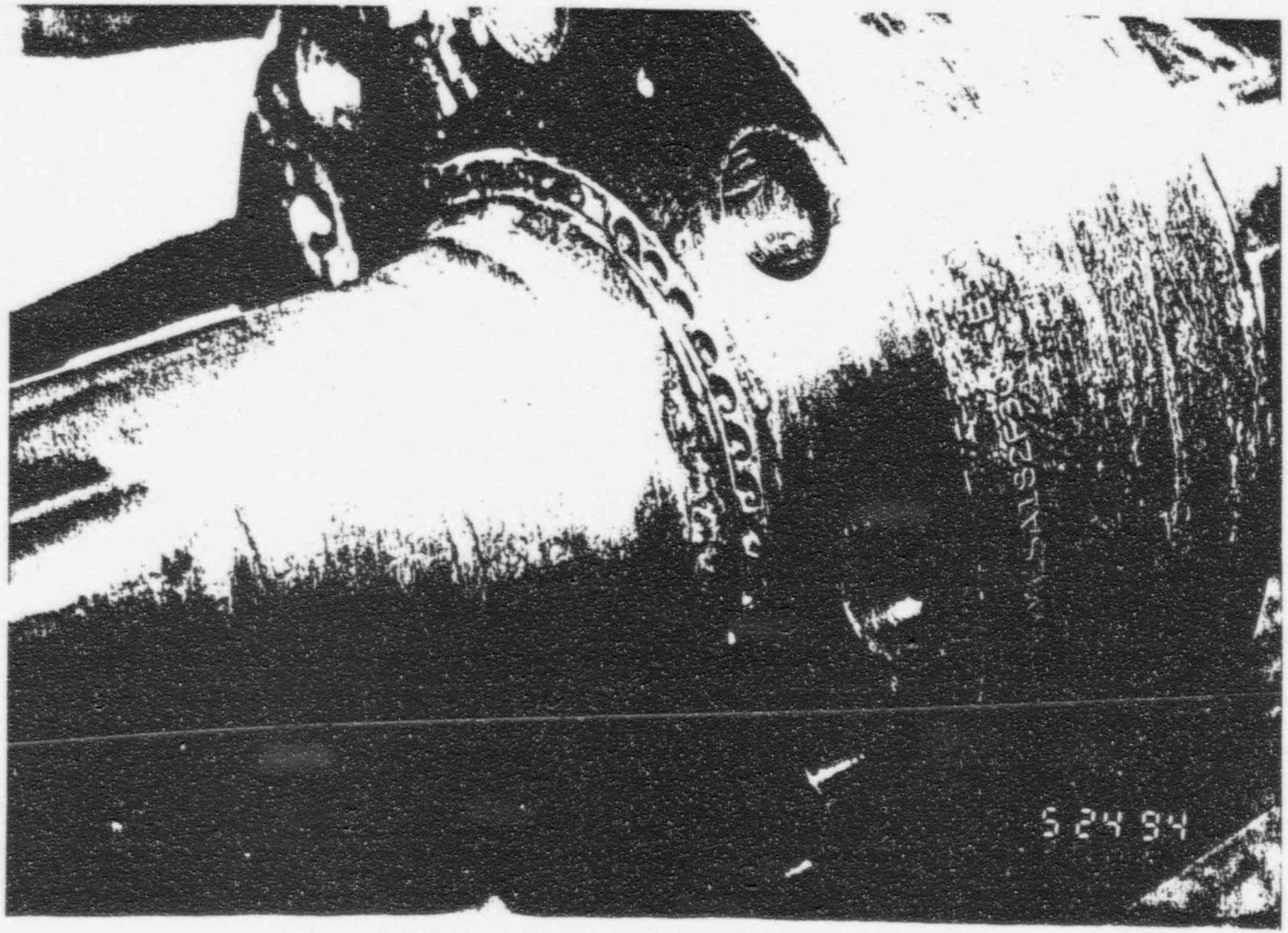


FIGURE: CRD 34-07 (S/N 4230)
Cylinder Tube and Flange

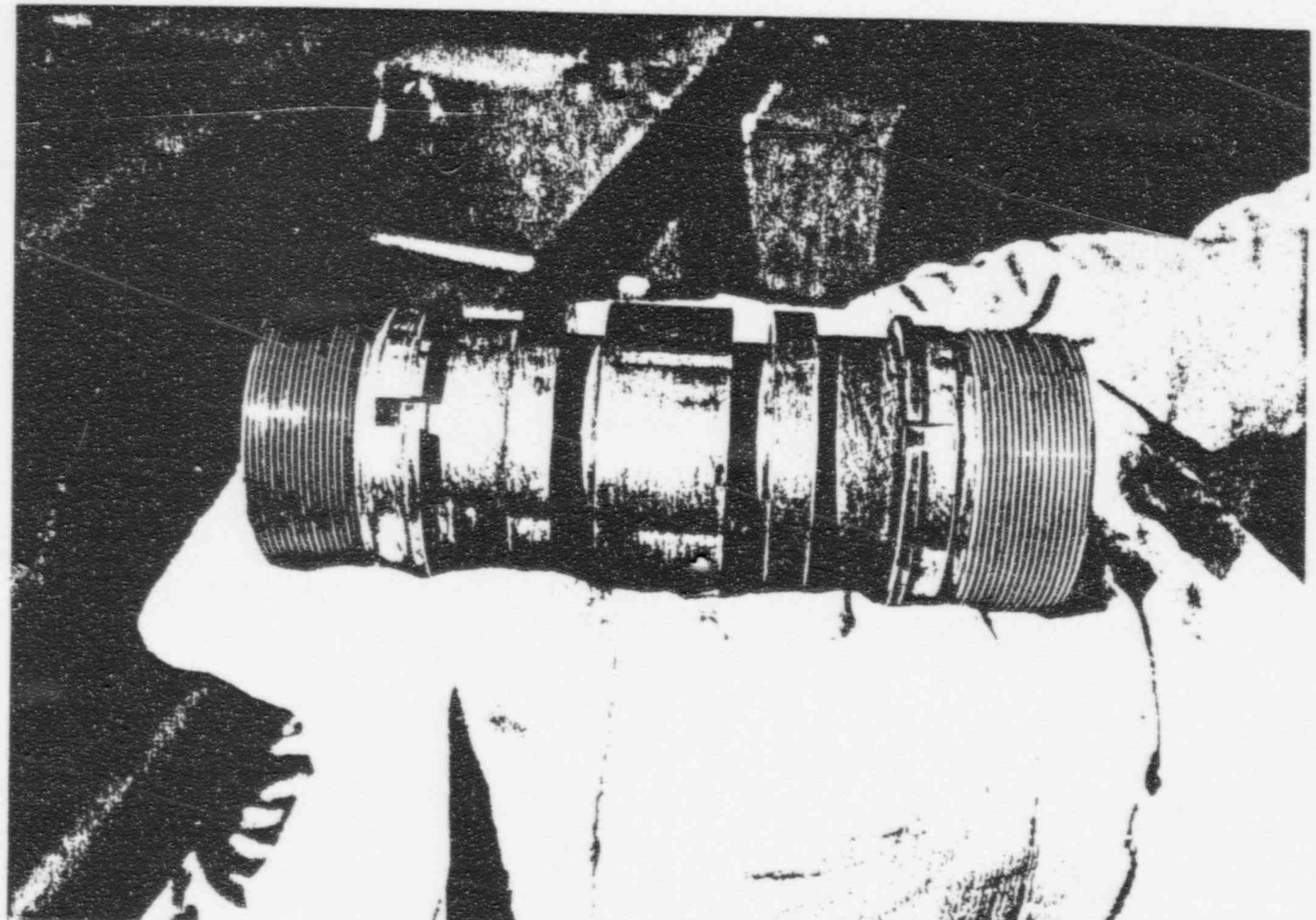


FIGURE: CRD 34-07 (S/N 4230)
Drive Piston

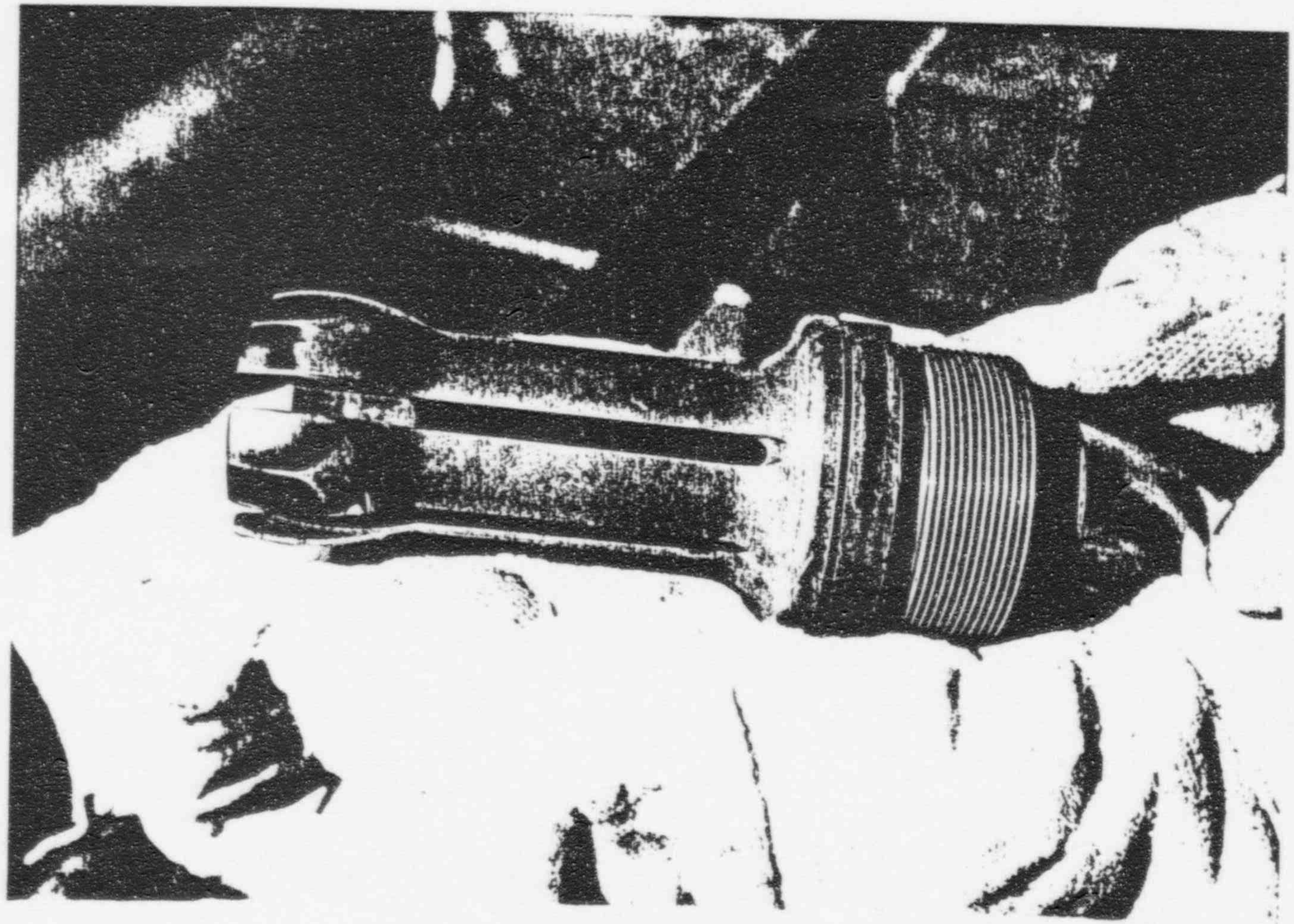


FIGURE: CRD 34-07 (S/N 4230)
Spud

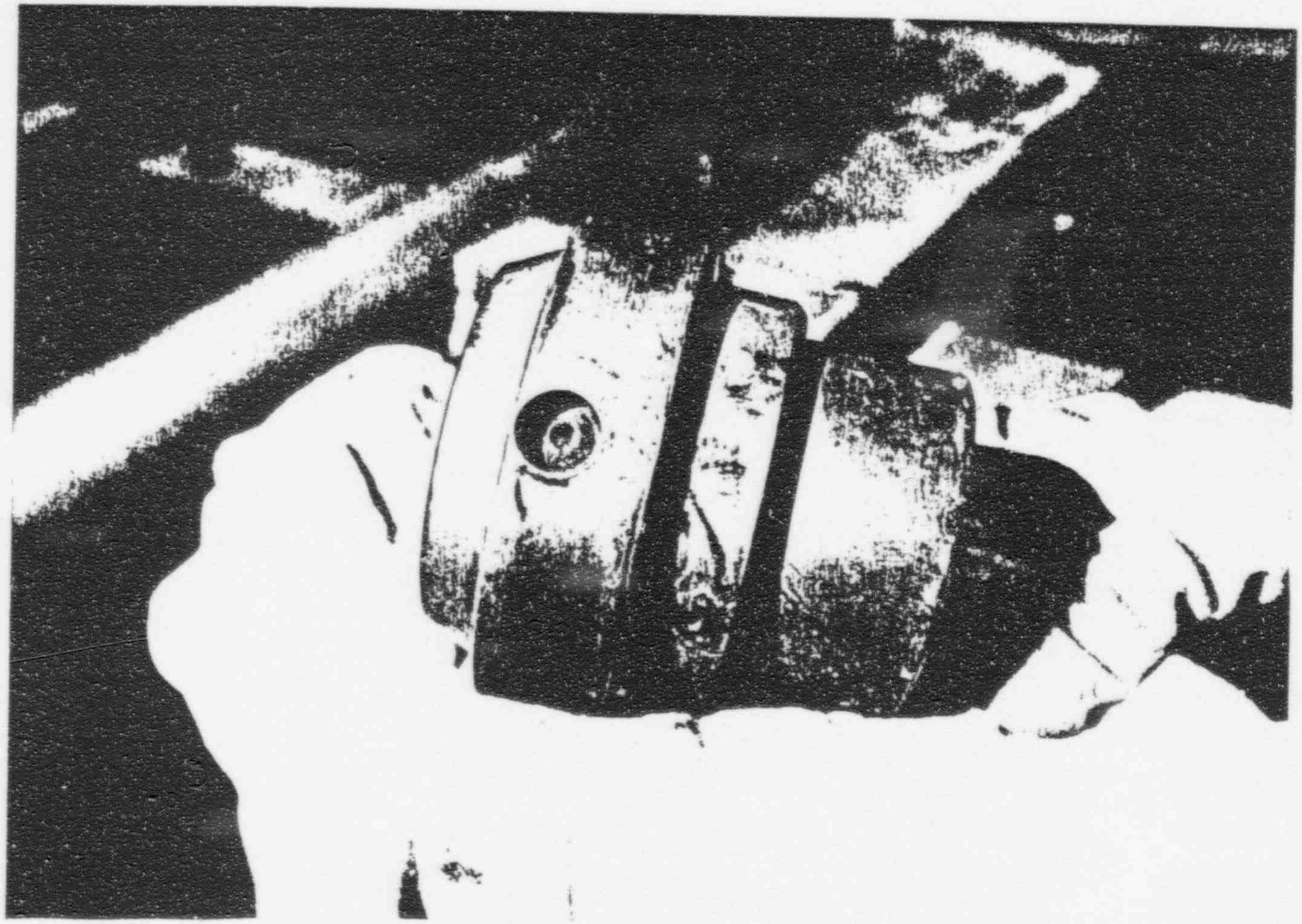


FIGURE: CRD 34-07 (S/N 4230)
Guide Cap

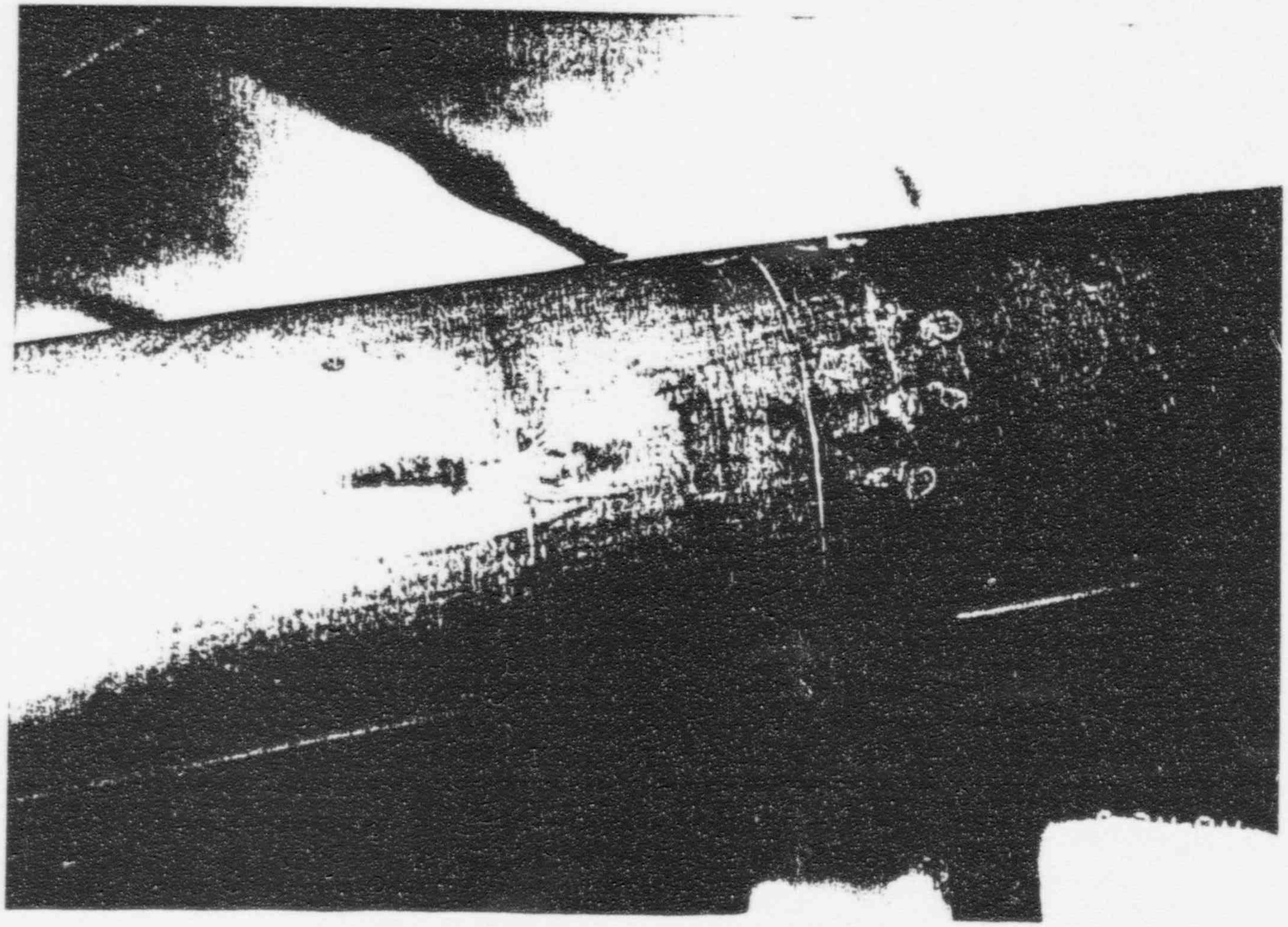


FIGURE: CRD 34-07 (S/N 4230)
Piston Tube

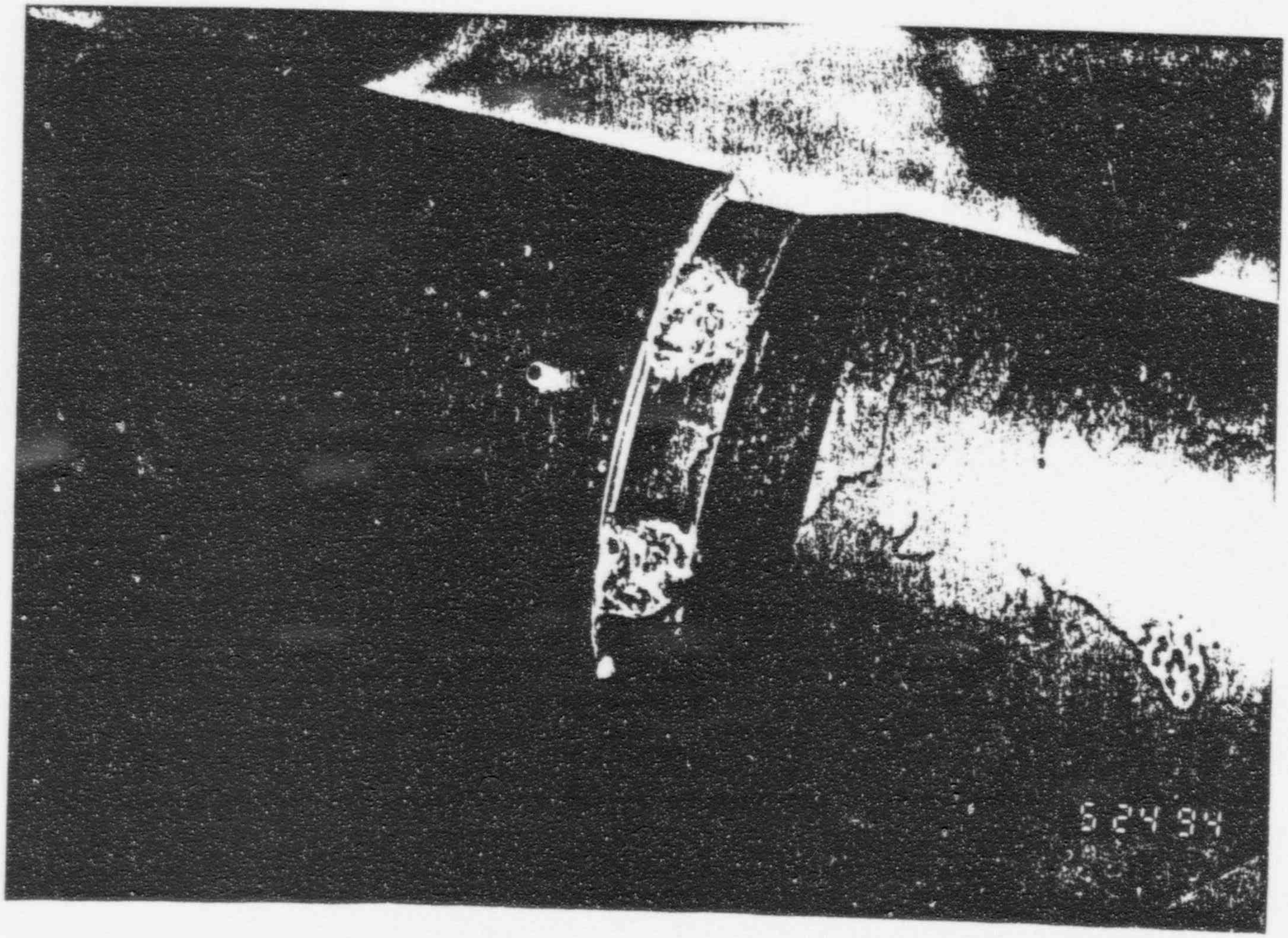


FIGURE: CRD 34-07 (S/N 4230)
Index Tube

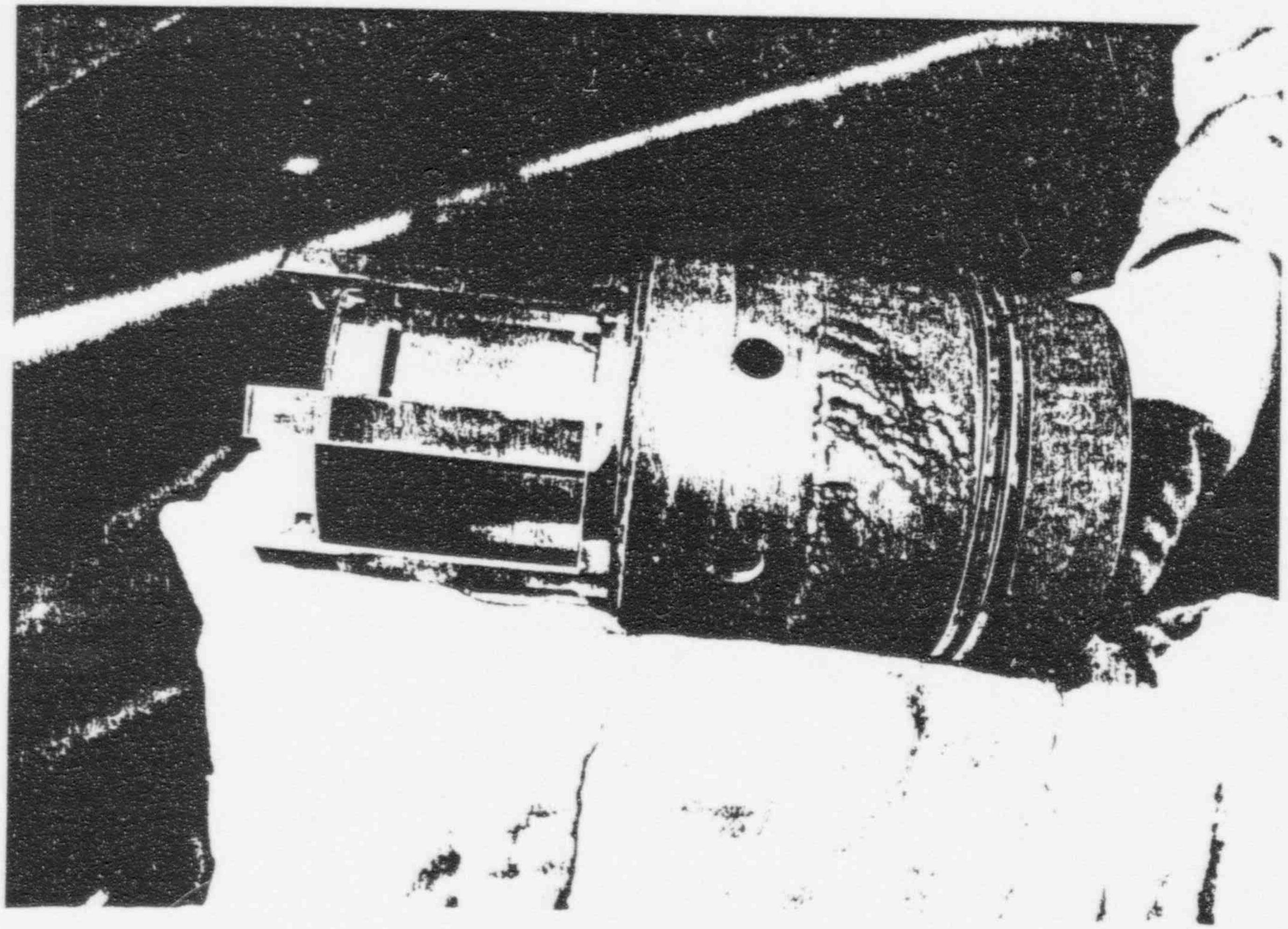


FIGURE: CRD 10-31 (S/N 4475)
Collet and Piston

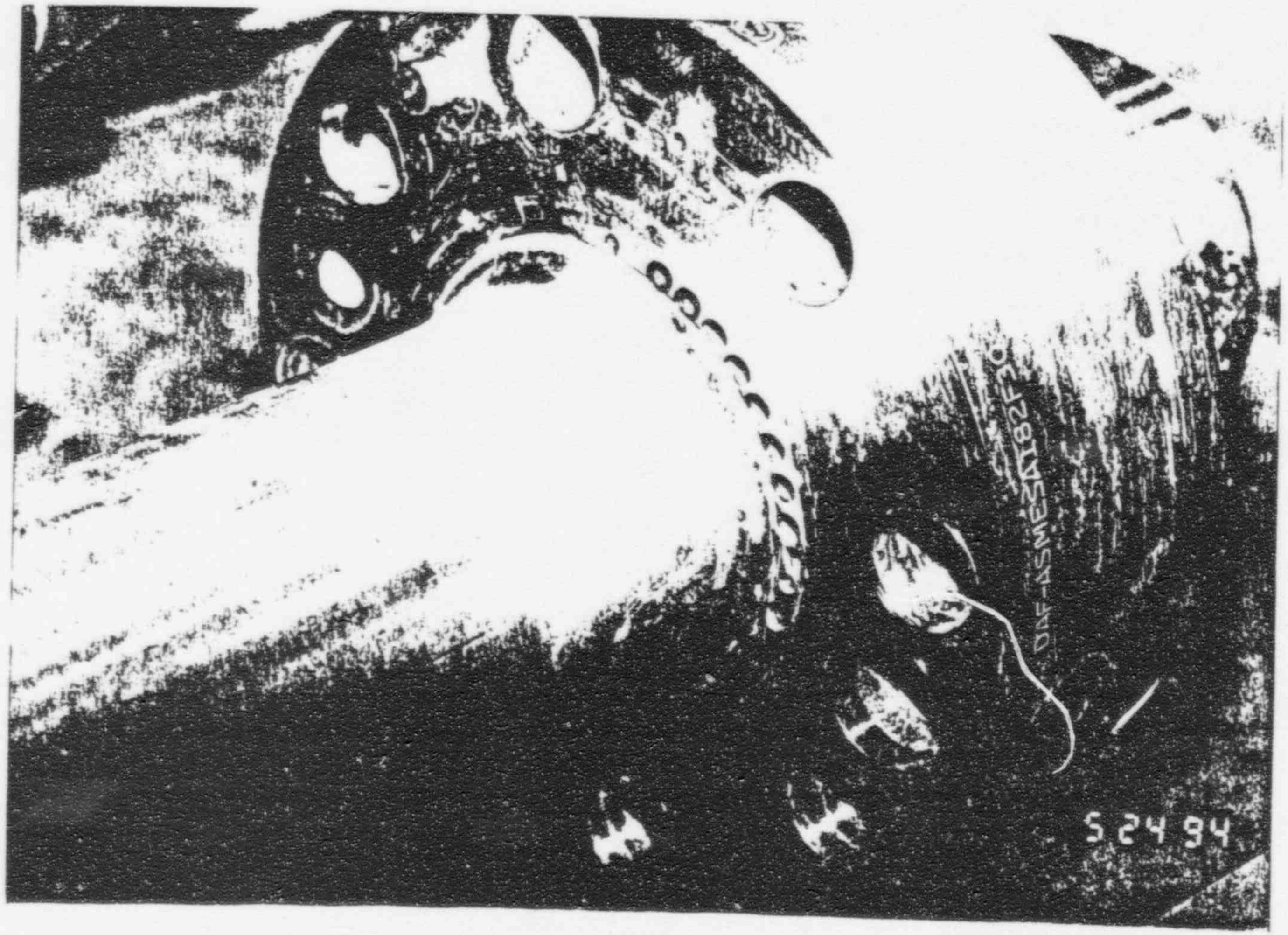


FIGURE: CRD 10-31 (S/N 4475)
Cylinder Tube and Flange

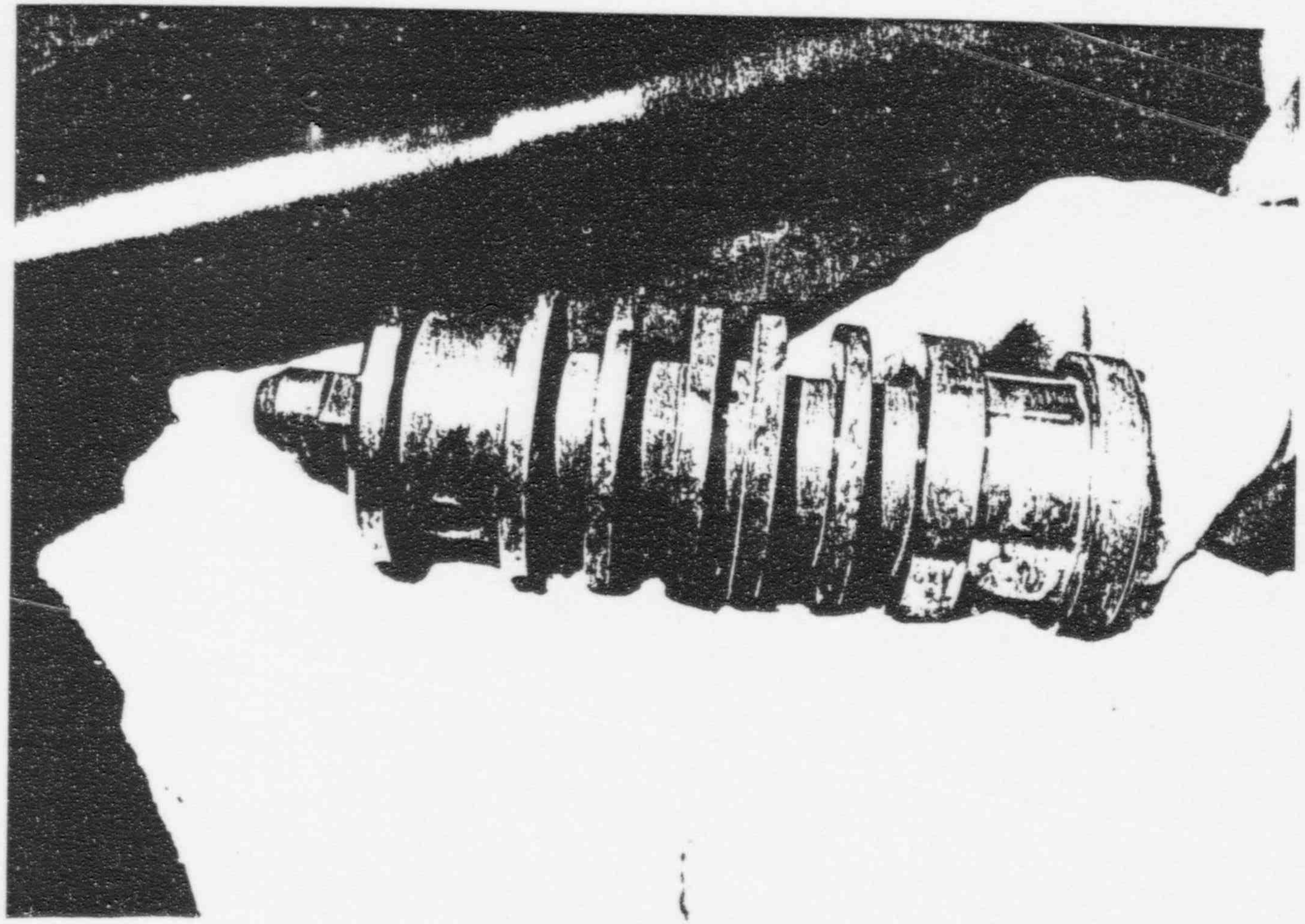


FIGURE: CRD 10-31 (S/N 4475)
Stop Piston

FIGURE: CRD 10-31 (S/N 4475)
Spud

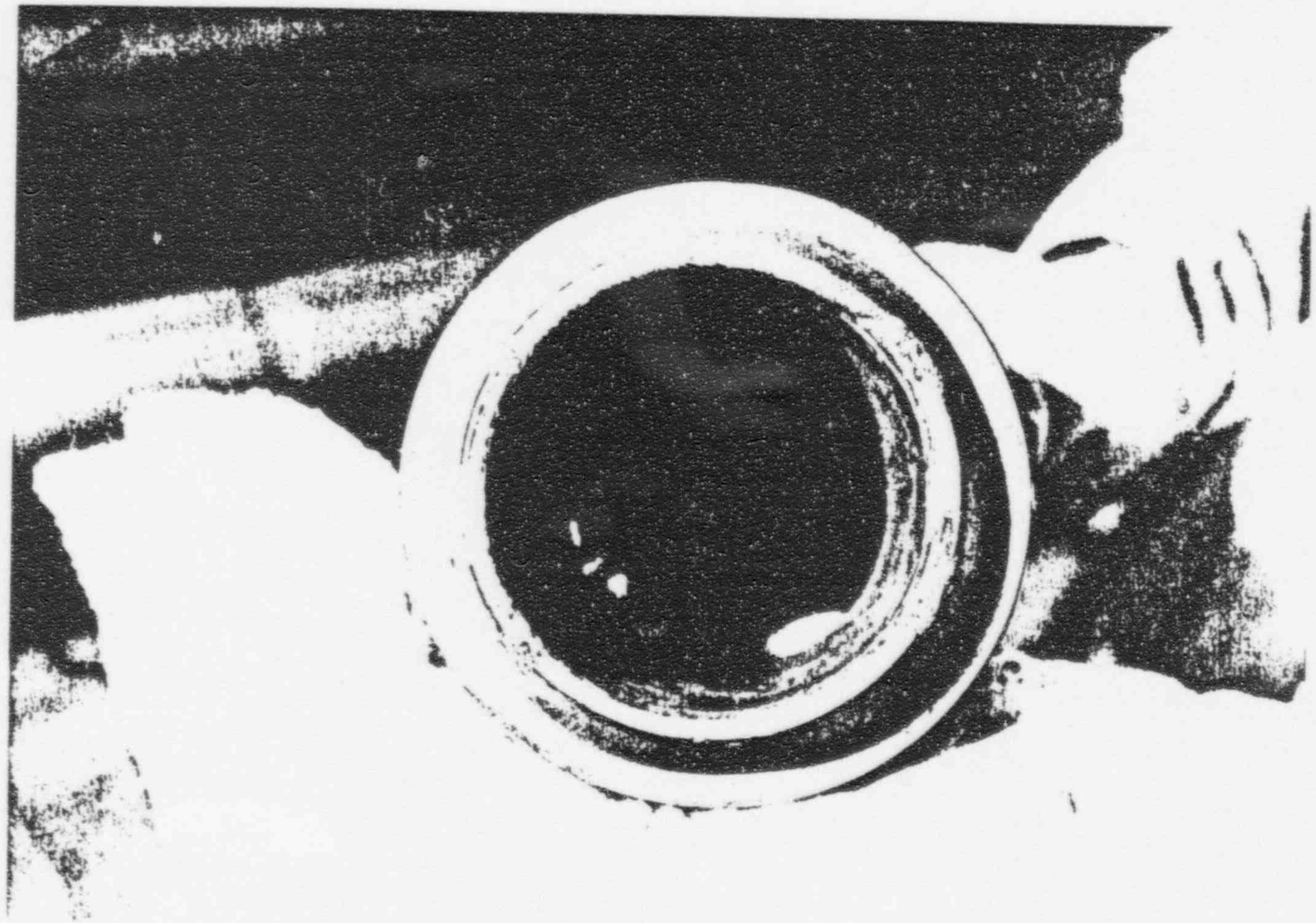


FIGURE: CRD 10-31 (S/N 4475)
Guide Cap

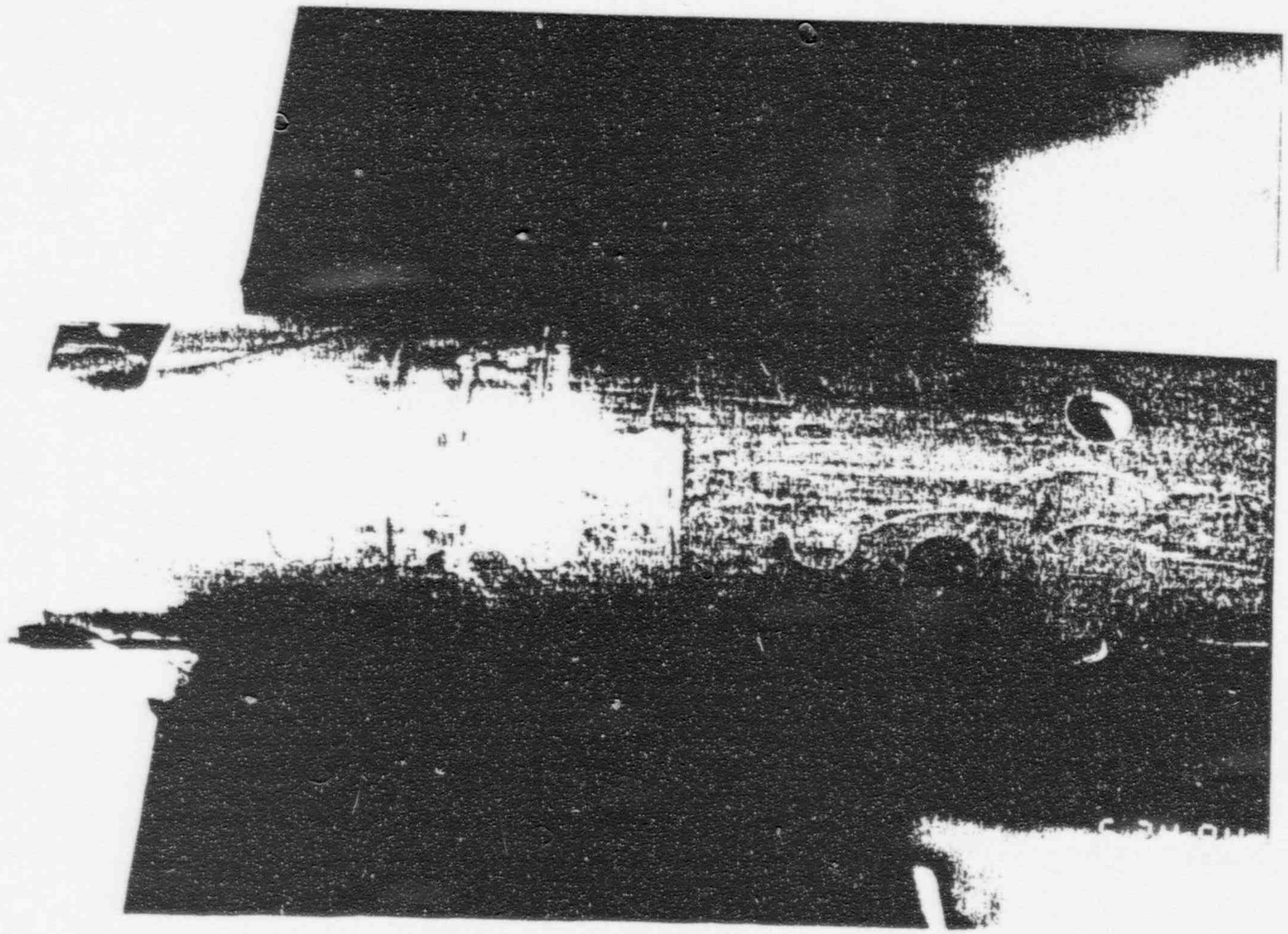


FIGURE: CRD 10-31 (S/N 4475)
Piston Tube

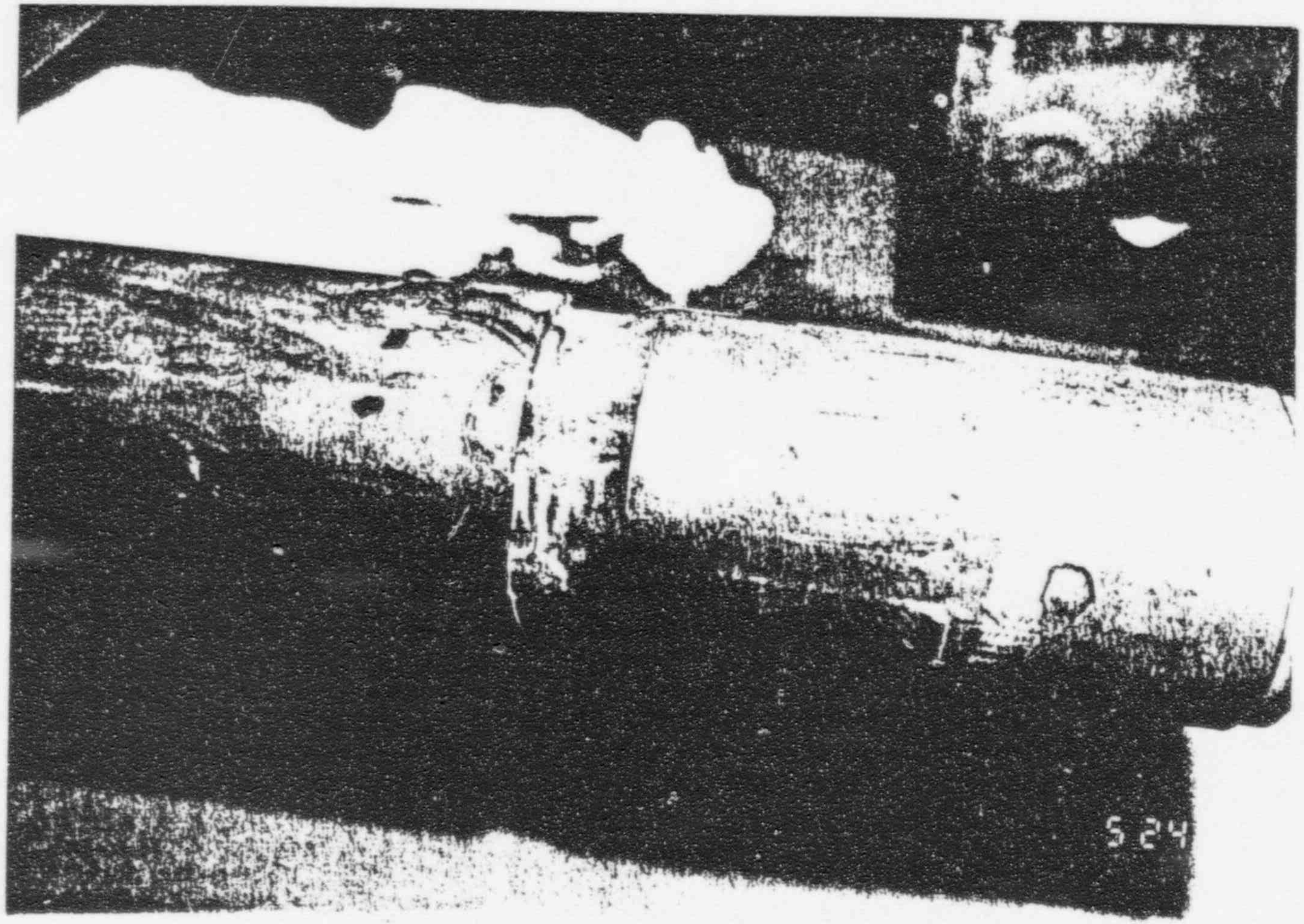


FIGURE: CRD 10-31 (S/N 4475)
Index Tube

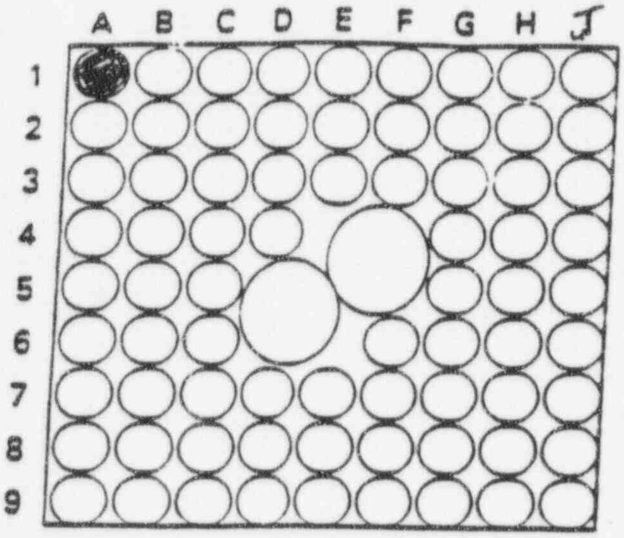
Appendix 5

Fuel Scrape Report

[ ]

ATTACHMENT 1
Logsheets

9 x 9



PLANT FERMI 2

DATE 5/24/94

BUNDLE I.D. YJ2-809

7th SPACER ELEV. [IN.] 53"

SAMPLE NUMBERS C TO 14

COMMENTS:

ALL DIAMOND 2 SCRAPES

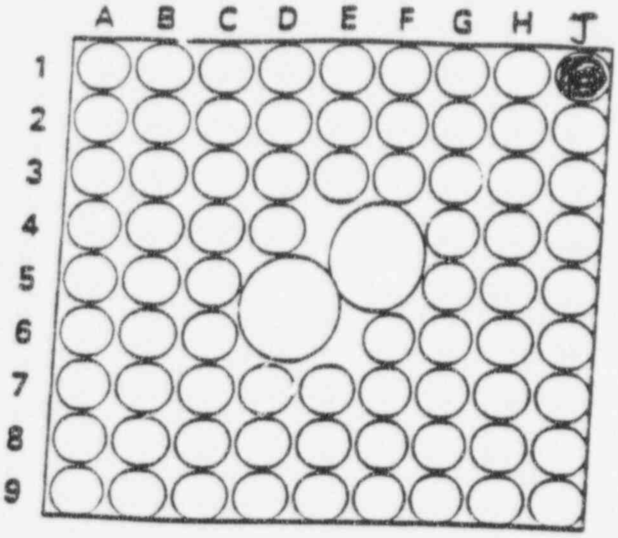
[signature]

A.E. CONTI [illegible]

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
C	FUEL POOL	—	—	5	BKG POOL H2O
CC	" "	—	—	2	" " "
1	A1S7B	63	130	10	
2	A1S7D	63	130	7	
3	A1S5B	103	90	11	
4	A1S5D	103	90	6	
5	A1S4B	123	70	2	
6	A1S4D	123	70	10	
7	A1S3B	147	46	8	SPECIAL SAMPLE
8	A1S3D	147	46	10	" "
9	A1S3B	143	50	7	" "
10	A1S3D	143	50	10	
11	A1S2B	163	30	3	
12	A1S2D	163	30	18	
13	A1S1B	183	10	8	
14	A1S1D	183	10	7	

ATTACHMENT 1
Logsheets

9 x 9



PLANT FERMI 2

DATE 5-24-94

BUNDLE I.D. YJ2809

7th SPACER ELEV. [IN.] 53"

SAMPLE NUMBERS 15 TO 24

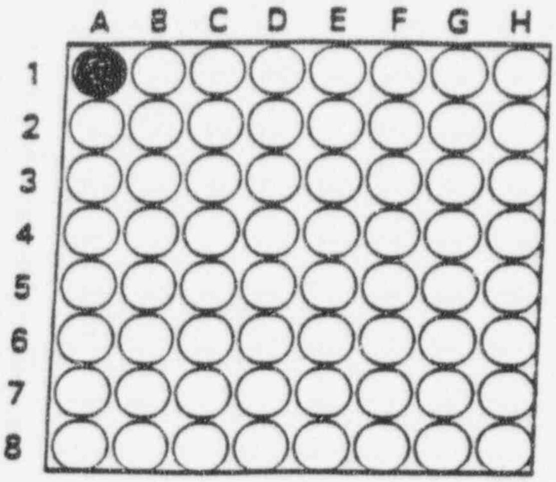
COMMENTS:

H. L. [signature]
AE Cont. Cllarch

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
15	JIS1B	183	10	10	
16	JIS1D	1@3	10	10	
17	JIS2B	163	30	5	
18	JIS2D	163	30	15	
19	JIS3B	143	50	12	
20	JIS3D	143	50	16	
21	JIS5B	139	54	12	
22	JIS3D	139	54	10	
23	JIS4B	1~~@~~23	70	20	
24	JIS4D	123	70	15	
25	JIS5B	103	90	16	
26	JIS5D	103	90	15	
27	JIS7B	63	130	15	
28	JIS7D	63	130	15	

ATTACHMENT 1
Logsheets

8 x 8



PLANT FERMI 2

DATE 5-25-94

BUNDLE I.D. LJK 961

7th SPACER ELEV. [IN.] 53"

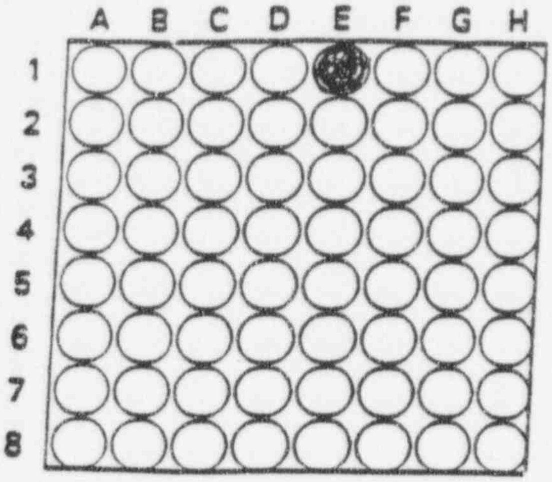
SAMPLE NUMBERS 29 TO 42

COMMENTS: ALL DIAMONDS
SCRAPE TWO TIMES
[signature]
A.E. CONTI [signature]

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
29	A1S7B	63	130	25	
30	A1S7D	63	130	35	
31	A1S5B	103	90	30	
32	A1S5D	103	90	45	
33	A1S4B	123	70	60	
34	A1S4D	123	70	60	
35	A1S3B	~~[illegible]~~ 139	54	110	*
36	A1S3D	~~[illegible]~~ 139	54	70	*
37	A1S3B	~~[illegible]~~ 143	50	125	
38	A1S3D	~~[illegible]~~ 143	50	75	
39	A1S2B	~~[illegible]~~ 163	30	300	
40	A1S2D	~~[illegible]~~ 163	30	110	
41	A1S1B	183	10	275	
42	A1S1D	183	10	80	

ATTACHMENT 1
Logsheets

8 x 8



PLANT FERMI 2

DATE 5/25/94

BUNDLE I.D. LJK 961

7th SPACER ELEV. [IN.] 53"

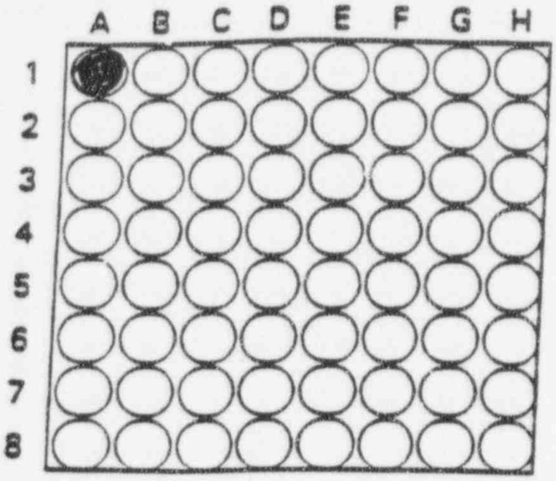
SAMPLE NUMBERS 43 TO 56

COMMENTS:

A.E. CONTI A.E. Conti

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
43	E1S1 B	103	10	300	
44	E1S1 D	103	10	120	
45	E1S2B	163	30	350	
46	E1S2D	163	30	140	
47	E1S3B	143	50	300	
48	E1S3D	143	50	90	
49	E1S3B	139	54	200	
50	E1S3D	139	54	70	
51	E1S4B	123	70	120	
52	E1S4D	123	70	35	
53	E1S5B	163	90	45	
54	E1S5D	103	90	35	
55	E1S7B	63	130	22	
56	E1S7D	63	130	30	

ATTACHMENT 1
8 x 8 Logsheets



PLANT FERMI 2

DATE 5/26/94

BUNDLE I.D. LYS486

7th SPACER ELEV. [IN.] 53"

SAMPLE NUMBERS 57 TO 70

COMMENTS:

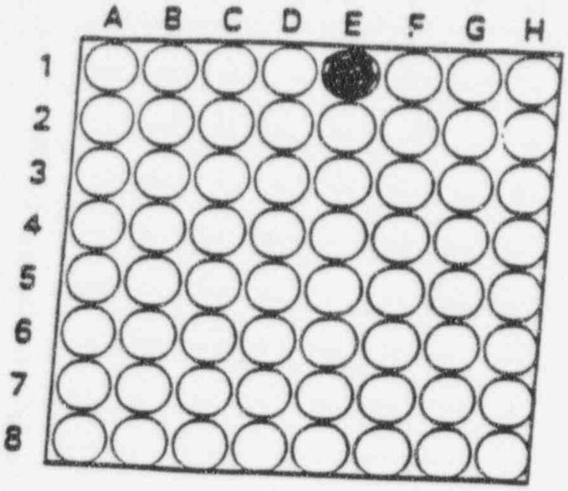
[illegible signature]

A.E. Cont. [illegible signature]

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
57	A157B	137	130	25	
58	A157D	137	130	20	
59	A155B	103	90	50	
60	A155D	103	90	70	
61	A154B	123	70	90	
62	A154D	123	70	100	
63	A153B	139	54	175	
64	A153B	139	54	70	
65	A153B	143	50	210	
66	A153D	143	50	120	
67	A152B	163	30	450	
68	A152D	163	30	95	
69	A151B	183	10	500	
70	A151D	183	10	100	

ATTACHMENT 1
Logsheets

8 x 8



PLANT FERMI 2

DATE 5/26/94

BUNDLE I.D. LYS486

7th SPACER ELEV. [IN.] 53"

SAMPLE NUMBERS 71 TO 84

COMMENTS:

A.E. CONTI

SAMPLE NUMBER	SAMPLE IDENTIFICATION	TAPE READINGS	DISTANCE TO LEP [IN.]	SAMP. DOSE mR/hr	COMMENTS
71	E1S1B	183	10	500	
72	E1S1D	183	10	100	
73	E1S2B	163	30	450	
74	E1S2D	163	30	90	
75	E1S3B	143	50	200	
76	E1S3D	143	50	90	
77	E1S3B	139	54	100	
78	E1S3D	139	54	75	
79	E1S4B	123	70	50	
80	E1S4D	123	70	65	
81	E1S5B	103	90	30	
82	E1S5D	103	90	60	
83	E1S7B	63	130	20	
84	E1S7D	63	130	15	

Appendix 6

Engineering Assessment

6-2.2 Effects of the Circulation Water Intrusion on Materials Performance

6-2.2.1 Stress Corrosion Cracking of Enrico Fermi 2 Structural Materials

6-2.2.1.1 Independent Effects of Sulfate and Chloride in Non-Acid Environments

The circulation water intrusion incident at Enrico Fermi 2 was characterized by the injection of high conductivity water containing some well-documented intergranular stress corrosion cracking (IGSCC) enhancing anions, including sulfate (10 ppm max.) and chloride (12 ppm max.). The relative independent IGSCC effect of these anions on lightly furnace sensitized stainless steel at 288°C [550°F] is presented in Figures 6-2.2-1 and 6-2.2-2 as evaluated by the [redacted] (Refs. 3 through 5). Figure 6-2.2-1 presents the relative effects of various salts on the stainless steel ductility values [redacted] Figure 6-2.2-2 presents relative [redacted] IGSCC crack growth rates. Albeit the [redacted] test is not considered ideal for determining IGSCC crack growth rates, the effect of sulfate on crack growth rate at a constant anion concentration of 0.1 ppm is clear. [redacted]

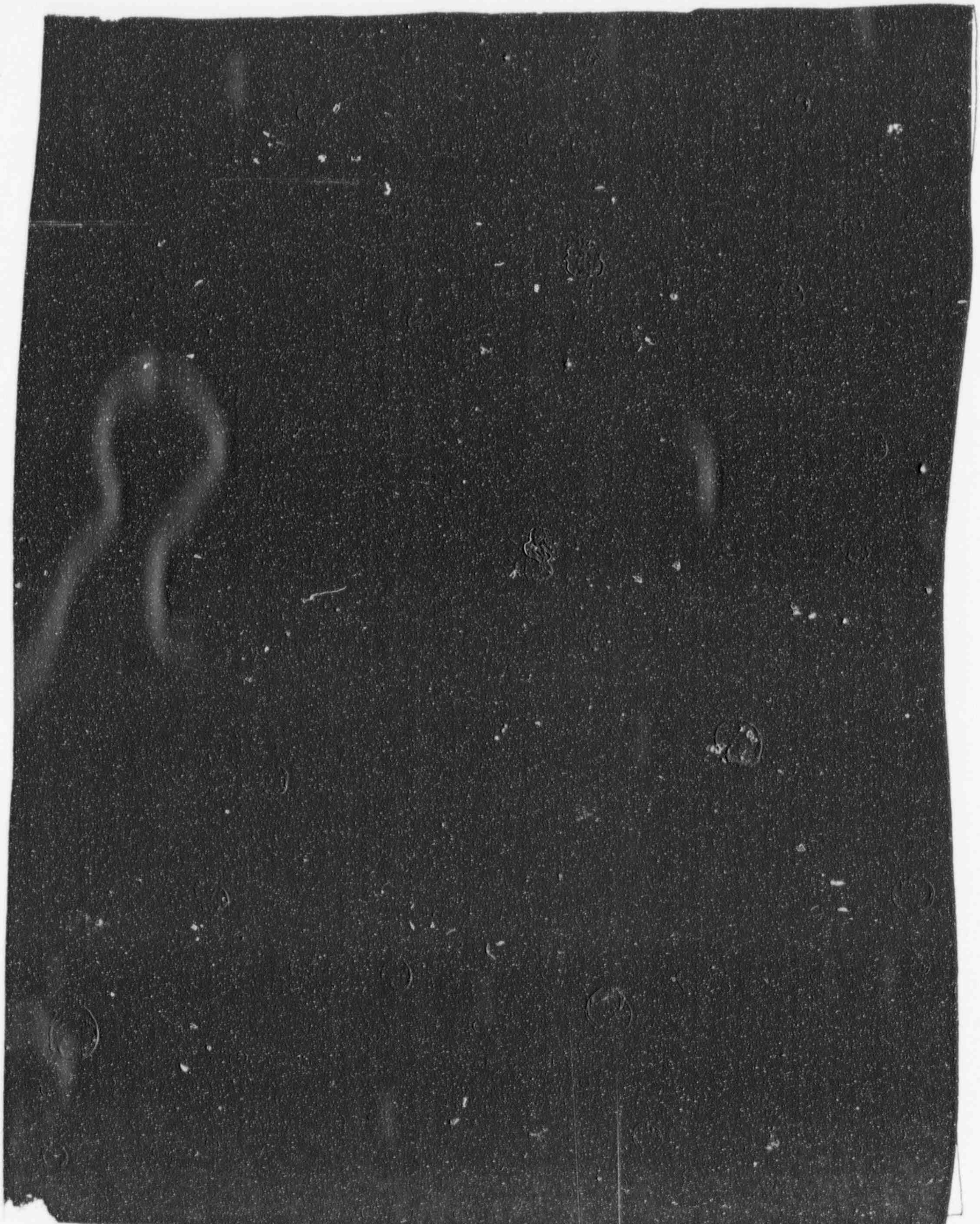
[redacted]

6-2.2.1.2 Combined Effects of Sulfate/Chloride in Non-acid Environments

There are relatively few stress corrosion cracking (SCC) studies in non-acid environments containing both sulfate and chloride. However, as will be discussed in Section 6-2.2.2.1 with [redacted]

6-2.2.1.3 Effects of Temperature and ECP in Sulfate and Chloride Solutions on SCC in Non-Acid Environments

[redacted]



[redacted]

6-2.2.1.4 Effects of pH in Sulfate and Chloride Solutions on SCC

The unique feature of the Fermi 2 circulation water intrusion incident is the very high pH. Although Fermi 2 circulation water pH is typical of PWRs, limited information was readily available on its effect on SCC in chlorinated and sulfated environments. Figure 6-2.2-12 presents the effect of pH 4 versus pH 10 environments for [redacted] (Ref. 23). The results indicate that for Alloy 600 in the solution [redacted] no SCC occurred at pH 10 [redacted]

[redacted]

6-2.2.2 Other Forms of Corrosion

Not only do chloride and sulfate detrimentally affect SCC propensities of numerous materials, but these two anions can intensify all other forms of corrosion by either simply enhancing the conductivity of the environment or by some other mechanism such as specifically attacking

[redacted]

protective passive films. Fortunately, many of the other forms of corrosion (e.g., general corrosion) will have little impact on Fermi 2 long-term performance. However, two forms of corrosion should be appraised: (1) pitting and (2) microbial (or microbiologically) induced/influenced corrosion (MIC).

6-2.2.2.1 Pitting

The tendency for pitting of stainless steels in chlorinated media was recognized soon after stainless steel was developed. Although many chloride pitting studies are performed at significantly higher chloride contents than Fermi 2 has experienced [redacted] the general pitting trends should be noted. Lower temperatures, lower concentrations, higher pH and the presence of other anions ($SO_4^=$, NO_3^-, and OH^-) result in a higher critical potential for pitting (i.e., to obtain pitting, higher potentials or more oxidizing environments are required) (Ref. 29). This would suggest that the pitting propensity for many Fermi 2 structural materials is low despite the anticipated longer than average plant shutdown. Also, active pits that initiate during stagnant shutdown conditions typically repassivate during operation. However, since it has been theorized in alkaline PWRs that the pitting mechanism for stainless steel and Alloy 600 is due to the presence of chloride, iron oxide and copper oxide or, in some cases, metal forming ferrous and cupric chloride (very strong oxidizing pitting agents) (Ref. 30), it is considered prudent to evaluate this phenomenon at Fermi 2.

In particular, it should also be noted that pitting has occurred in the BWR in high purity environments in the control rod drive (CRD) [redacted] stainless steel index and piston tubes. The Fermi 2 high conductivity/high chloride water would be expected to adversely affect this system. Pitting of the [redacted] surface can lead to general softening of the [redacted] case and SCC of the stainless steel. [redacted] stainless steel index and piston tubes would be more resistant to IGSCC.

6-2.2.2.2 Microbiologically Induced Corrosion (MIC)

MIC has been recognized as a potential problem in nuclear power plants for several years (Ref. 31). Since MIC, like pitting, is most likely to occur under stagnant conditions or operation with low or intermittent flow, the anticipated longer than average shutdown period for Fermi 2 also makes the plant a candidate for this type of attack. (It should be noted that MIC typically produces pitting.) Since the intrusion at Fermi 2 involved water sources that could be rich sources of organics, an evaluation of MIC is especially important. MIC does not represent a new form of corrosion, it is only the influence of viable microorganisms on electrochemical reactions.

[redacted]

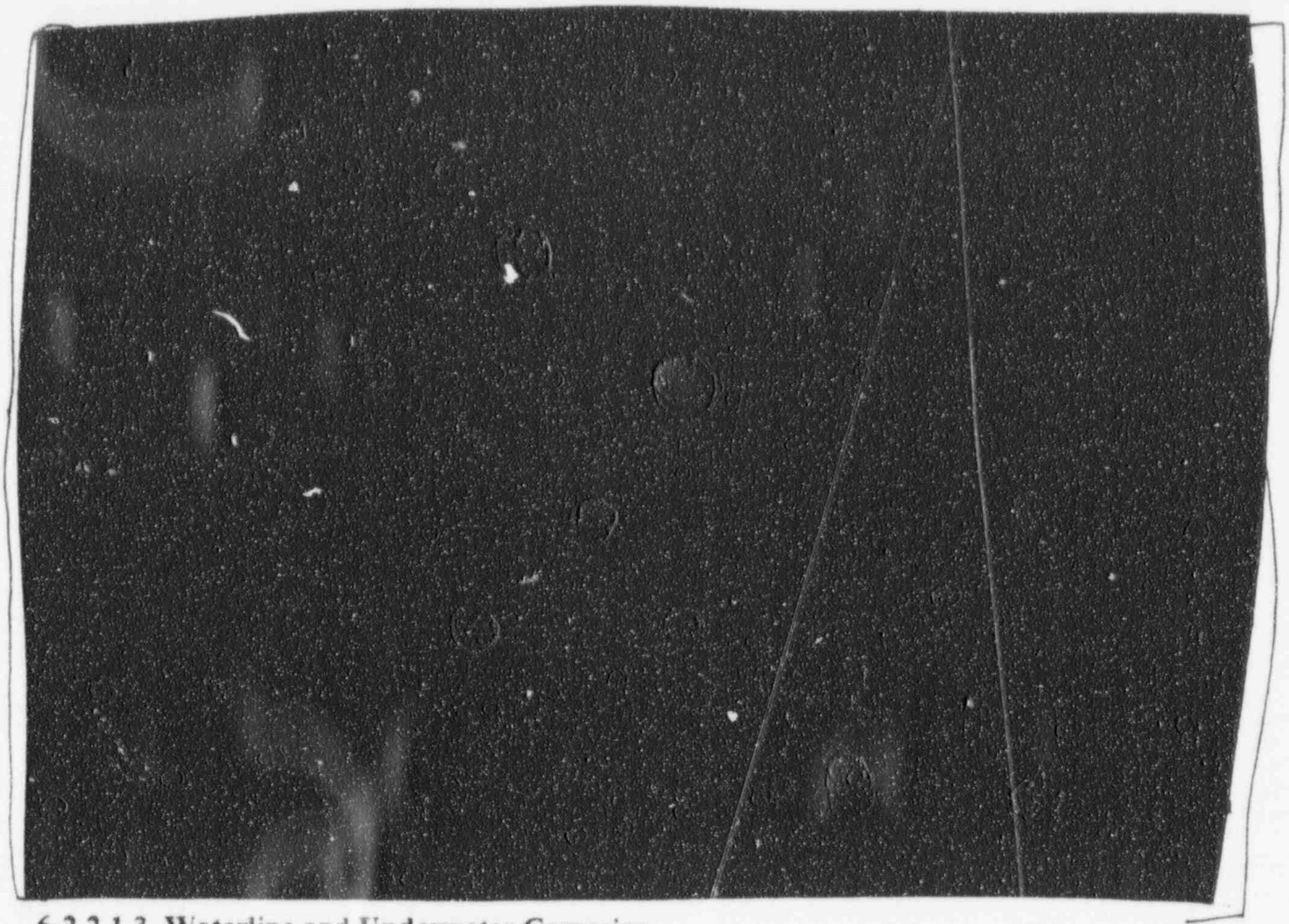
To unequivocally determine the presence of MIC requires the expertise of microbiologists and corrosion scientists. Definite proof of MIC is expensive, since it typically requires a lengthy research program. Other more qualitative methods are available. Finally, it is important to note that the initial premise should be that any corrosion identified in Fermi 2 was not caused by MIC (i.e., MIC is the cause of corrosion if and only if the attack cannot be explained by any other corrosion mechanism).

The initial MIC assessment should consist of the following items (Ref. 31):

[redacted]

Although all of the following water sampling techniques may not be applicable to the Fermi 2 RPV, the recommended practices are provided for information and background.

Flow-through methods are strongly recommended, since random grab samples can be unreliable for MIC. Filtering a process stream (probably not applicable for Fermi 2) with [redacted] Turbidity, color and odor can provide a qualitative indication of MIC activity. The absolute value of a microbial count is of little value unless the number is zero. Also, the sample does not necessarily reflect the numbers or activity of organisms at the metal surface. Sampling of a fluid stream is useful for identifying heavily infested systems and selecting areas for subsequent investigation, evaluating mitigation techniques, characterizing areas with high microbe growth potential and future trending.

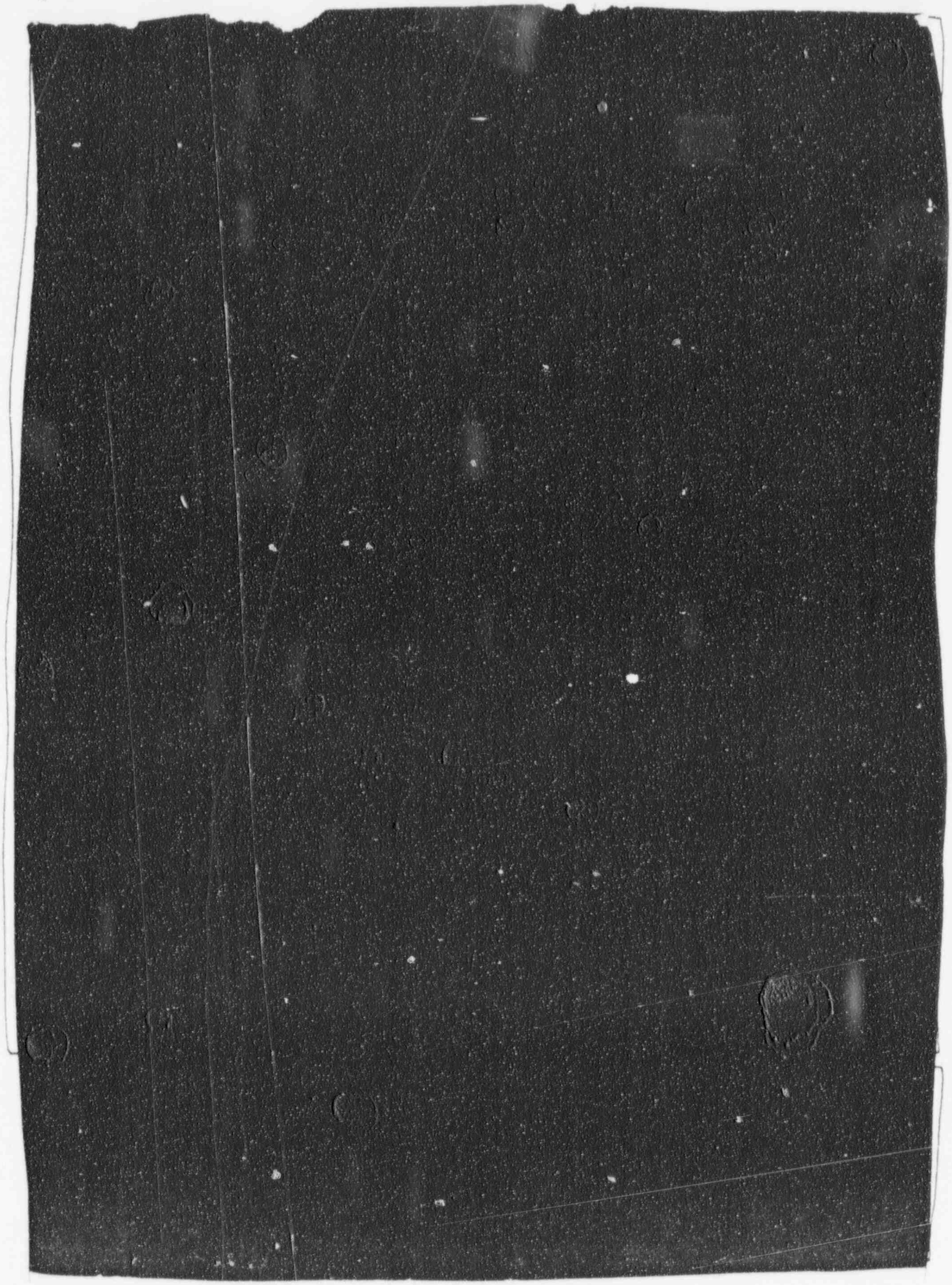


6-2.2.1.3 Waterline and Underwater Corrosion

Although not considered one of the eight or nine "forms" of corrosion, waterline corrosion is a type of localized corrosion that can occur during extended stagnant layup in tanks, pools and, now, the Fermi 2 stainless steel clad RPV. Waterline corrosion is a classic example of a differential aeration cell. Corrosion depletes the water of dissolved oxygen, which is most readily replaced near the meniscus interface of the metal surface and the stagnant solution. The cathode is formed at the more oxygen rich interface, while the corroding anode occurs just below the surface in the more oxygen depleted area. General or localized corrosion (e.g., pitting) occurs just below the waterline in this oxygen depleted zone. Due to the limited throwing power of this galvanic couple, the amount of attack decreases with increasing depth. If surfaces in the oxygen rich region are covered with oxygen shielding organisms (MIC), then more severe pitting can be promoted.

Examination of the Fermi 2 reactor pressure vessel waterline indicates this type of attack. A "bath tub ring" is clearly visible as decorated by pits. As anticipated, the density of pits decreases with depth. The downward vertical stains emanating from some of the pits reflects superficial corrosion due to the leakage of the pit's higher density/more corrosive (low pH, concentrated sulfate, concentrated chloride) solution.

The corrosion identified on the unclad low alloy steel feedwater nozzle region appears to be general corrosion with localized areas where the corrosion product has been mechanically



removed by flow or scale exfoliation. These areas may also be associated with local material inhomogeneities such as grinding marks (cold work) or stringers. Only a more detailed examination would reveal its root cause.

6-2.2.3 Comparison to Other BWR Intrusion Materials Behavior

A list of known BWR transients is given in Table 6-2.2-1 (Ref. 34). The available data indicates that Fermi 2 suffered the most severe transient. To determine the long-term effects on Fermi 2 structural material integrity, a comparison with two BWRs with somewhat similar experiences has been performed.

An immediate result of the plant AL intrusion was the failure of 116 out of 120 LPRMs and some minor SCC of some fuel hardware (a few nuts, locking tab washers, a spacer band dimple). However, eight years later, SCC of unprecedented extent for large diameter piping (complete 360° cracking) was identified on the isolation condenser on the safe end side (Ref. 35). It was conclusively determined that the IGSCC propagated from shallow TGSCC in essentially annealed material near the weld fusion line and in base material away from the weld as a result of the earlier chloride intrusion incident.

Four years after the plant N intrusion in June 1978, the creviced Alloy 600 recirculation inlet safe ends suffered extensive IGSCC. This was the first BWR creviced Alloy 600 failure in the field. Sulfate was determined to be one of the key contributors to the premature cracking of the safe ends (Ref. 2).

Although the Fermi 2 recent intrusion incident is arithmetically worse than either the 1972 intrusion at plant AL or the 1974 intrusion at plant N (based on conductivity) and second to the 1972 intrusion at plant AL (as based on chloride content), the Fermi 2 pH is approximately six orders of magnitude higher than the other plants. As demonstrated by most of the data presented in Sections 6-2.2.1.4 and 6-2.2.2.1, elevated pH has a clear beneficial effect on a material's resistance to SCC and pitting.

However, it is critical to note that even low levels of ionic impurities have a strong effect on BWR long-term materials performance, as reflected by the correlations between plant average conductivity and the IGSCC of several BWR creviced components:

- Stainless steel safe ends (Figure 6-2.2-14) (Ref. 25)
- Stainless steel control blade sheaths (Figure 6-2.3-15)
- Stainless steel IRM/SRM dry tubes (Figure 6-2.2-16) (Ref. 25)
- Alloy 600 access hole covers (AHCs) (Figure 6-2.2-17)
- Alloy 600 shroud head bolts (SHBs) (Figure 6-2.2-18)

These correlations clearly indicate that poor water quality results in premature IGSCC. Since the cleanup process at Fermi 2 will most likely be protracted due to the leaching out of impurities out of dead legs, crevices, crud, etc., it is important to evaluate these possible consequences. It is also important to note that despite being characterized by an overall excellent average plant conductivity, plant N suffered an inordinate amount of shroud head bolt (SHB) cracking that was probably related to its startup chemistry problems.

6-2.3 Effects of the Circulation Water Intrusion Chemistry on Fuels Performance

6-2.3.1 Water Chemistry Impact on Fuel

It is anticipated that the impact of the circulation water intrusion on the Zircaloy components of the fuel, including fuel rods, cladding, spacers, and channels, will be insignificant. In previous transients, although of lesser magnitude, no significant impact on these components was observed.

However, stainless steel and [redacted] fuel bundle components may be affected through intergranular stress corrosion cracking, particularly in highly stressed and creviced components.

Previous experiences of intrusions have shown evidence of intergranular attack in some of those components. However, it was found by detailed examinations and evaluations that the extent of attack was sufficiently low that replacement of parts was not necessary. Continued successful operation in those cases confirmed the analyses.

6-2.3.2 Fuel Performance Following Comparison Plant Transients

The fuels performance after the transient at plant AL in September of 1972 and plant N in the spring of 1974 showed no failures due to either transient. For the case of plant AL, fuel failures in three later cycles were attributed to pellet cladding interaction, which is unrelated to the chemistry transient. In the case of plant N, there were no failed rods in all four cycles following the event. These results are summarized in Tables 2.3-1 and 2.3-2.

6-2.4 Impact on Vessel Internal Components

Motivated by the corrosion concerns discussed in Section 6-2.2, it is considered prudent to evaluate the potential degradation in the structural integrity of Fermi 2 reactor internals and other components attached to the reactor, such as control rod drives (CRDs), LPRM and SRM/IRM dry tubes. A review of the Fermi 2 components reveals that there exists both welded stainless steel and Alloy 600 components that are undoubtedly subjected to a significant stress in the proximity of a crevice. Similar evaluations for fuel and associated hardware and control rod components are given in Section 6-2.5 and in Section 6-2.6 for external systems, such as recirculation piping.

A priority of generalized concerns for IGSCC for the various reactor internal components was constructed based on the presence of a crevice and stress estimates from similar plant designs. Table 6-2.4-1 presents such a relative ranking where position is suggested by an estimated priority of inspection. The ranking is based on [redacted]

[redacted] Subsequent rankings were estimated by [redacted] The utilization of more IGSCC resistant materials was also considered. However, [redacted] "Nuclear Grade" materials are not immune to IGSCC. Prudent judgment should be exercised in the application of this table, since the rankings are only a best estimate and cannot be warranted for absolute completeness or correctness at this time.

6-2.4.1 Vessel Internals

Table 6-2.4-1 represents a complete listing of reactor pressure vessel internal components except for the fuel assemblies, control rod blades, and in-core sensors. Also, the reactor vessel components which are not in contact with the reactor water (e.g., the reactor pressure vessel closure flange bolting and the seal leak detector nozzle) are not included.

The table identifies the critical factors which could lead to component cracking. In the crevice column, components were identified as having a crevice concern when the crevice was associated with a weld heat-affected zone (HAZ). In other cases, there are crevice conditions present in base materials, but since the crevice is not expected to have a detrimental effect, it has not been identified as such in this table.

In reviewing Table 6-2.4-1, the materials which are of greatest concern are [redacted] In general, most of the reactor internal components have high structural margins, and the effect of the water chemistry transient will not have an immediate impact on the function or structural integrity of the reactor pressure vessel components. A good indicator of where problems may occur is from the field experience at older BWR operating plants; however, the material conditions which led to cracking must be compared to the Fermi 2 conditions to make correct assessments.

6-2.4.1.1 Comparison of Fermi 2 Reactor Internals to other BWR Plants

The following components have experienced IGSCC at other operating BWR plants:

- CRD stub tube
- CRD return nozzle
- In-core housing
- Recirc inlet nozzle safe ends
- Recirc outlet nozzle safe ends
- Core spray nozzle safe ends
- Core spray internal piping
- Jet pump beam
- Jet pump instrument nozzle safe end
- Shroud
- Shroud head bolts
- Access hole covers
- Steam dryer

In reviewing the above list against the material conditions at Fermi 2, there are several components where the materials and/or geometry were improved at Fermi 2 to provide more resistance to IGSCC prior to startup of the plant (Table 6-2.4-2). The recommendations in Table 6-2.4-1 are consistent with this table. In general, the Fermi 2 components that have improved IGSCC resistance were not recommended for additional inspection as a result of the transient. For components that are similar to those that have experienced IGSCC at other BWRs, additional inspection was recommended, unless an inspection program is already in place or unless another component was judged to be more critical.

A review of other reactor internals which have not experienced cracking, but are considered susceptible to IGSCC, was completed. Table 6-2.4-3 shows the Fermi 2 components whose designs are different from the typical BWR plants, primarily due to preferences by the vessel fabricator. The table also shows the specific recommendations (consistent with Table 6-2.4-1) that address these differences.

6-2.4.1.2 Detailed Discussion of Recommendations

In reviewing the current water chemistry event, there are three categories of recommendations:

- **Replacement of Components** - This type of recommendation is only made for highly susceptible components which have short times to failure once a crack has initiated, and where the current water chemistry condition could have caused a crack to initiate.

- **Inspection** - Inspection is generally a visual or ultrasonic test, and there are two separate reasons for making the recommendation: (1) to examine a component which may already have defects which will be further aggravated by the water chemistry event (immediate impact), and (2) to obtain a baseline examination of a susceptible component which is anticipated to have cracking issues at a later time period. If defects are detected, it may be necessary to make a repair or replace the component and extend inspection to other components. A good example of a component in this category is the shroud head bolts, which have had a number of cases where cracking has been detected at BWR operating plants.

- **Flushing** -For components which have stagnant areas where normal circulation in the vessel is not likely to remove contaminants before the reactor is brought to full temperature conditions, a flush such as with a hydrolazing wand is recommended.

The above recommendations are shown along with the components in Table 6-4.2-1. The only component designated for replacement was the jet pump beams. Due to the recent cracking at a BWR/6, there was concern that beams which did not have the new heat treatment may not be capable of operating one fuel cycle if they had cracks which initiated at the ends of the beam. Also, since there is currently no means of performing an adequate ultrasonic examination, it is not possible to determine the exact structural integrity of the beams at this time. Therefore, since a broken beam would cause the plant to shut down and cause other damage within the reactor vessel, it was recommended that the beams be changed-out prior to restart of the plant. All the jet pump beams were successfully replaced by 24 June 1994.

The [redacted] are the most susceptible. The components which have [redacted] of concern are the shroud head bolts and the shroud-to-shroud support weld. Since shroud head bolts have cracked at several operating plants, this is potentially a component which could already have IGSCC present, and may need to be replaced. NDE determined that 16 of the 48 shroud head bolts contained rejectable ultrasonic indications. Appendix B contains a complete copy of the inspection report. A stress analysis is currently underway to determine if the replacement of the sixteen rejected shroud head bolts will be sufficient for startup (Proposal No. 295-1EOGL-KH1). It was also recommended that metallurgical failure analysis of one of the rejected shroud head bolts be performed to determine the failure mode. A proposal for the metallurgical evaluation is being prepared.

The shroud-to-shroud support weld was constructed with a backing ring, which forms a crevice. Because of the backing ring, the access for inspection is restricted, and has prevented any worthwhile inspections from being performed at any operating plants. Therefore, this is a location which should be inspected but no inspection methods are currently available to perform an adequate inspection. An ultrasonic inspection has been under evaluation for this location and is considered feasible, but the equipment is not yet available. It is recommended that this location be examined whenever inspection techniques are available.

The stainless steel components which are judged to be most susceptible to IGSCC are the safe ends on the recirculation inlet nozzles, recirculation outlet nozzles and the jet pump instrumentation nozzles. The recirculation inlet and outlet nozzles experience pressure and pipe reaction loads, and differential thermal expansion stresses which can lead to IGSCC. The jet pump instrumentation nozzle primarily experiences pressure and differential thermal expansion stresses, but also has restricted circulation of reactor water due to the sensing lines routing through the nozzle. In addition to having high carbon stainless steel safe end materials, these nozzles have an [redacted] on the end of the nozzles which is susceptible to IGSCC. To reduce the susceptibility to IGSCC, the Mechanical Stress Improvement Process (MSIP) has previously been applied to the recirculation nozzle safe end welds, but because of geometry and differential expansion of materials, the full benefit of this process to reverse stresses may not be accomplished. Therefore, the ultrasonic examinations, for baseline purposes, are recommended at the nozzle-to-safe end weld location. For the recirculation inlet nozzle, it is recommended that two or three nozzles be ultrasonically inspected at the nozzle-to-safe end weld. This should be performed on nozzles which have not been inspected at outages following the application of the MSIP process and is intended to be a representative sample of this nozzle. Also, for the recirculation outlet nozzle, only one examination is specified, since the other nozzle has been examined at a subsequent outage following application of the MSIP process.

The next component identified for inspection is the feedwater nozzle inner blend radius. This area has base low alloy steel material which is susceptible to pitting under poor water chemistry conditions. The feedwater nozzle was selected as a representative location for visual inspection, since it is a location which potentially could have high stresses due to thermal cycling, and at other BWR plants had fatigue cracks when gross thermal sleeve leakage was present. Visual inspections performed with a remote video camera have indicated that there is corrosion activity near the feedwater nozzle area on the unclad surface of the reactor pressure vessel (RPV). A recommended RPV corrosion evaluation plan was written (NEDC-32374) and is currently under customer review. The plan recommends the use of a diver to determine the extent of the corrosion damage to the RPV clad and unclad surfaces. The diver shall also collect corrosion products for chemical and microbiological evaluation. Appendix C contains a complete copy of the plan.

The last components identified for inspection are the jet pump riser brace and the steam dryer support brackets. The construction of these brackets is typical of all the stainless steel brackets in the vessel. The steam dryer support brackets are a cast stainless steel material which is resistant to IGSCC, but the attachment weld was made with [redacted] materials. The [redacted] material was used because it is a good transition material between low alloy steel and stainless steel connections. The [redacted] materials are not creviced, but are considered susceptible to IGSCC. Although there have not been any field problems identified, it was felt that at least one representative reactor vessel attachment component should be visually inspected as a baseline examination. The steam dryer support bracket has been identified for inspection, since it may have come into contact with the reactor water during or after the transient. Due to the thermal expansion deadweight loads from the jet pump, the jet pump riser braces experience the highest loads of the group of in-vessel internal attachments. A visual inspection should be performed, since these brackets are readily accessible for inspection. The attachment of the riser brace to the reactor pressure vessel is stainless steel instead of [redacted]

It was also recognized that NRC IE Bulletin 80-13 requires that a visual inspection be performed on all core spray piping and sparger welds in the reactor pressure vessel at each refueling outage. Therefore, these components have not been selected, since they should already be identified in the in-service inspection program at Fermi 2.

The recommendations for flushing are indicated for locations where the reactor flow is stagnant. These areas have been common sites for corrosion and crud buildup, which are technical concerns, since contaminants in the water could concentrate in these areas and become part of the crud composition. The specific areas identified are the annulus spaces between the nozzle and the thermal sleeve for the recirculation inlet, core spray and feedwater nozzles, and the CRD return nozzle, which is capped off. These are areas that have IGSCC susceptible materials and have experienced large amounts of crud. It has been common to hydrolaze these areas to remove crud and reduce dose rates. Other areas which are recommended to be cleaned by vacuuming are the flat areas on the horizontal plates of the shroud support, which can collect corrosion products and have susceptible [redacted] Included in this area are the pocket areas around the jet pump diffusers, where significant amounts of corrosion products are expected. For the areas around the diffusers and the corners formed by the gusset plates, hydrolazing should be performed, since vacuuming alone will not completely clean the area. Another area where crud deposits have been common is the bottom head region near the drain nozzle. This area contains [redacted] materials on the stub tubes where it is important to maintain good water chemistry conditions. Because cleaning this area involves complete disassembly of fuel cells, and because

Fermi 2 has been a relatively low iron plant since reactor startup, this area is not included as a recommended area for cleaning on Table 6-2.4-1; however, DECo should determine whether they should expend the effort necessary to clean this area. The flushing specified for the core spray internal piping and the Jet Pump Instrument nozzle involve injecting water into the lines to flush the internal surfaces. Additionally for the jet pump instrument nozzle, the nozzle annulus space should be flushed due to the stagnant areas created by the sensing lines routing through the nozzle base.

6-2.4.2 Other Vessel Internal Components

6-2.4.2.1 Control Rod Drives (CRDs)

Components of the CRDs which are judged to be most affected by the current water chemistry transient are the collet retainer tube, the index tube and the piston tube of the older style CRD assemblies (7RDB144BG001) (Table 6-2.4-4). Fermi 2 has 170 out of a total of 185 CRDs of this style.

These components have been shown to be susceptible to intergranular attack (IGA), stress corrosion cracking (SCC) and pitting under normal water chemistry conditions. Their susceptibility is expected to be aggravated by the higher conductivity water experienced during this event. Improvements made to the newer versions of the CRDs (7RDB144BG006) currently installed in Fermi 2 have essentially eliminated their susceptibility under normal water chemistry conditions.

The CRD System provides constant cooling water flow to maintain the CRDs below the temperature alarm setpoint of 121°C (250°F). Temperature data for rod 26-31 (typical for other rods) (Figure 6-2.4-1) indicated that the CRDs were subjected to temperatures up to 232°C (450°F) and 149°C (300°F) for approximately one hour and less than 20 hours, respectively. These relatively short temperature excursions should not adversely affect the CRD components, including the [redacted] seals and bushings. However, it was recommended that the [redacted] seals and bushings be visually inspected at the same time the samples of CRDs were examined during the outage.

It was recommended that during the outage, a representative sample of each type of CRD be examined using normal CRD rebuilding techniques to establish a baseline of their present condition. The baseline criterion for the collet retainer tube was established using the inspection recommendations of SIL 139, revised Supplement 1, Attachment 2 for crack location and size (Ref. 42). For the index tube and piston tube, corrosion products and pitting were recorded using the Operation and Maintenance Instructions (GEI-92809) checklist (Appendix A-1). A separate interim report (GE-NE C1100297-01) was issued in June 1994, which detailed the inspection findings. Appendix D contains the color photographs of the examined CRDs. The results and conclusions from report GE-NE C1100297-01 are as follows:

- Corrosion deposits were found on the CRD components, especially on the index tube and piston tube surfaces. The deposits suggest that the index tube and piston tube corrosion was promoted by the circulation water transient. In comparison to CRDs of similar service life, Fermi 2 CRDs appear to be worse than the average.

- The general corrosion observed on the index tubes and piston tubes is moderately severe. However, stress corrosion cracking is not expected to initiate from these corrosion sites.

- Based on the results, it is concluded that it would be prudent to periodically flush the crevice areas formed by the seals/bushings and the collet fingers with the [redacted] surfaces of the piston and index tubes. Flushing of the control rod drives has been recommended and a procedure has been provided under separate cover for that purpose.

- Based on the condition of the CRDs inspected, it is concluded that there is no immediate need for refurbishment of additional CRDs beyond those planned for RF04. This conclusion is based on the condition the CRDs are exercised daily when possible to minimize the effect of crevice corrosion in the regions of the seals/bushings and collet fingers in contact with th[redacted]surfaces.

- The CRD scram function would not be adversely affected by the observed corrosion condition. However, continued corrosion degradation may result in excessive seal degradation and leakage which may lead to early CRD refurbishment.

Subsequent metallurgical examination of selected components can be used to determine if this event has an adverse effect on the normal degradation rate of the CRD components so that future maintenance practices can be adjusted accordingly. A contract change is underway to include metallurgical analysis of selected components at Vallecitos Nuclear Center.

6-2.4.2.2 Local Power Range Monitors (LPRMs)

As discussed earlier, there have been known failures of LPRM sensors as a result of chemistry intrusions. The first occurred at plant AL, where 116/120 LPRMs had failed within hours of the transient (Ref. 1). In another plant (referred to as Plant K in Table 6-2.2-1), at least three LPRMs failed during the transient and it is indicated that, subsequent to the intrusion, "numerous" LPRMs failed (Ref. 36). In both of these cases, the LPRM sensor was a model NA200 sensor. The failure is believed to occur at the crevice location in the relatively thin detector wall. A sketch of the NA 200 design is shown in Figure 6-2.4-2. Newer model LPRM detectors (NA300 model) have eliminated this crevice.

The failures at plant AL were high-current, low-insulation resistance failures, which indicated moisture penetration of the sensor. It was believed that the likely "cause of the" failure was penetration of the detector itself by moisture, as opposed to penetration of the mineral insulated cable that connects to the sensor (Ref. 1). In both plants (AL and K), all of the LPRMs were replaced prior to restarting the plant.

As shown in Table 6-2.4-5, Fermi 2 has 29 LPRMs with NA200 detectors (4 detectors each) and 14 LPRMs with NA300 detectors. One NA200 LPRM detector string (48-49B) had failed at 33.75 hours after the scram. The second NA200 LPRM detector string (40-25C) failed on March 11, 1994, approximately 11 weeks after the transient. Perhaps the high pH lessened the severity of the environment on the sensors; however, it is difficult to predict if the remaining NA200 sensors will fail within the next cycle if they remain in the core. The contaminated water will remain in the crevice; therefore, the possibility of later failures cannot be excluded.

The impact of this type of failure could result in an automatic shutdown of the reactor if the number of NA200 detectors in a given APRM causes an upscale trip. Twelve NA200 LPRMs were already planned for replacement in this refueling outage. Failure of the NA200 LPRM detectors remaining in the core would cause an automatic reactor shutdown; therefore, it was recommended all of the NA200 LPRM detectors be replaced prior to reactor restart. DECo has subsequently replaced the NA200 LPRM detectors prior to reactor restart.

6-2.4.2.3 SRM/IRM Dry Tubes

As stated in Section 6-2.2.3, there is a correlation between observed cracking in stainless steel SRM and IRM dry tubes and average reactor water conductivity: the lower the conductivity, the longer time it takes for cracking to be observed. The cracking is believed to be caused by a combination of crevice corrosion cracking and irradiated assisted cracking (IASCC). All of the crack indications have been observed in the top portion of the dry tube assembly adjacent either to the weld between the tube and the guide plug or the weld between the tube and the primary pressure boundary (Figure 6-2.4-3). The cracks are primarily in the perforated tube, which is not part of the pressure boundary. Some cracks have penetrated into the pressure boundary. No instruments have failed to function as a result of these cracks, none of the cracks have caused any detected leakage, and there has been no reported penetration of the primary pressure boundary. The inspections show that no loose pieces have been generated. It should be noted that the dry tubes from plant AL discharged in 1991 (Ref. 39) showed no cracks after being installed for 20 years with 15 full power years.

Design improvements have been incorporated into the replacement dry tube assemblies and into the corresponding locations of the new wide range neutron monitors. The improvements consist of elimination of crevices and the use of improved IASCC resistant material (Ref. 38).

From Table 6-2.4-5, Fermi 2 has 12 original equipment SRM and IRM dry tubes (same type in which cracking has been observed) (Ref. 37), and inspections should therefore be performed as recommended in GE Service Information Letter (SIL) 409 and replacements with the improved design made as necessary (Ref. 38). This recommendation is consistent with the SIL recommendations (for original equipment such as installed in Fermi 2, and for water chemistry meeting EPRI NP 3589 SR LD, inspections should be performed during the fourth outage). The inspections should refer to SIL 409 for other information regarding precautions, etc.

6-2.5 Impact on Fuel and Associated Components

6-2.5.1 Fuel Rods, Spacers, and Channels (Zircaloy)

While no significant impact of the intrusion is expected on these components, it is prudent and convenient to perform visual inspections of these Zircaloy components.

In addition, the fuel rod cladding is the major repository of crud deposits, and crud scraping of fuel rod surfaces will provide an assessment of the crud deposit quantities and compositions which will remain on the fuel cladding and other surfaces.

Specific bundle selection were made by DECo. The recommended bundles are shown in Table 6-2.5-1. Additionally, it was recommended that selected bundles received exposure in mid-core positions.

Bundle LJK961 was selected as the reference bundle for "normal" water chemistry. This three-cycle bundle was discharged following the end of Cycle 3 and moved to the spent fuel storage pool. Bundle LYS486 was exposed during Cycles 2-4 and was incore for the reactor water intrusion. This bundle was discharged following the Cycle 4 intrusion and will not be reinserted in the core. Bundle YJ2809 was exposed only during Cycle 4 and also experienced the reactor water intrusion. It is currently planned that this bundle will be reinserted in the core for future exposure.

All bundles were inspected and/or handled in accordance with the Test Plan and Procedures (Ref. 47). Bundles selected for fuel deposit sampling were previously determined to be non-leaking bundles. Bundle YJ2809 was visually examined by the GENE fuel inspection crew following fuel deposit sampling. Inspection results for Bundle YJ2809, and other inspected bundles, are reported in the Fermi-2 EOC-4 Irradiated Fuel Inspection Exit Report (Ref. 48). Visual examinations were not performed on the discharge Bundles LJK961 and LYS486.

Fuel deposit sampling was performed in the spent fuel storage pool. Bundle disassembly was not required, as only peripheral rods were sampled. Two rods were sampled per bundle, rods A1 and J1 of Bundle YJ2809, and rods A1 and E1 from Bundles LJK961 and LYS486 [redacted]

[redacted]

Appendix E shows sample sheets listing sample number, identification, sampling elevation and measured dose rate for each collected sample. The sample identification indicates rod, position, and type of sample. For example, A1S7B identifies rod A1 sampled at the S7 position with the brush (B) deposit sampler. A1S7D identifies rod A1 sampled at the S7 position with the diamond stone (D) sampler. Rod sampling positions S1-S8 are identified in Figure 6-2.5-1.

The three bundles were selected for sampling based on exposure histories and core locations as listed in Table 6-2.5-2.

[redacted]

6-2.5.2 Fuel Hardware

Table 6-2.5-2 shows the fuel hardware components at Fermi 2 along with the recommendations for inspections. Essentially, the lock tab washers, hex nuts, expansion springs, and channel fastener bolts are recommended for visual and penetrant examination during the already planned fuel inspection. Selected components from four bundles would be removed and retrieved for hot cell examination.

The selection of these candidate fuel components was based on essentially three interdependent criteria. The first selection criterion was based on the successful investigation of plant AL's post-intrusion fuel hardware evaluation and other known failures of the channel fastener bolts. The second and third criteria were based on the accessibility of the hardware (i.e., the ease of performing the inspection) and the relative value of the information obtained from such an evaluation. Plant AL's fuel hex nuts, locking tab washers and upper tie plate were readily visually, dye penetrant and metallographically inspected (as necessary) and inexpensively replaced (as necessary to replace components removed for inspection). In the case of plant AL, both the annealed stainless steel hex nuts and cold worked stainless steel locking tab washers indicated transgranular stress corrosion cracking attack, a typical effect of chloride on stainless steel.

6-2.5.3 Control Blades

There are known incidences of stress corrosion cracking in control rod sheaths and absorber tubes in the original equipment design (814E934G001). Fermi 2 has 20, out of 185 total, of these control rods. The remaining 165 control rods are a combination of [redacted] advanced control rods. The 20 original equipment control rods are located on the core periphery, where they are used as shutdown control rods with ≤ 20% depletion, the absorber tube cracking threshold.

The original equipment control rod structure was fabricated from fully anneale[redacted] Other materials used in smaller sub-components ar[redacted]

[redacted]

6-2.5.3.1 Sheath Cracking

The original equipment control rod structure contains four sheaths which are spot welded to the upper handle, lower velocity limiter and center tie rod. The four sheaths contain the absorber tubes, which have limited free movement within the sheath. The regions in the control rod that have been shown to be most susceptible to crevice corrosion cracking when subjected to both high conductivity [redacted] and irradiation are adjacent to the spot welds (Ref. 41). The overlapping metal surrounding the spot welds forms a wet crevice region where oxide buildup and fabrication stresses result in high local stress and local cracking. See Figure 6-2.5-1 for an example of typical cracking when located in high conductivity water for an extended period of time (one cycle or more). To date, cracks surrounding the spot welds have not been structurally limiting when history average conductivity value is less than [redacted] averaged over many years of operation (Ref. 42). Although the conductivity for the Fermi 2 water transient is much greater than this value, the time duration is significantly less.

The [redacted] control rods do not have the spot welded structure. Full penetration welds were used to eliminate crevices between the sheath and handle, tie rod and velocity limiter. Therefore, the [redacted] control rods are not susceptible to this failure mechanism.

6-2.5.3.2 Absorber Tube Cracking

In the original equipment control rod design, the absorber tubes are susceptible to Irradiation Assisted Stress Corrosion Cracking (IASCC). The severity of cracking has been correlated to local boron depletion and has shown no dependence on water conductivity. The outer two edge tubes in the wing are also susceptible to crevice corrosion cracking due to the limited coolant circulation inside the bend radius of the sheath. To date, the effect of crevice corrosion cracking in the outer edge rods of the original equipment control rods has been masked by IASCC, which is a more severe failure mechanism than crevice corrosion cracking.

Due to their susceptibility to IASCC, the original equipment control rods have a recommended depletion limit of 20% or less (Ref. 43) when used in a shutdown position with an undefined residence time. This depletion limit maintains the limiting absorber tube below the cracking threshold for IASCC and crevice corrosion cracking. Previous examinations have shown no evidence of conductivity effects on IASCC in control rod absorber tubes; therefore, there is no additional degradation expected due to the Fermi 2 water transient.

In the [redacted] control rods, the absorber tubes have been replaced with high purity stainless steel, which is more resistant to IASCC. The material change in the absorber tubes is, however, not effective for prevention of crevice corrosion cracking. The [redacted] control rods have the flow holes in the sheath further out to the edge than the original equipment control rod to promote more coolant circulation to the outside two absorber tubes. Nevertheless, the lifetime for [redacted] Control Rods has been reduced to be the same as the Original Equipment Control Rods (Ref. 46).

The [redacted] control rods use hafnium in the three outer edge positions of each wing, thereby eliminating the concern for having stainless steel absorber tubes in the creviced outer edge positions.

6-2.5.3.3 Inspection Recommendations

Since the control rod spot weld regions are the most susceptible to cracking as a function of water conductivity, it is recommended that a minimum of two original equipment control rods be visually inspected this outage. The inspection should provide a video of the spot weld region between the sheath and upper handle for both sides of each of the four wings. Inspection of the spot welds along the tie rod and sheath to velocity limiter region should be performed only if cracks are observed adjacent the upper handle spot welds. The same two original equipment control rods should be inspected the following outage to determine if the water transient has a longer term effect on the spot weld creviced regions.

If the inspection of the original equipment control rods reveals cracking severity outside of the experience base, the potential effect on absorber tube cracking should be re-evaluated.

Since the absorber tubes cannot be inspected for cracks without performing a destructive examination, there are no recommended inspections for the [redacted] control rods.

6-2.6 Impact on External Systems

6-2.6.1 Piping Systems

The piping systems potentially affected by the circulation water intrusion were identified by listing all nozzles on the RPV and listing the first barrier. The results, as well as the status of the piping during and after the event, are given in Table 6-2.6-1, along with a recommendation for inspection and/or for flushing. Weld inspection would only be recommended only if the piping contains unmitigated SCC susceptible welds exposed to the high conductivity water. Flushing is recommended for stagnant systems or systems exposed to the high conductivity water for a limited time during the transient. It is assumed that systems in operation since the transient will be flushed with continued operation during the cleanup process; however, flushing of dead legs and instrument lines in these systems is recommended. It is also assumed that systems exposed to steam instead of water will be the least impacted and no flushing is recommended at this time.

There are no systems where inspection is recommended beyond what is already recommended for vessel internals, unless the vessel internals inspection results warrant further inspections. According to information provided by DECo, the only major piping systems with unmitigated welds susceptible to IGSCC are the feedwater and condensate systems, nozzle to safe end welds. Crack growth calculations (Section 6-2.2.3.1) for the 24" feedwater piping show that because of the relatively low concentration of oxygen in the feedwater (20 to 50 ppb), little crack growth is predicted. Additionally, since these welds are categorized as Category D per NUREG-0313, there should be an inspection plan in place.

A procedure should be developed to flush the portions of piping outlined in Table 6-2.6-1. To this effect, a procedure for flushing the CRDs has been supplied by GENE under separate cover. Because of the magnitude of the transient, it may be prudent to perform a flush similar to one performed prior to initial reactor operation.

6-1.6.2 Layup Recommendations

With the expected outage duration of at least six months, the need to perform special layup procedures should be evaluated. To date, the RCIC and HPCI turbines are under investigation as to the appropriate layup practices for the given time frame. Other systems will be evaluated for components that require layup.

6-3.0 Effect of Fermi 2 Circulation Water Intrusion on Future Structural Materials Performance

The long term impact on vessel internals is presented as crack growth acceleration factors. These acceleration factors are an estimate of how much sooner cracking will be evident at Fermi 2 as a result of the transient.

6-3.1 Background

As discussed in Section 1.1.1, the circulation water intrusion incident was characterized by the injection of high conductivity water containing some well documented IGSCC enhancing anions especially sulfate and chloride. However, this water was also characterized by a high pH (pH 10.6), an environment that typically mitigates general corrosion. However, despite this high pH, the loss of two LPRM's suggests that some corrosion damage did occur during this transient. The subsequent non-destructive examination (NDE) identification of 16 shroud head bolts indications may also indicate the aggressiveness of this intrusion incident. It would be highly desirable to be able to mathematically interweave the data on the effects of sulfate, chloride, temperature, ECP and pH on IGSCC plus the LPRM failures to globally predict future Fermi 2 plant materials performance. Unfortunately, as is the case for most natural phenomena, this is not mathematically feasible. Only some trends and model predictions based on several fixed assumptions can be suggested.

Perhaps the single most significant impediment to a detailed quantitative materials performance analysis is the paucity of a relevant range of available and statistical IGSCC data. Therefore, only relative conclusions can be gleaned from the limited data presented in Sections 6-2.2.1.1 through 6-2.2.1.4. [redacted] While IGSCC would most likely initiate more rapidly in this [redacted] environment, subsequent crack propagation would depend not only on the particular material affected and the stress intensity, but would depend, inter alia, on future Fermi 2 water chemistry purity and ECP.

6-3.1.1 Engineering Judgment Evaluation

To provide an engineering judgment as to the effects of the circulation water intrusion on subsequent materials performance, a number of factors were considered. First, the above laboratory studies suggest [redacted] in IGSCC initiation time. Second, a field comparison of IGSCC of highly stressed creviced safe ends at Plant N (Table 6-2.2-1) (throughwall leaks 3.7 years after a large sulfate intrusion) and Plant B (50% throughwall cracks 8.3 years after multiple chloride intrusions) suggest a [redacted] in IGSCC initiation time as compared to the BWR fleet. Third, tests performed after Plant N intrusion on pipes with thermal sleeve mockups (Alloys 600 an [redacted]

To model the effects of the circulation water intrusion on subsequent materials performance, a number of assumptions have been made.

- No cracks currently exist in any of the internal or piping components discussed below.

[redacted]

- Since it is not possible to predict future Fermi 2 water chemistry, subsequent crack growth will be based on the average 1993 water chemistry purity (0.10 μS/cm). For calculation purposes, it was assumed that IGSCC mitigating hydrogen water chemistry will not be implemented.

- The Fermi 2 crack growth predictions are based on the [redacted] model [redacted] Almost all metals of engineering significance derive their corrosion resistance from "passivity", in which the formation of a thin, protective oxide film on the surface greatly decreases the alloy's corrosion rate. When ruptured, rapid corrosion and subsequent "repassivation" occurs. Since strains in the underlying metal become localized at surface defects and in existing cracks, the frequency of oxide film rupture is increased locally and cracks propagate.

[redacted]

Predictions from the [redacted] model have been extensively compared with laboratory and field data and has provided validation of the technique. For example, [redacted] predicts the crack growth rate in stainless steel and low alloy steel within [redacted] Likewise, it provides a very reasonable mean value and can accurately bound the observed crack growth rate in stainless piping and other components. Aside from piping predictions, [redacted] has been successfully used for the following:

- in-plant crack arrest verification (CAV) data
- safe ends (avoiding mid-cycle plant shutdowns)
- non-sensitized (stabilized) stainless steels
- reactor internals (the core shroud, top guide, access hole cover and in-core monitor housing)

A number of Fermi 2 internals were evaluated using [redacted] and the above assumptions. Emphasis was placed on a Type 304 stainless steel core shroud (the Fermi 2 shroud is Type 304L stainless steel), the 4-inch diameter Schedule 40 core spray sparger and the shroud-to-shroud support weld. The few Type 304 stainless steel unmitigated piping weld were also evaluated. It was assumed that the initial defect/intergranular attack (IGA) as produced by the sulfate/chloride intrusion environment was a "short crack" (2 mils deep) and that this "short crack" was satisfactorily modeled by [redacted] (Ref. 45). All the cracks were assumed to be circumferential in orientation. It was assumed that the non-intrusion control "short crack" was 0.1 mils deep and that this very shallow "short crack" could develop a local crevice chemistry.

As noted above, the degree of sensitization was assumed to be [redacted] representative of weld sensitization) and the future Fermi 2 reactor water conductivity was assumed to be 0.10 μS/cm. The average ECP of the Type 304 stainless steel core shroud and core spray sparger was assumed to be [redacted]. The average ECP of the nickel-base alloy shroud-to-shroud support weld was assumed to be [redacted] (except for Table 6-3.1-1), while the feedwater piping ECP was assumed to be [redacted] No irradiation effects on materials, axial cracking or crack branching were considered.

Figure 6-3.3-1 indicates little crack propagation after the first several months of restart for a conservatively assumed weld sensitized Type 304 stainless steel shroud the Fermi 2 shroud is Type 304L stainless steel). After ~2.5 years of post-intrusion exposure, a readily measurable crack depth (~100 mils) could be expected. The shift of the non-intrusion shroud curve to longer times was estimated from the amount of time to grow a "short crack" from 0.1 to 2 mils (38 months) in the nominal Fermi 2 core environment using the [redacted] model. The relative position of the two curves suggest that the planned Fermi 2 internals inspection frequency should be doubled since it appears that the estimated time to reach a fixed crack depth for the intrusion model is approximately one half the non-intrusion model time.

A model evaluation was also attempted for a non-sensitized Type 304L stainless steel Fermi 2 shroud [redacted] with no radiation effects, but since essentially no crack growth was calculated, a plot of crack growth versus time was not warranted. A new version of the [redacted] model incorporating the effects of irradiation on the degree of sensitization (EPR)/radiation induced segregation (RIS), material yield stress and local ECP, etc. will be used to evaluate the Fermi 2 shroud in the future.

For the 4-inch Type 304 stainless steel Schedule 40 Fermi 2 core spray sparger, Figure 6- 3.1-2 reveals a delay in crack growth of approximately 54 months without the intrusion. Since the ratio between the intrusion and non-intrusion model curves (at 100 mils of IGA) is calculated at ~2.4, a doubling of the inspection frequency again seems reasonable. As was the case with sulfate data described above, it is the ratio between the two evaluations that is most relevant, not so much the absolute model calculated values.

Due to the low ECP [redacted] and assumed future low conductivity (0.13 μS/cm), little crack growth is predicted for the 24-inch piping regardless of intrusion history. The model predicts essentially no growth even with the assumed initiated 2 mil short crack. For example, the model suggests only 1.3 mils of growth (2 to 3.3 mils) in a clean post-intrusion environment after ~20 years of exposure. Therefore, the model suggests no IGSCC concern for the 24-inch welded pipe. Obviously, the non-intrusion model evaluation, based again on the amount of time to grow a "short crack" from 0.1 to 2 mils, also suggests no IGSCC concern.

Table 6-3.1-1 presents a summary of selected Fermi 2 vessel internal components and the relative intrusion/non-intrusion crack depth ratios based on time to reach 100 mils of crack depth. (Fermi 2 components that received MSIP are considered mitigated and were not evaluated.) Although many of the earlier noted assumptions are not accurate (e.g., ECP values) for all the components evaluated, the assumptions appear reasonable for comparing crack growth penetration ratios of a single component. However, changing the ECP will change the calculated crack depth ratio where the lower the ECP, the higher the ratio. For example, for ECPs of [redacted] the calculated crack depth ratios are [redacted] respectively. This result is reasonable since the more aggressive/oxidizing the environment, the smaller the crack growth contribution of other environmental parameters such as conductivity (i.e., higher ECPs overwhelm other environmental factors). However, these lower ECPs with higher crack growth ratios are accompanied by significantly longer times to achieve the 100 mil crack depth. [redacted] Therefore, the doubling of the inspection frequency remains reasonable. Finally, it also appears that the crack depth ratios are fairly independent of stress profiles and stress intensity, as illustrated in Table 6-3.1-1.

[redacted] calculations were performed to evaluate the effect of the Fermi 2 restart water chemistry on future materials performance. Again, assuming an initial flaw of 2 mils,

Figure 6-3.1-3 reveals the difference in core spray sparger performance between an assumed "worst case" coolant cleanup restart as characterized by a series of two-week (360 hours) exposures of 0.5, 0.4, 0.3 and 0.2 µS/cm conductivities followed by continuous 0.10 µS/cm operation and an "instant" clean 0.10 µS/cm operation. The model suggests that the 100 mil defect would appear approximately one year earlier for the "worst case" example.

Figure 6-3.1-4 reveals the relative effects of post-intrusion water chemistry on the highly stressed shroud-to-shroud support weld. Although the absolute values of the model crack growth rates are high, the relative positions of the curves indicate the effect of conductivity and ECP. There is a significant materials performance improvement in reducing the conductivity from [redacted] µS/cm and complete crack mitigation with HWC. In fact, the implementation of HWC at Fermi 2 would essentially eliminate Fermi 2 materials performance concerns.

Again prudent judgment should be exercised in the application of these figures and Table 6-3.1-1, since these model evaluations are only an engineering judgment based on best-estimate assumptions and obviously cannot be warranted for accuracy.

Table 6-2.2-1 Severe Transients in BWRs

Rank	Plant	Max Cond. µS/cm	pH, min/ max	Max Cl, ppb	Max SO4 ppb	Power Level	Date yr-mo-d	Comments
1	**Fermi 2**	**180.0**	**10.6**	**12000**	**10000**	**P**	**931225**	**Turbine Blade Through Condenser, Circ Intrusion**
2	AG	95.0	4.5	100		P	780307	Cond Demin Resin Bleed Through
3	AG	88.0				P	800802	Condensate Demin Resin Intrusion
4	**AL**	**84.0**	**3.2**	**14500**		**P**	**720901**	**Condenser Leak, Demin Depleted**
5	ND	72.0		560		P	660820	
6	AG	70.0	4.6	198		P	771116	Crud & Condensate Demin Resin Intrusion
7	N	54.0	3.8			P	740804	Resin Bead Intrusion *
8	AB	40.5	3.9			P	740608	Air/Air Resin Mixture Injected into Rx from RWCU
9	**N**	**33.0**	**4.0**		**	**P**	**740426**	**Resin Bead Intrusion ***
10	AC	30.0				P	710903	High Conductivity Water in CST
11	ND	28.5				P	661130	
12	B	25.6	4.1	50		P	770601	Resin Intrusion
13	B	25.0		2500		P	810412	Condenser Leak
14	J	23.6				P	800205	Possible Condensate Demin Resin Intrusion
15	ND	23.0		3000		P	790407	Leakage of Cooling Water into RPV via Core Spray
16	W	23.0		30		P	730406	Air Injected Into Rx from RWCU
17	AG	22.0				P	771212	Condensate Demin Resin Intrusion
18	K	21.0	4.6	2500		P	820428	Trichloroethane via CST from Radwaste via Drain
19	AG	20.0	4.5			P	821004	
20	F	17.0				P	801001	Condenser Tube Leaks
21	C	14.0				P	750605	RWCU Out of Service
22	T	13.8	4.7	100		P	781110	Organic Intrusion via Condensate, Decon Deter/Oils
23	AB	13.5				P	740925	High Cond Water
24	AB	13.0		100		P	800428	Unknown (Long Shutdown)
25	T	12.1				P	780225	RWCU Resin Intrusion
26	O	12.0	4.8	50		P	761025	RWCU Resin Trap, RWCU Inoperable
27	Q	12.0				P	750702	Condenser Tube Leak
28	T	11.8				P	800812	Organic Intrusion
29	Q	11.5	4.8	60		P	750127	RWCU Resin Intrusion
30	ABW	11.3	4.7			P	830106	Possible Condensate Demin Resin Intrusion
31	B	10.8	4.5	50		P	750601	Resin from Fluffing Condensate DF/D
32	AG	10.6	4.5	100		P	730507	RWCU Resin Intrusion
33	Q	10.0				P	741208	Condenser Leak
34	AG	10.0				P	820818	RWCU Resin Intrusion
35	H	9.2	7.4	57		P	780211	Condensate Demin Resin Intrusion
36	B	8.2	4.3	50		P	751210	Washout of Impurities from Turbine
37	B	8.0	5.0	500		P	790516	
38	B	7.5				P	810411	RWCU Resin Intrusion
39	C	7.1		100		P	811010	Decomposition of Radwaste Resins due to Hot Water
40	C	6.5				P	810210	Caustic Intrusion via Condensate Storage
41	K	6.2	4.8	20		P	741118	Suspected Resin Intrusion
42	O	5.8	4.5	50		P	730812	Suspected Resin Intrusion
43	AA	5.6				P	700123	Resin Intrusion When C/D Returned to Service
44	B	5.4	4.7	50		P	751218	Probable RWCU Resin Intrusion
45	H	5.1		68		P	770727	Condensate Demin Resin Intrusion, Anion Rich
46	B	5.1				p	810220	Organic Intrusion via Radwaste
47	O	5.1	4.8	50		P	760806	Condensate Demin Resin Intrusion

Table 6-2.2-1

Severe Transients in BWRs (continued)

Rank	Plant	Max Cond. µS/cm	pH, min/max	Max Cl, ppb	Max SO4, ppb	Power Level	Date yr-mo-d	Comments
48	C	5.0		100		P	750309	Possible Condensate Demin Resin Intrusion
49	Q	4.9	4.9	50		P	760522	Suspected Resin Intrusion
50	T	4.5	5.0	50		P	781227	Organic Intrusion via Condensate System
51	Q	4.3	4.9	48		P	760221	Suspected Resin Intrusion
52	K	4.1	5.1	80		P	741015	RWCU Resin Intrusion
53	C	3.3	5.2	38		P	750309	Possible Resin Intrusion
54	**AL**	**3.3**	**5.4**	**50**		**P**	**770126**	**Improper Rinse of Condensate Demin**
55	B	3.2				P	810715	RWCU Resin Intrusion
56	S	3.2	4.7	495		P	780131	Resin Intrusion
57	H	3.0	5.6	96		P	750902	Suspected Resin Intrusion
58	B	2.9	5.4	50		P	751126	Probable RWCU Resin Intrusion
59	T	2.8	5.2	65		P	770912	Improper Rinse of Condensate Demin
60	B	2.7	7.6			P	750626	Resin Intrusion
61	T	2.3				P	800824	Organic Intrusion
62	T	2.2	5.5	50		P	790108	Suspected Organics in Condensate Storage
63	Y	1.8	5.4	355		P	781208	Condensate Demin Resin Intrusion
64	AJ	1.4				P	750906	Suspected Floc/Filter Aid/Surface from Radwaste
65	AC	1.4	5.6	83		P	741125	Valving Error During Resin Transfer
66	H	1.4	8.1	38		P	780112	Condensate Demin Resin Intrusion
67	H	1.1	8.8	72		P	780511	Condensate Demin Resin Intrusion
68	Q	1.1	5.6	30		P	770225	Suspected Resin Intrusion
69	P	1.0				P	810622	Oil Intrusion Into Hotwell
70	W	1.0				P	811030	Glycol Intrusion via Radwaste
71	AS			725		P	711113	High Feedwater Conductivity
72	B			1200		P	760708	Condensate System Momentarily Bypassed
73	AR			600		P	750103	RWCU Out of Service
74	B			540		P	780129	
75	B	641.0	3.5	87000		S	790426	Cooling Water Ingress from RHR, RPV H2O to Hotwell
76	B	423.0	3.2			S	740801	Acid into RPV from Demin Storage Tank
77	H	140.0				S	760519	
78	T	45.9	3.8	244		S	761103	Torus Water Pumped into RPV Prior to Startup
79	B	13.3		1800		S	760520	
80	A	13.0				S	780801	Leak in RHR Heat Exchanger
81	B	12.9				S	770917	RWCU Out of Service
82	T	12.1				S	800815	
83	**AL**	**11.6**				**S**	**730903**	**RWCU Out of Service**
84	O	11.2				S	801219	
85	B	11.2				S	800822	
86	B	10.5	5.6	140		S	780923	RWCU Resin Intrusion
87	F	10.5				S	820427	Possible Organic Intrusion
88	H	10.3				S	750405	RWCU Out of Service
89	AS	10.0		730		S	720604	Depleted RWCU Demin
90	Q	5.0	5.5	60		S	740829	Condensate Demin Resin Intrusion

Table 6-2.2-1

Severe Transients in BWRs (continued)

Rank	Plant	Max Cond. µS/cm	pH, min/ max	Max Cl, ppb	Max SO4, ppb	Power Level	Date yr-mo-d	Comments
91	AX	4.5	5.2	220		S	830505	Organic Intrusion via Radwaste
92	B	4.2	5.3	600		S	781110	Organic Intrusion via Condensate, Decon Deter/Oils
93	AP	1.0				S	820900	Glycol Intrusion via Radwaste
94	O			500		S	801017	
95	F			700		S	800305	
96	AC			683		S	770309	
97	T			1200		S	790316	Condenser Leak, Condensate Depleted, Cl into CST
98	T			1300		S	790329	Condenser Leak, Condensate Bypassed, RWCU out
99	K					S	830213	Glycol into Radwaste, Detected Prior to Cond Stor
100	B			800		S	771206	RWCU out of Service

Note: BWRs Ranked in the Following Order:

1. Power (P) or Shutdown (S)
2. Conductivity

Other Notes:
* = Resin Beads Provide Long Term Low pH
** = High but unreported concentration sulfate present from resins

Table 6-2.3-1

Failure Events at Plant AL after Fall of 1972

Cycle	EOC Date	Reload	EOC GWD/MT	# Rods Failed	Failure Mechanism	Design
1	1 September 1972	IC	8.4	80	PCI	GE2
2	30 August 1974	IC	12.7	26	PCI	GE2
3	12 September 1975	IC	13-15	31	PCI	GE2
3	12 September 1975	IC	8.4	8	PCI	GE2

Table 6-2.3-2

Failure Events at Plant N after the Spring of 1974

Cycle	EOC Date	Reload	EOC GWD/MT	# Rods Failed	Failure Mechanism	Design
1A	6 June 1975	IC	5.0	0	—	GE3
1B	14 February 1976	IC	9.9	0	—	GE3
2	12 March 1977	IC	14-16	0	—	GE3
3	17 March 1978	IC	19.0	0	—	

Table 6-2.4-1

Vessel Internals Component List and Recommendations

Component	Material	Wetted Crevice	Stresses	Rank	Recommendations				
					Replace	Inspection Imm. Imp.	Inspection Baseline	ISI Method	Flush
Guide Rod Bracket	[redacted]	No	Low						
Guide Rod		No	Low						
Surv Specimen Holder Spt Brkt		No	Low						
Surv Specimen Holder		Yes	Low						
RPV Flange and Seal Surface		Yes	Medium						
Shroud Support		No	Low-Medium						X-vacuum
Control Rod Guide Tube		Yes	Low						
CRD Stub Tube		No	Medium						
CRD Return Nozzle/Cap		No	Low-Medium						X
Incore Housing Penetration		Yes	Medium						
Incore Housing Guide Tube		Yes	Low						
Incore Hsg. Guide Tube Stabilizer		Yes	Low						
CORE Delta P & SLC Nozzle		Yes	Medium						
CORE Delta P & SLC Piping		Yes	Low						
RPV Bottom Drain Nozzle		No	Low-Medium						
Recirc Inlet Nozzle Safe End		No	Medium	4				UT/2 0R 3	X (Note B)
Recirc Inlet Nozzle Thermal Sl		No	Low-Medium						
Recirc Outlet Nozzle/Safe End		No	Medium	4			X	UT (Note C)	
Feedwater Nozzle/Safe End		Yes	Medium	6			X	VT (Note A)	
Feedwater Nozzle Thermal Sl		Yes	Low-Medium						X (Note B)
Feedwater Sparger		No	Low						
Feedwater Support Brkt		No	Low						
Core Spray Nozzle/Safe End		No	Medium						
Core Spray Nozzle Thermal Sl		Yes	Low						X (Note B)
Core Spray Internal Piping		Yes	Low						X (Note D)
Core Spray Pipe Support Brkt		No	Low						
Core Spray Sparger		Yes	Low						X
Jet Pump Riser		Yes	Low-Medium						
Jet Pump Riser Brace		Yes	Medium-High	3			X	VT	
Jet Pump Diffuser		No	Low						X
Jet Pump Sensing Line		Yes	Low						
Jet Pump Beam		Yes	High	2	X				
Jet Pump Instrument Nozzle		Yes	Medium	6			X	UT	X (Note B,D)
Shroud		No	Low						
Shroud to Shroud Support Weld		Yes	Medium						
Shroud Head Bolt Lugs		No	Medium						
Shroud Head & Steam Separator		Yes	Low						
Shroud Head Bolts		Yes	Medium	1			X	UT	

Table 6-2.4-1

Vessel Internals Component List and Recommendations (Continued)

Component	Material	Wetted Crevice	Stresses	Rank	Recommendations				
					Replace	Inspection Imm. Imp.	Inspection Baseline	ISI Method	Flush
Top Guide	[redacted]	Yes	Low						
Top Guide Hold Down		Yes	Low						
Core Plate		Yes	Low						
Core Plate Bolts		Yes	Medium						
Access Hole Cover		Yes	Low						
Steam Dryer		Yes	Low-Medium						
Steam Dryer Support Brkt		No	Low-Medium				X	VT	
Steam Dryer Hold Down Brkt		No	Low						
Orifice Fuel Support Casting		Yes	Low						
Peripheral Fuel Support		Yes	Low						
Water Level Nozzle		No	Low-Medium						
Top Head Nozzle/Flanges		Yes	Medium						
Steam Nozzle/Safe End		No	Medium						
Note A Unclad Nozzle Inner Blend Radius Note B Nozzle annulus Note C 1 Nozzle By end of RF05 Note D Flush inside of piping/lines									

Table 6-2.4-2

Comparison of Fermi 2 Reactor Internal IGSCC Improvements to Reactor Internals that Have Experienced IGSCC

Component	Fermi 2 IGSCC Improvements	Recommendation for Additional Inspection or Replacement per Table 6-2.4-1
CRD stub tube	Cracks have been observed in furnace sensitized stainless steel material; whereas Fermi 2 has Alloy 600 materials which have provided better operating service but are still susceptible to IGSCC.	No
CRD return nozzle	This nozzle has been capped at Fermi 2 to eliminate thermal stresses. Since the nozzle [redacted] an Alloy 600 cap was installed prior to plant startup. The nozzle butter is susceptible to IGSCC.	No
In-core housings	No improvement.	No. Safe ends on recirc inlet, recirc outlet and jet pump instrumentation nozzles are more susceptible to IGSCC; therefore, inspection of these nozzles would bound the in core housings. No additional in-core housing inspection is recommended unless there is a significant concern identified during the inspection for Type 304 stainless steel.
Recirc inlet nozzle safe end	The original stainless steel safe end is in place, but the Mechanical Stress Improvement Process (MSIP) has been applied to increase resistance to IGSCC.	Yes
Recirc outlet nozzle safe end	Same as the recirc inlet nozzle.	Yes

Table 6-2.4-2 (Continued)

Comparison of Fermi 2 Reactor Internal IGSCC Improvements to Reactor Internals that Have Experienced IGSCC

Component	Fermi 2 IGSCC Improvements	Recommendation for Additional Inspection or Replacement per Table 6-2.4-1
Core spray nozzle safe end	Cracking has been observed in creviced stainless steel and Alloy 600 materials. The Fermi-2 safe ends were changed to a non-creviced low carbon stainless steel design prior to startup; however, the nozzle still has a[redacted]which is susceptible to IGSCC.	No
Core spray internal piping	No improvement.	No. Inspection required every outage as part of NRC IE Bulletin 80-13. No additional inspection recommended.
Core spray sparger	No improvement.	No. Inspection required every outage as part of NRC IE Bulletin 80-13. No additional inspection recommended.
Jet pump beam	No improvement.	Yes
Jet pump instrument nozzle safe end	The early jet pump instrument seal design which experienced cracking was a welded assembly which had eccentric reducers, and each of the welds was susceptible to IGSCC. The newer design which has been installed at Fermi 2 is a solid block design which has only one major weld at the safe end attachment.	Yes
Shroud	Cracking has been observed in high carbon stainless steel materials; whereas, Fermi 2 was constructed from 304L material, which is more resistant to IGSCC. L grade materials are still susceptible to irradiation assisted stress corrosion cracking (IASCC), but this does not occur until much higher radiation is accumulated during plant operation.	No
Shroud head bolts	No improvement.	Yes

Table 6-2.4-2 (Continued)

Comparison of Fermi 2 Reactor Internal IGSCC Improvements to Reactor Internals that Have Experienced IGSCC

Component	Fermi 2 IGSCC Improvements	Recommendation for Additional Inspection or Replacement per Table 6-2.4-1
Access hole covers	Cracking has been observed in creviced Alloy 600 materials. Fermi 2 has an alternate design which eliminated the Alloy 600 crevice, but still ha[redacted]eld materials which may have longer term cracking issues. One of the covers at Fermi 2 has a crevice in [redacted] stainless steel material.	No
Steam dryer	No improvement.	Yes. Steam dryer support bracket.

Table 6-2.4-3

Comparison of Fermi 2 Reactor Internals to Typical BWR Reactor Internals that are Susceptible but Have Not Experienced IGSCC

Component	Design Difference	Recommendation per Table 6-2.4-1
Shroud support	The typical BWR design has stilts supporting the shroud support plate which attach to the vessel bottom head. This design is made entirely from Alloy 600 materials and [redacted] weld materials which are very compatible with the reactor vessel low alloy steel material. Therefore, the stresses in this structure are very low and are generally compressive. For Fermi 2, the design has gussets on the top surface of the plate which help to react the dead weight loads of the shroud, top guide, and shroud head and separators. This design is also made from Alloy 600 materials an[redacted] weld material, but the stresses are larger and are generally tensile. Since the gussets protrude upward from the plate, there is a greater tendency to collect debris and corrosion products in the area.	Vacuum flat areas on horizontal plates.
Jet pump diffuser	The jet pump diffuser on the majority of BWR plants attaches to the shroud support plate using an adapter that welds directly to these components. On older BWRs a backing ring was used to weld the diffuser to the adapter, which created a stainless steel crevice condition. At Fermi 2, the adapter has a "J" shape which welds to the bottom of the support plate instead of the top. This shape creates a circular pocket area which will tend to collect corrosion products and debris. The attachment of the diffuser to the adapter does not have a backing ring and no crevice condition.	Flush by hydrolazing in pocket areas.
All internal bracket attachments	The majority of BWR plants have stainless steel brackets which are attached to weld buildup pads on the vessel which are also stainless steel. At Fermi 2, the stainless steel brackets were attached to welded pads on the vessel which are [redacted] materials. This was done because [redacted]aterials provide a good transition between stainless steel and low alloy steel because their coefficient of thermal expansion is between that of these two materials; however, the susceptibility of IGSCC is increased.	Steam dryer support bracket attachment weld recommended for inspection.

Table 6-2.4-4

CRD Hardware Inspection Components

Fermi 2 CRD Hardware Inspection Components					Recommendations				
CRD Components	Material	Met Cond.	Wetted Crevice	Stress	Replace	ISI Imm.	ISI Base	ISI Method	Flush
CRD Piston Tube	[redacted]	[redacted]	Yes	Low	No	Yes	Yes	GEI 92809	Yes
CRD Index Tube	[redacted]	[redacted]	Yes	Low	No	Yes	Yes	GEI 92809	Yes
CRD Collet Retainer Tube	[redacted]	[redacted]	Yes	Low	No	Yes	Yes	SIL 139	Yes

Table 6-2.4-5

LPRM and SRM/IRM Dry Tube Components

Fermi 2 LPRM/SRM IRM Dry Tube Hardware inspection Components									
					Recommendations				
Components	Material	Met Cond.	Wetted Crevice	Stress	Replace	ISI Imm.	ISI Base	ISI Method	Flush
NA200 LPRM Components (29)									
LPRM NA200 Housing	[redacted]	[redacted]	Yes	Low	No	No	No	N/A	No
LPRM NA200 Sensor/Cable	[redacted]	[redacted]	Yes	Low	Yes	No	No	N/A	No
LPRM NA200 Plunger	[redacted]	[redacted]	Yes	Low	No	No	No	N/A	No
LPRM NA200 Gland	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA200 Calibration Tube	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA200 Plunger Spring	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
NA300 LPRM Components (14)									
LPRM NA300 Housing	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA300 Sensor/Cable	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA300 Plunger	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA300 Gland	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA300 Calibration Tube	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
LPRM NA300 Plunger Spring	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
Original Equipment Dry Tubes (12)									
Dry Tube Housing	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
Dry Tube Plunger	[redacted]	[redacted]	Yes	Low	No	No	Yes	SIL 409	No
Dry Tube Plunger Spring	[redacted]	[redacted]	No	Low	No	No	No	N/A	No
Dry Tube Gland	[redacted]	[redacted]	No	Low	No	No	No	N/A	No

Table 6-2.5-1

Recommended Fuel Bundles for Fuel Deposit Sampling

Number of Bundles	Bundle Exposure # Cycles	Reload #	Discharge Cycle	GE Bundle Type
1	3	0	3	GE6
1	3	1	4	GE8
1	1	3	(Incore during Cycle 4, remain incore for additional exposure)	GE11

Table 6-2.5-2

Recommended Fuel Bundles Histories and Core Locations

		Exposure	Core Location by Cycle			
Bundle	Fuel Type	[GWD/MT]	1	2	3	4
LJK961	GE-6	26.5	(29,08)	(25,04)	(23,22)	
LYS486	GE-8	27.0		(27,54)	(21,58)	(23,22)
YJ2809	GE-11	11.0				(31,52)

Table 6-2.5-3

Fuel Hardware Components for Inspection

FERMI 2 Fuel Hardware Inspection Components									
					Recommendations				
Component	Material	Met. Cond.	Wet Crev.	Stres	Replace	ISI Imm.	ISI Base	ISI Method	Flush
Hex Nuts	[redacted]	[redacted]	Yes	Med	No	No	Yes	VT, PT, MET	No
Finger Springs	[redacted]	[redacted]	Yes	High	No	No	No		No
Locktab Washers	[redacted]	[redacted]	Yes	High	No	No	Yes	VT, PT, MET	No
Channel Spacer	[redacted]	[redacted]	Yes	Med	No	No	No		No
Lower Tie Plate	[redacted]	[redacted]	Yes	Low	No	No	No		No
Upper Tie Plate	[redacted]	[redacted]	Yes	Low	No	No	No		No
Expansion Spring	[redacted]	[redacted]	Yes	Med	No	No	Yes	VT,PT,MET	No
Spacar Springs	[redacted]	[redacted]	Yes	Med*	No	No	No		No
Channel Fasteners	[redacted]	[redacted]	—	—	—	—	Yes	VT, PT, MET	
- Guard	[redacted]	[redacted]	Yes	Low	No	No	—		No
- Spring	[redacted]	[redacted]	Yes	Med	No	No	—		No
- Lock Washer	[redacted]	[redacted]	Yes	High	No	No	—		No
- Cap Screw	[redacted]	[redacted]	Yes	Med	No	No	—		No

*(GE8/GE6 only)

Code to Met. Condition
A=Aged
CW=Cold worked
HTA=High Temperature Annealed

Code to Inpections
VT= Visual Inspection
PT=Penetrant Inspection (Hot Cell)
MET= Metallurgical Evaluation (as necesary) (Hot cell)

Table 6-2.6-1
Vessel Interfacing Piping Systems Recommendation

Nozzle	First Barrier	Status	Inspection	Flushing
Head spray-head	Flange	Steam only environment		
Vent-head	Dw MOV	Steam only environment		
Reference leg tap-head	Condensing chamber	Steam only environment		
Main steam	MSIV	Steam only environment		
	SRV	Steam only environment		
	RCIC MOV	Steam only environment		
	HPCI MOV	Steam only environment		
	MSL drains	Steam only environment		
Reference leg instrument taps	Condensing chamber	Steam only environment		
Narrow range variable instrument taps	Transmitter	Stagnant line -no flow		X
Feedwater	Main condenser	Entire system exposed to high conductivity water		X
	RWCU return	Effluent relatively low conductivity with RWCU maintained in operation		Instrument lines, dead legs
	RCIC return	System exposed to high cond. water for short time		X

Table 6-2.6-1 (Continued)
Vessel Interfacing Piping Systems Recommendation

Nozzle	First Barrier	Status	Inspection	Flushing
	HPCI return	System exposed to high cond. water for short time		X
Core spray	Injection MOV	Stagnant line		X
CRD return nozzle	Capped	Stagnant region		per Section 6-2.4
Wide range variable instrument taps	Transmitter	Stagnant line		X
Recirc. inlet	Recirc piping	Entire system potentially affected	Nozzle/safe end per Section 6-2.4	X
	RHR return	Entire system potentially affected		Instrument lines, dead legs
Recirc. outlet (suction)	Recirc piping	Entire system potentially affected	Nozzle/safe end per Section 6-2.4	X
	RWCU piping	System in operation		Instrument lines, dead legs
	RHR piping	System in operation		RHR trains operated and then isolated should be flushed
Jet pump instrument	Transmitter	Stagnant line	Nozzle/safe end per Section 6-2.4	X
SLC injection/core spray delta P	Transmitter	Stagnant line		X
	SLC check valve	Stagnant line		X
Bottom head drain	RWCU piping	System in operation in line is normally flowing		

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Table 6-3.1-1

Estimated Crack Growth Time Ratios Between Intrusion and Non-Intrusion Fermi 2 Environments for Reactor Internals

[redacted]

Effect of Various Sodium Salts on the [redacted] Ductility of FS Type 304

[redacted]

Figure 6-2.2-1. Effect of Sodium Salts on the [redacted] Ductility of Furnace Sensitized Type 304 Stainless Steel

Effect of Various Sodium Salts on the [redacted] Crack Growth Rate of FS Type 304

Crack Growth Rate, mils per hour

[redacted]

Figure 6-2.2-2. Effect of Sodium Salts on the [redacted] Crack Growth Rate of Furnace Sensitized Type 304 Stainless Steel

Acceleration Factor

[redacted]

Figure 6-2.2-3. Sulfate IGSCC Initiation Acceleration of Sensitized Type 304 Stainless Steel

Effect of Na_2SO_4 on IGSCC of Creviced Constant Load FS T304 in 8 ppm O2 - 250C

[redacted]

[redacted]

GE Proprietary Information

Figure 6-2.2-4 Effect of Sodium Sulfate on IGSCC of Creviced Constant Load Furnace Sensitized Type 304 Stainless Steel in 8 ppm Oxygenated Water at 250°C (482°F)

[redacted]

Relative IGSCC Resistance at 2.5 Sm
Creviced Constant Load - 8 ppm O2/288C

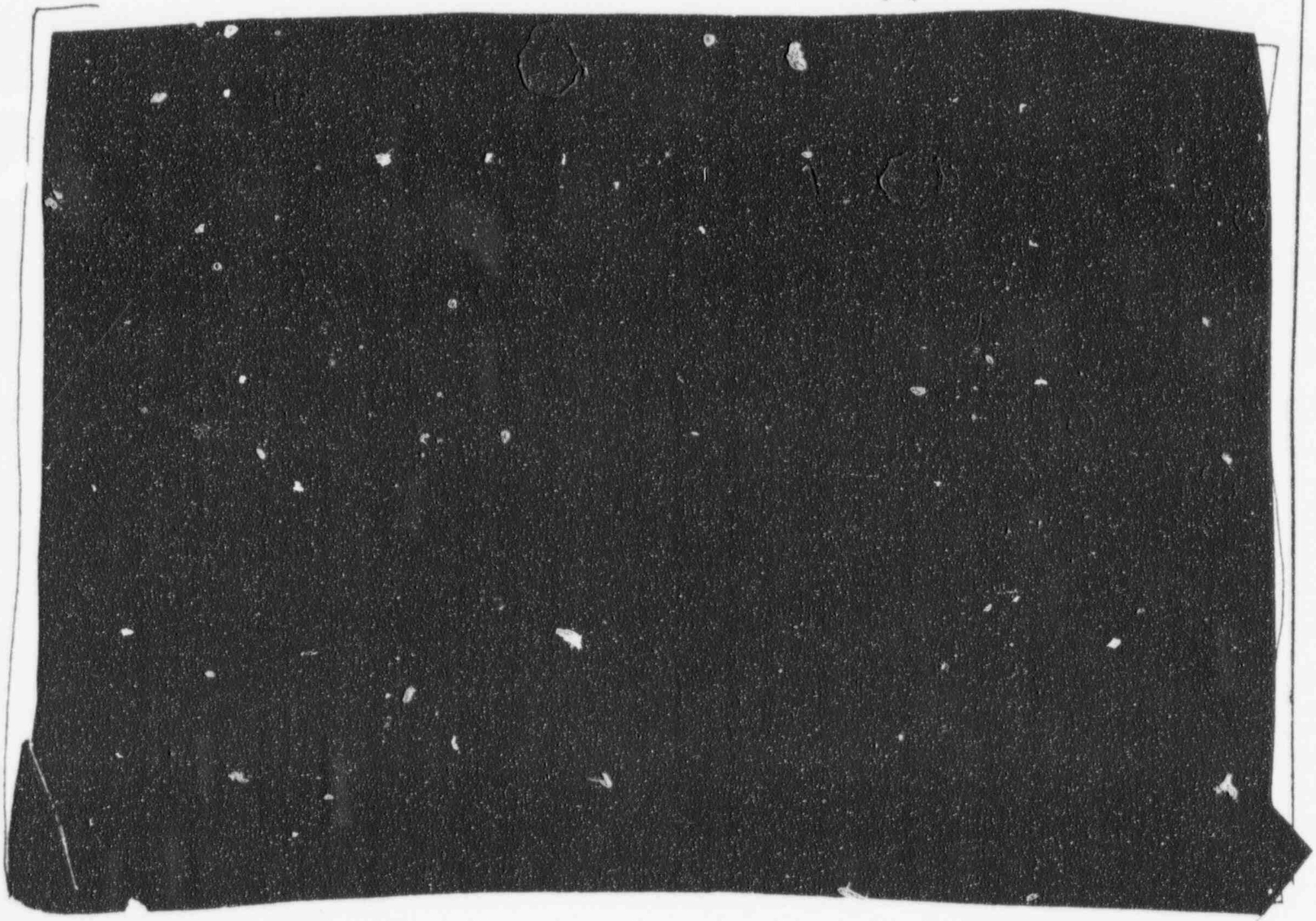


Figure 6-2.2-5. Relative IGSCC Resistance of Various Materials at 2.5 Sm, Creviced, Constant Load in 8 ppm Oxygenated Water at 288°C (550°F)

Relative IGSCC Resistance at 2.5 Sm Uncreviced Constant Load - 8 ppm O_2/288C

[redacted]

Figure 6-2.2-6. Relative IGSCC Resistance of Various Materials at 2.5 Sm in Uncreviced, Constant Load in 8 ppm Oxygenated Water at 288°C (550°F)

Figure 6-2.2-7. Effects of Oxygen and Chloride on Stress Corrosion Cracking of Austenitic Stainless Steels in High Temperature Water (250 - 350 °C [482 - 662°F])

TABLE 7-1

Control Rod Drive Parts

Elemental Composition

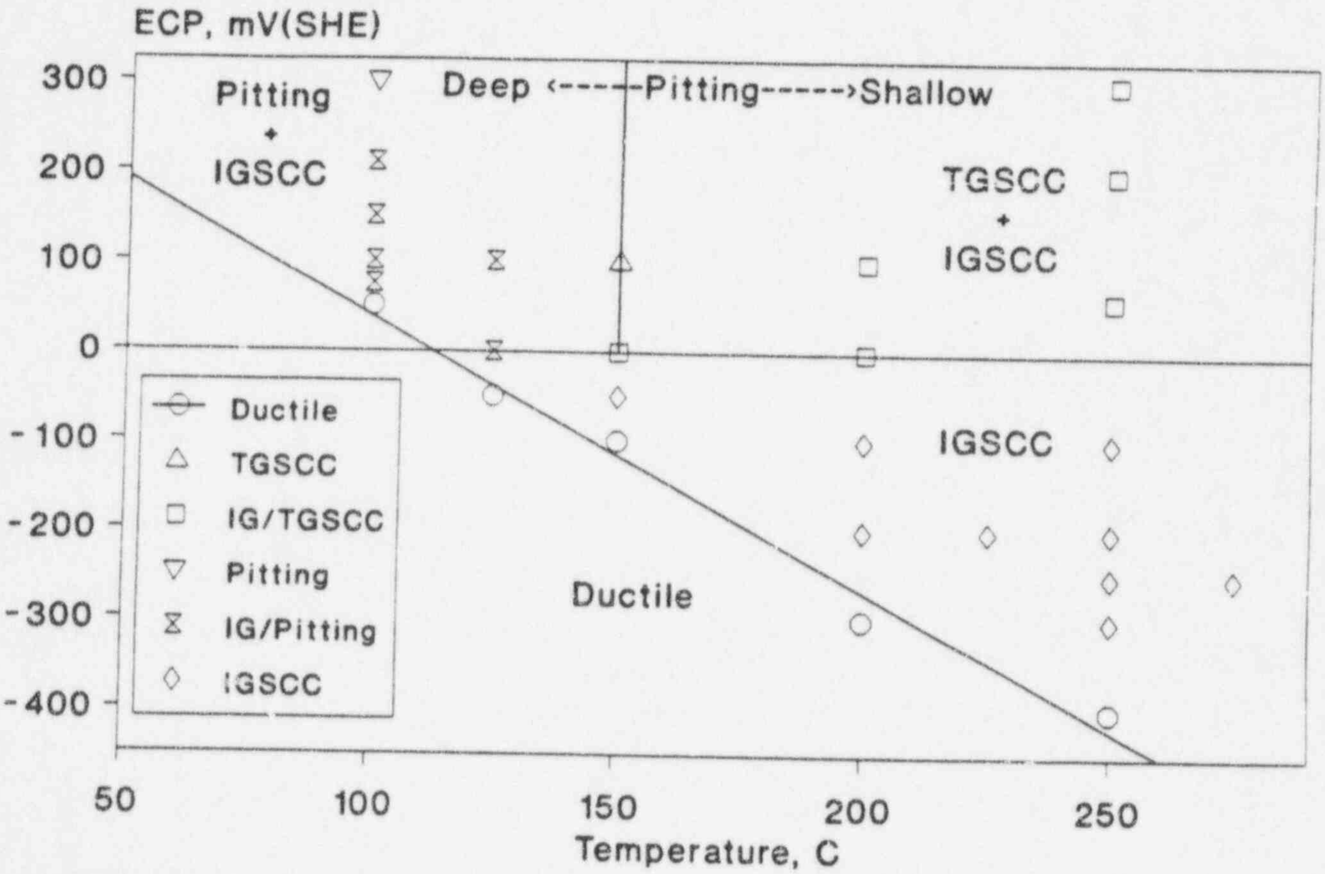
[redacted]

TABLE 7-2

EDS Results

[redacted]

FS Type 304 SS ECP/Temperature Diagram



0.01 M NaCl CERT
FS 650C/12 hours
L. F. Lin et al, Cor. Vol. 37, No. 11

Figure 6-2.2-8 FS Type 304 SS ECP/Temperature Diagram

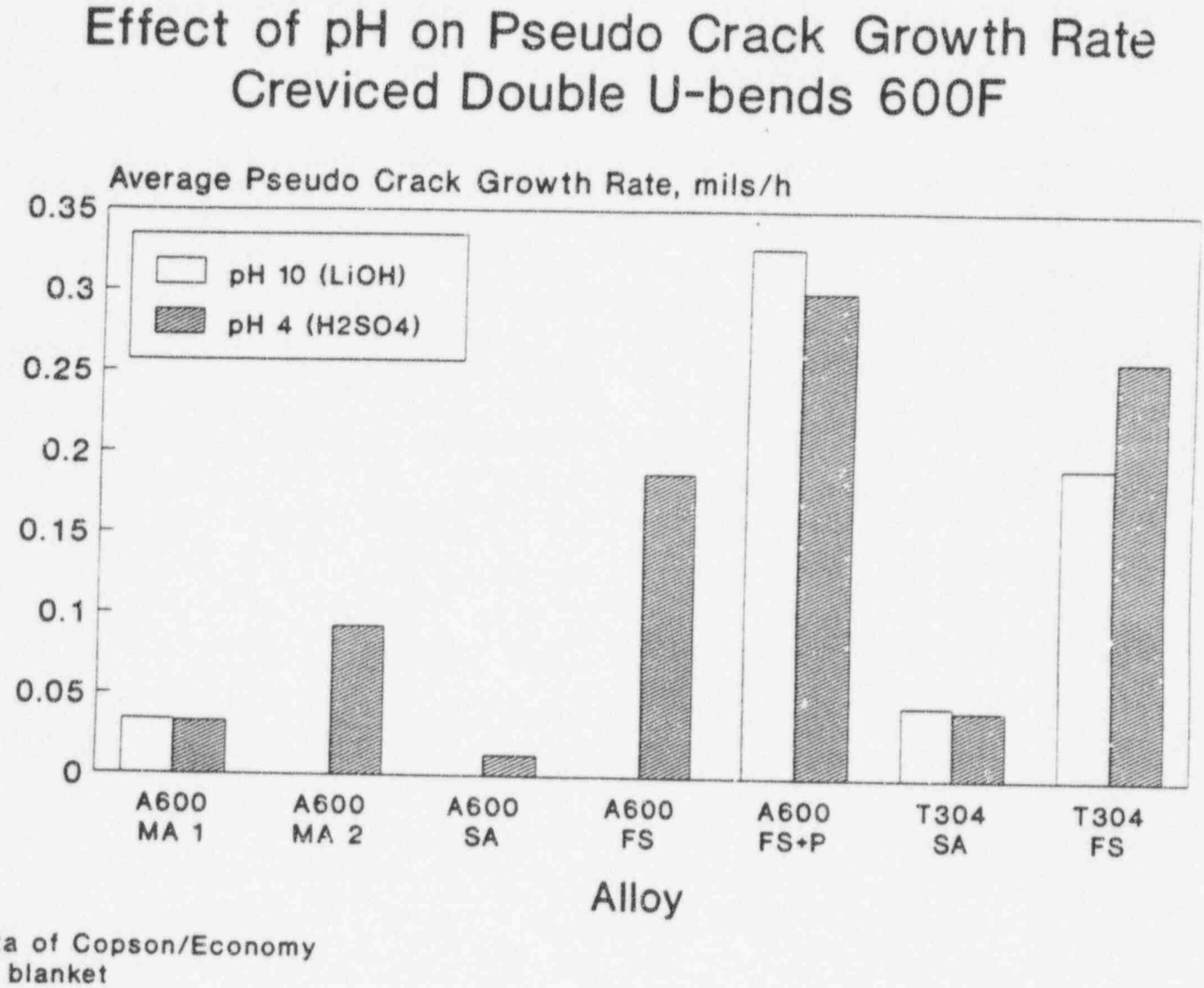


Figure 6-2.2-9 Effect of potential on the time to failure of sensitized (15 hours at 650°C) Type 304 stainless steel in Na_2SO_4 and NaCl solutions at 100°C (Ref. 17)

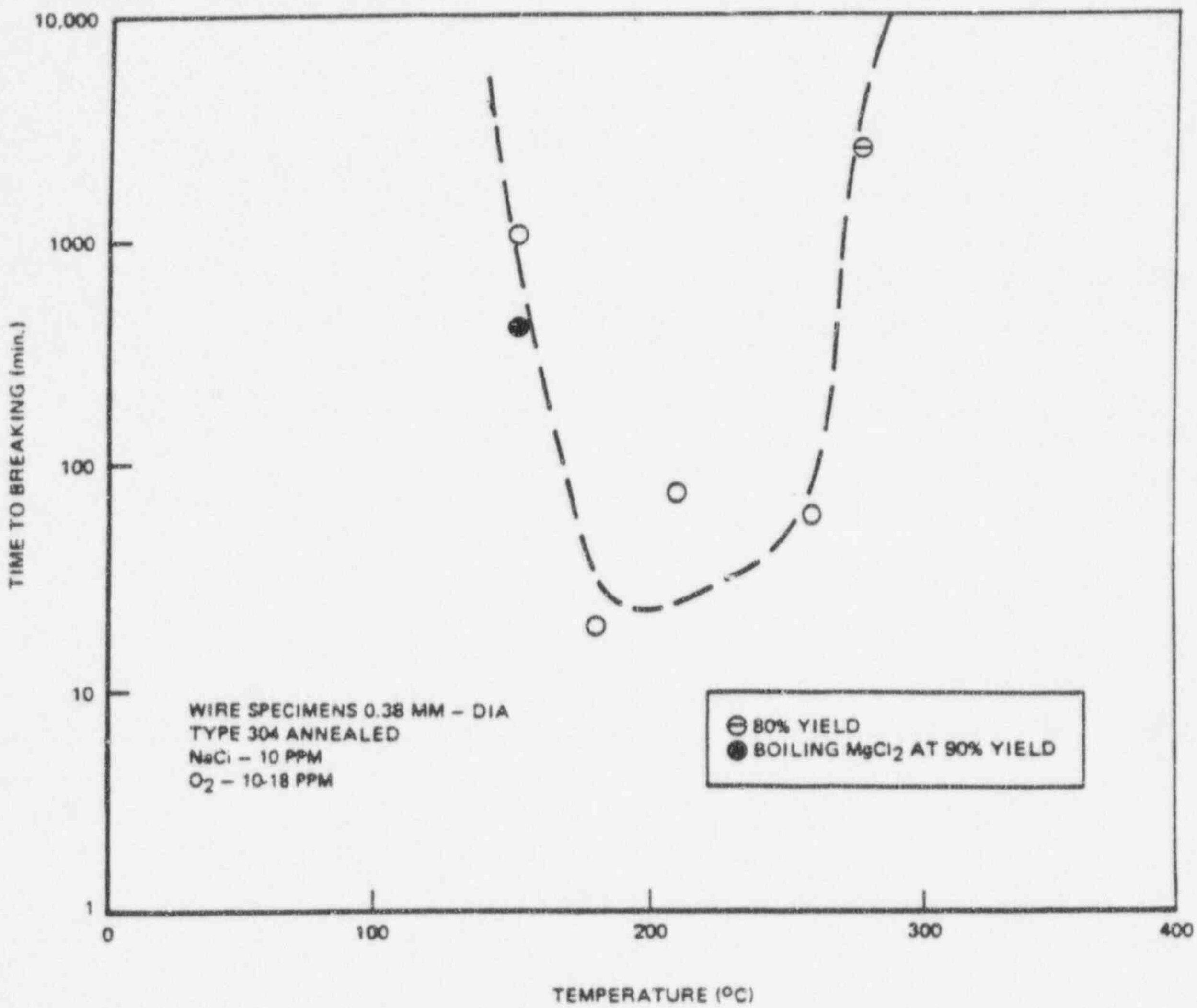
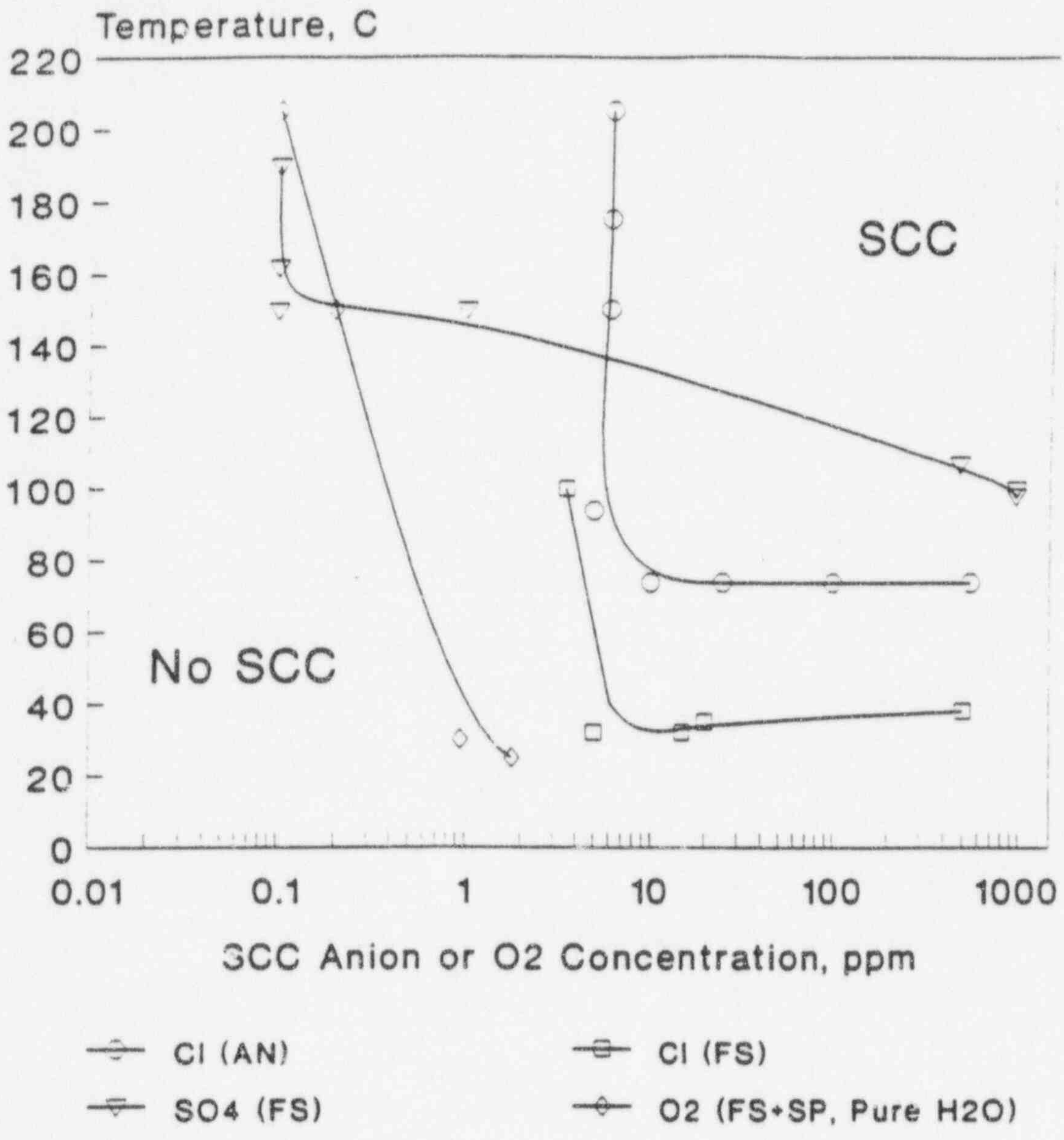


Figure 6-2.2-10. Time to cracking for Type 304 stainless steel loaded to 100% of its yield stress as a function of temperature in autoclave tests. Tensile specimen, 0.38 mm diameter (Ref. 18).



AN = annealed
FS = furnace sensitized
SP = shot peened

Figure 6-2.2-11 Effects of Anions or Oxygen on Stress Corrosion Cracking of Type 304 Stainless Steel in Neutral Water as a Function of Temperature

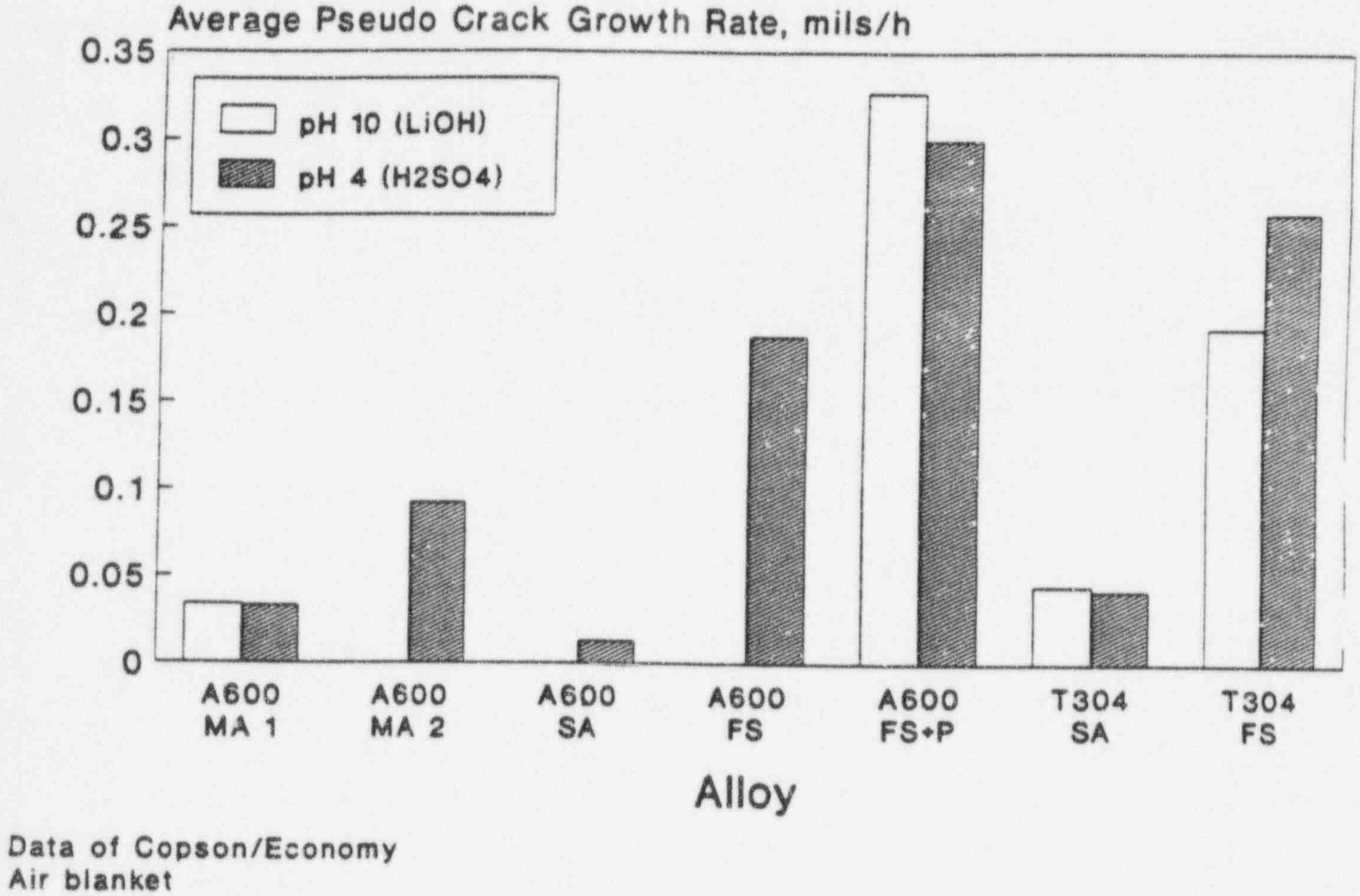


Figure 6-2.2-12. Effect of pH on the Pseudo-Crack Growth Rate of Creviced Double U-Bend Specimens at 600 °F (316°C)

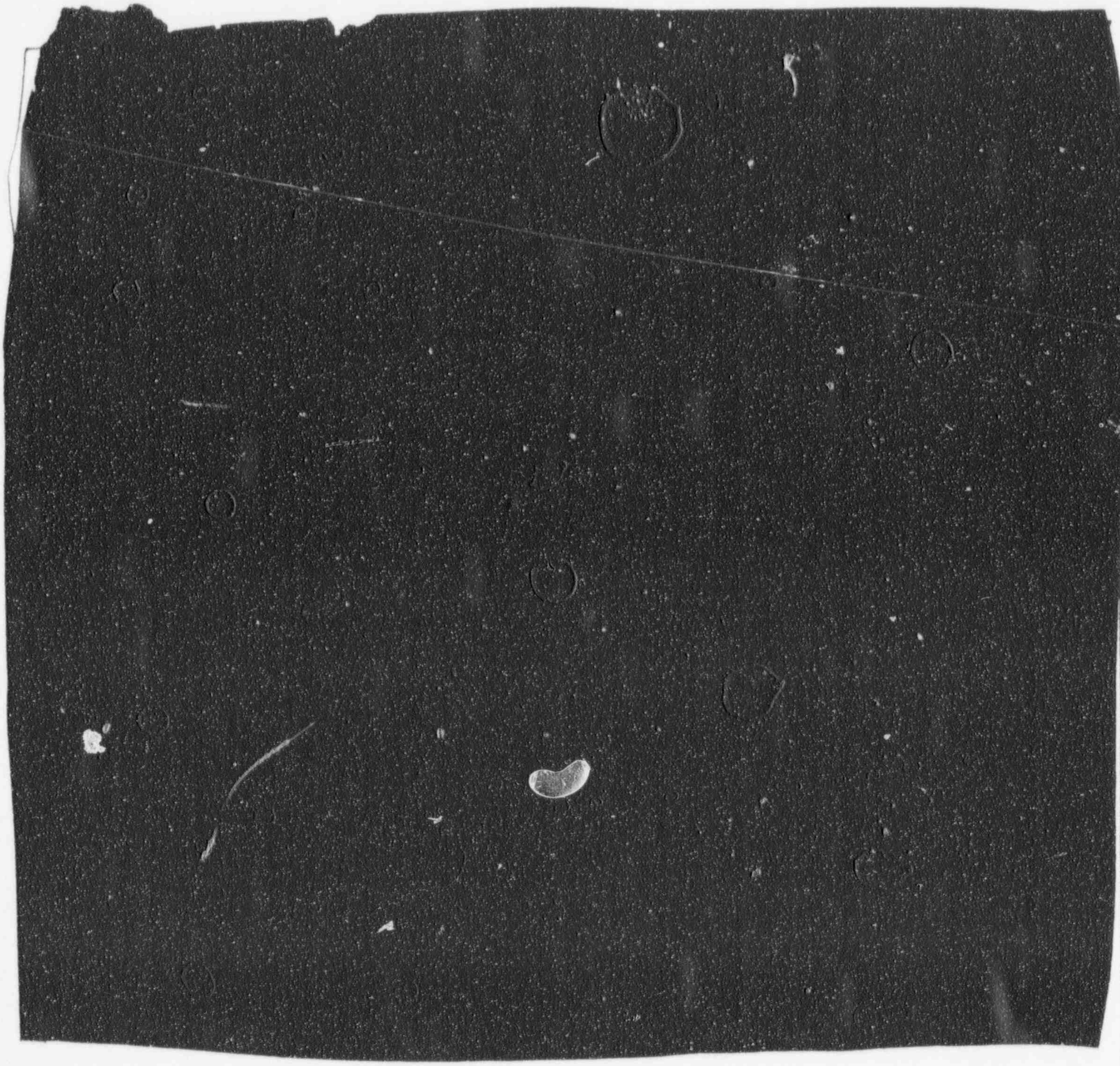


Figure 6-2.2-13 Effect of Impurities on Crack Initiation as Measured During Repeated Interruption During Slow Strain Rate Testing of Stainless in 288°C (550°F) Water

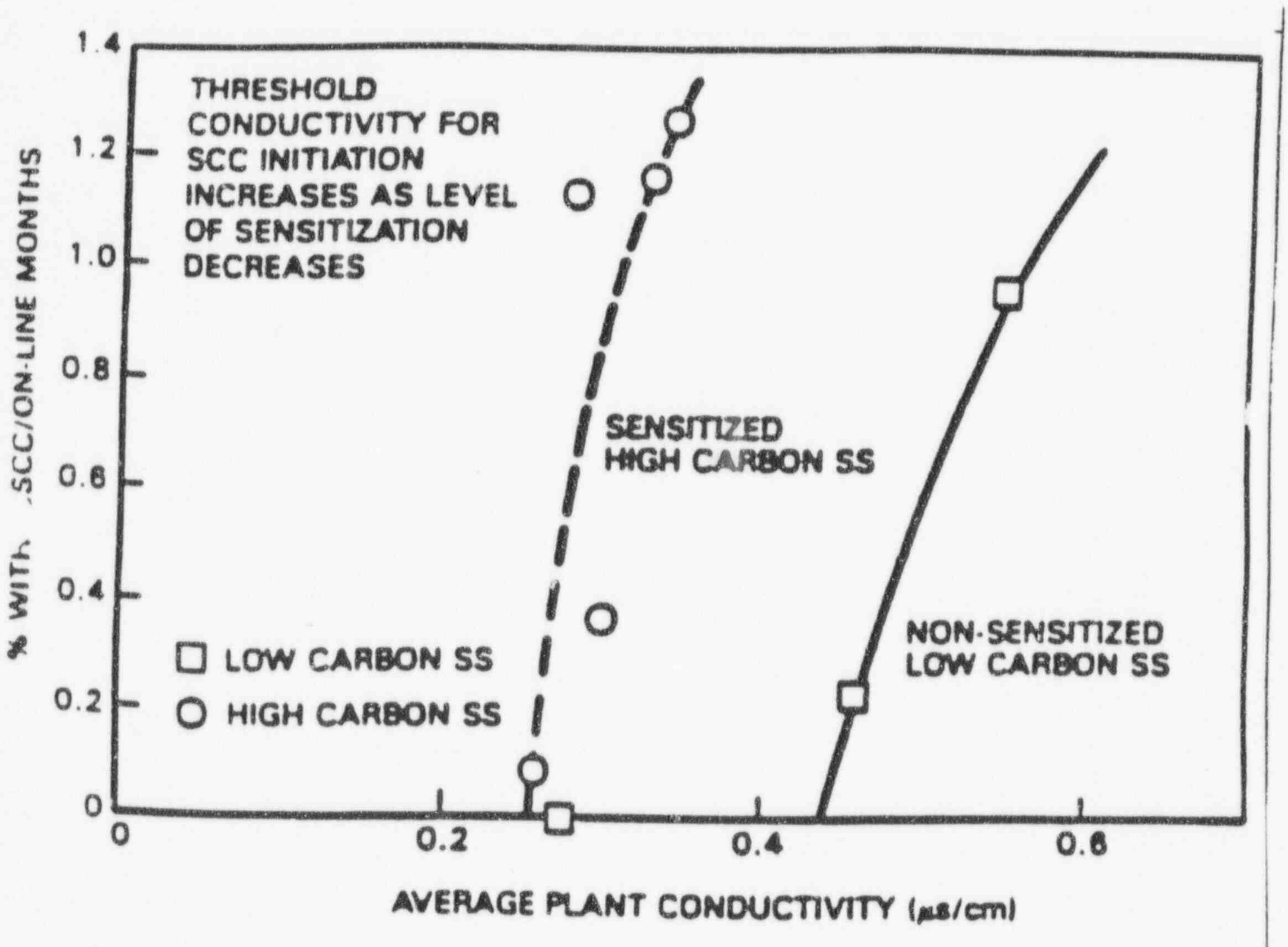


Figure 6-2.2-14 Correlation Between Plant Average Conductivity and IGSCC of Creviced Stainless Steel Safe Ends

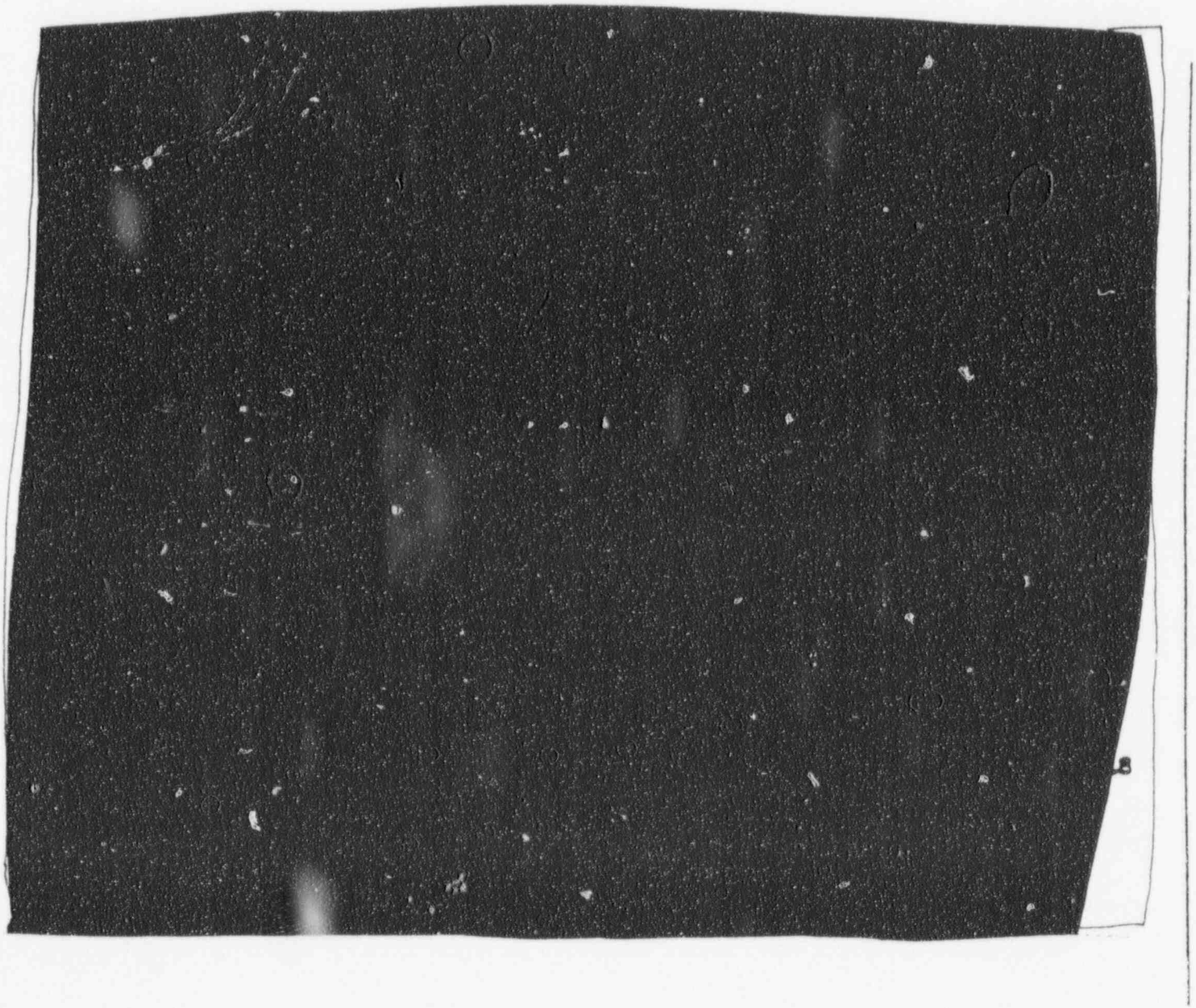


Figure 6-2.2-15. Correlation Between Plant Average Conductivity and IGSCC of Creviced Spot Welds in Stainless Steel Control Blade Sheaths

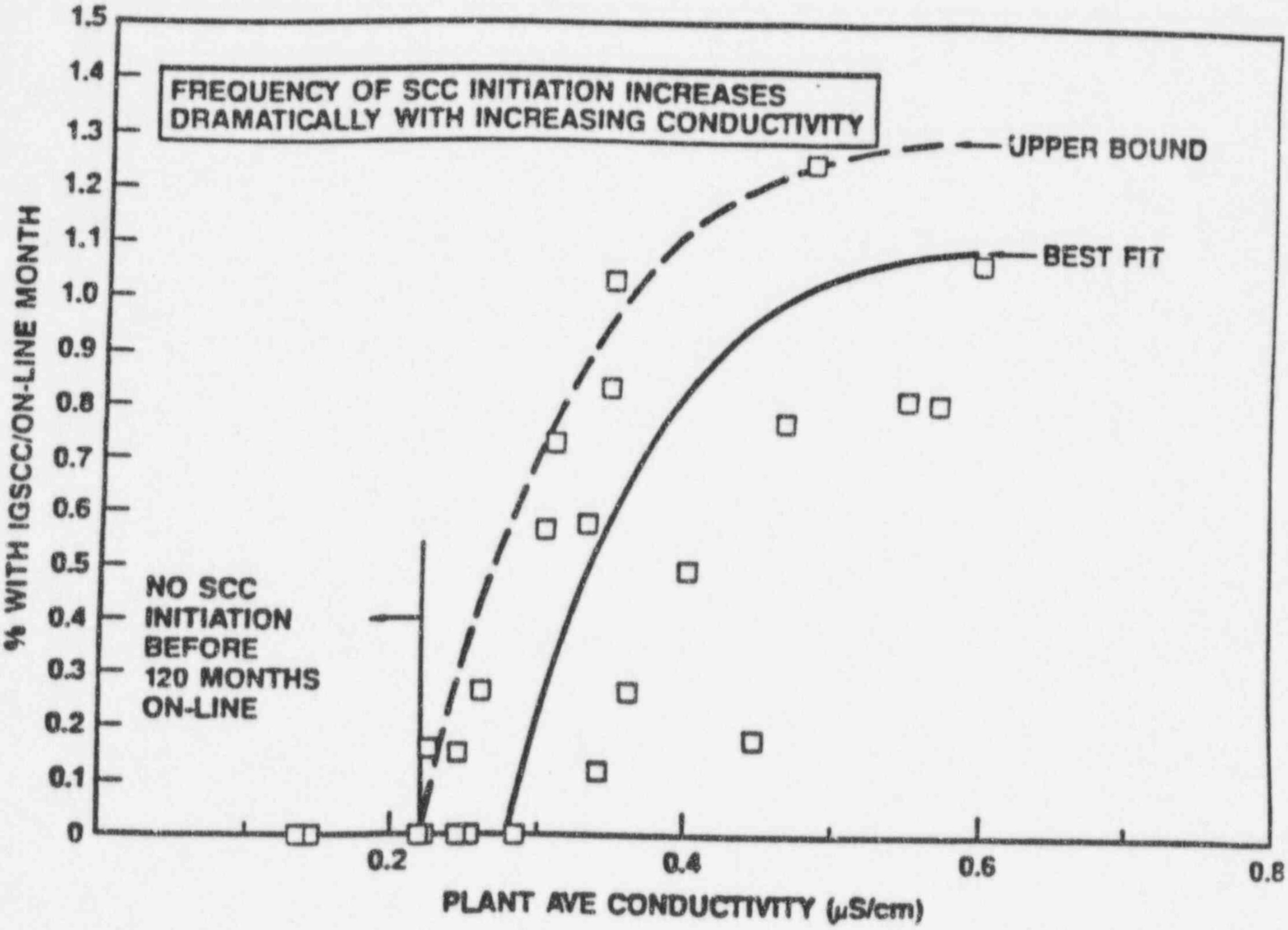


Figure 6-2.2-16. Correlation Between Plant Average Conductivity and IGSCC of IRM/SRM Dry Tubes

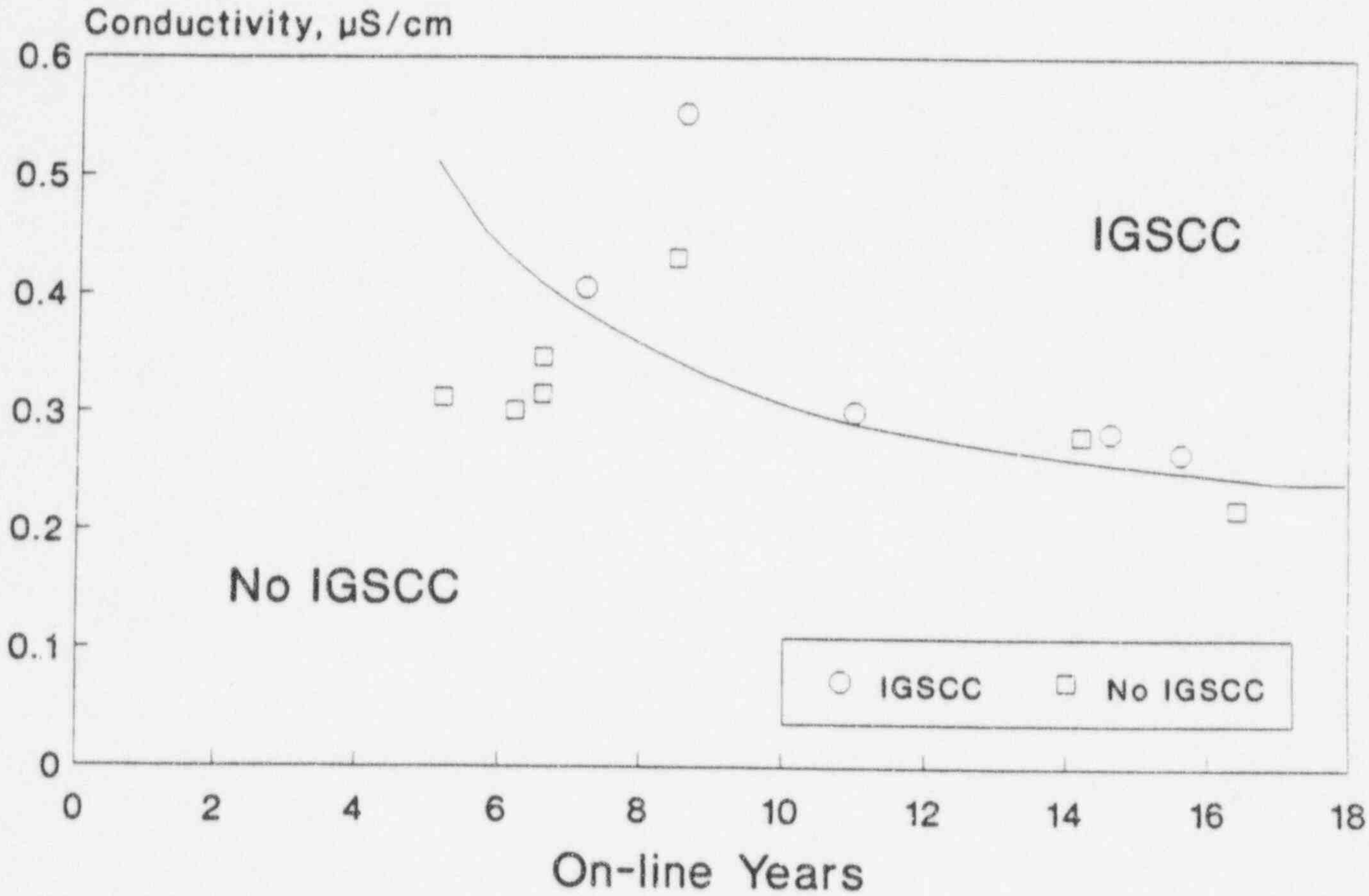
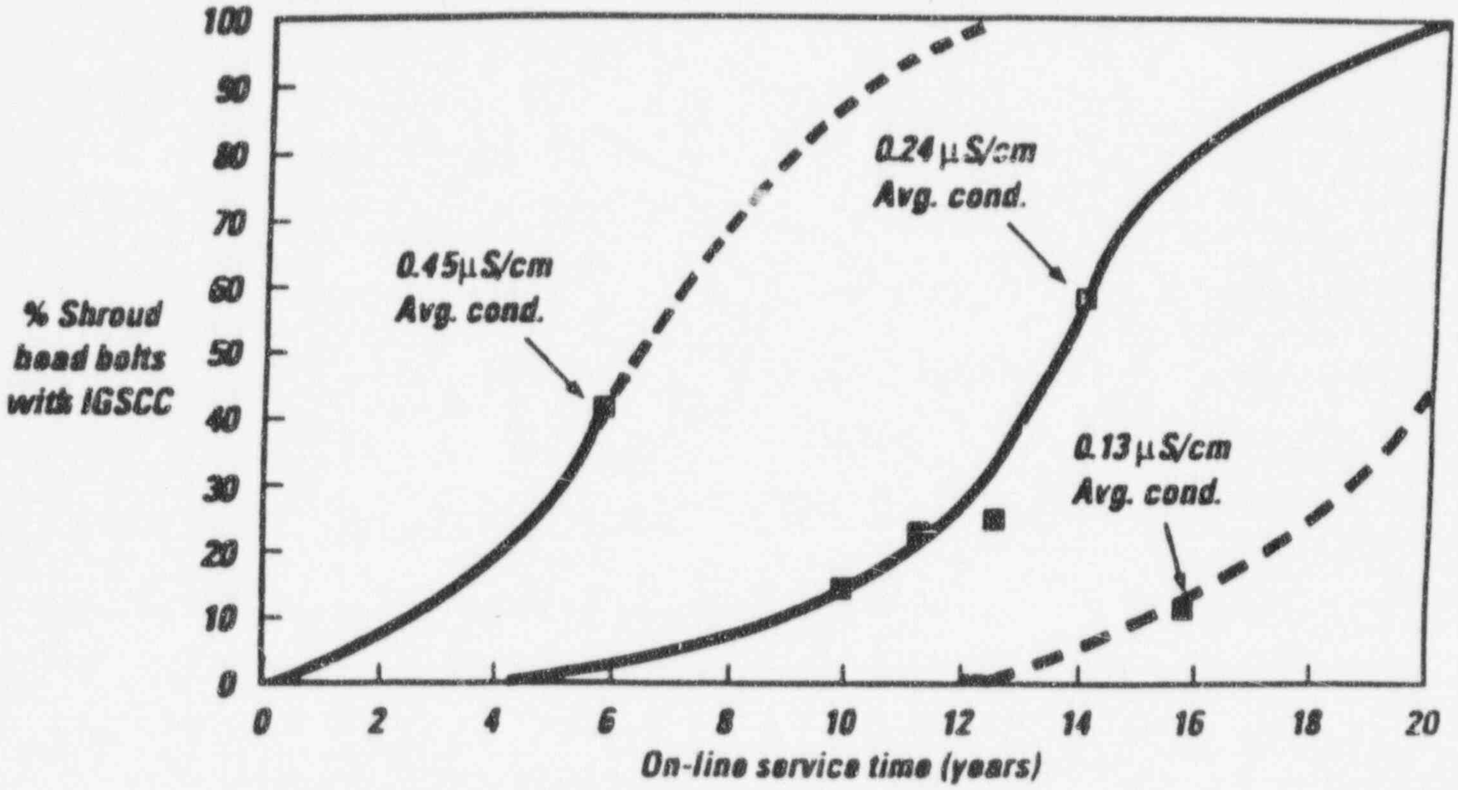


Figure 6-2.2-17. Correlation Between Plant Average Conductivity and IGSCC of Thin Access Hole Covers

IGSCC Field Experience



Creviced component IGSCC incidence increases with conductivity

High purity water can extend component life

Figure 6-2.2-18. Correlation Between Plant Average Conductivity and IGSCC of Creviced Alloy 600 Bolts

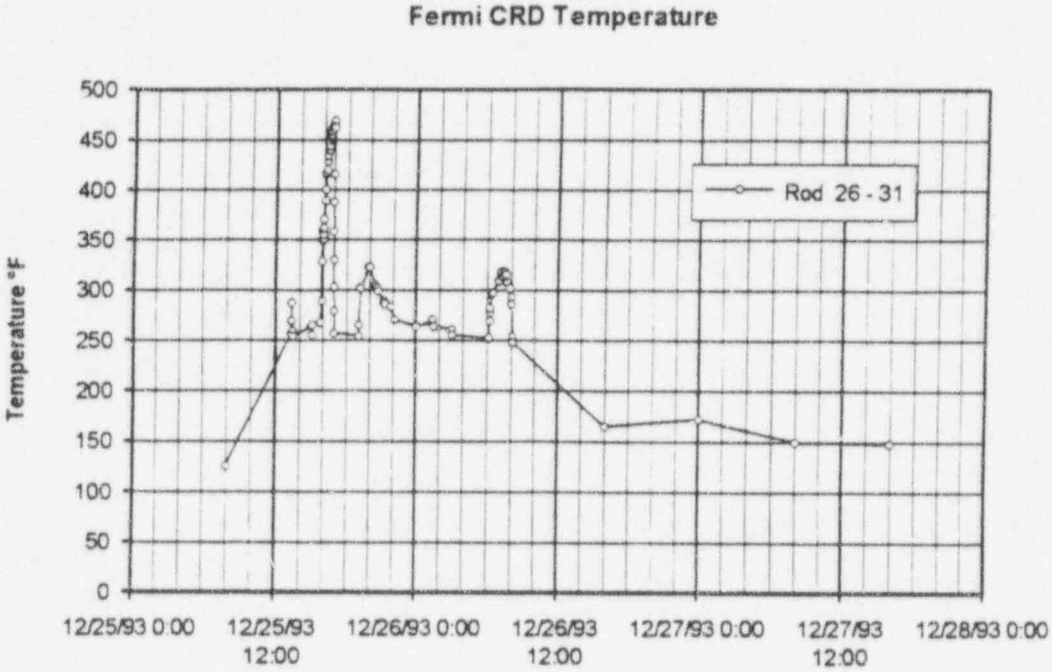


Figure 6-2.4-1 Temperature Profile at Typical Control Rod Drive

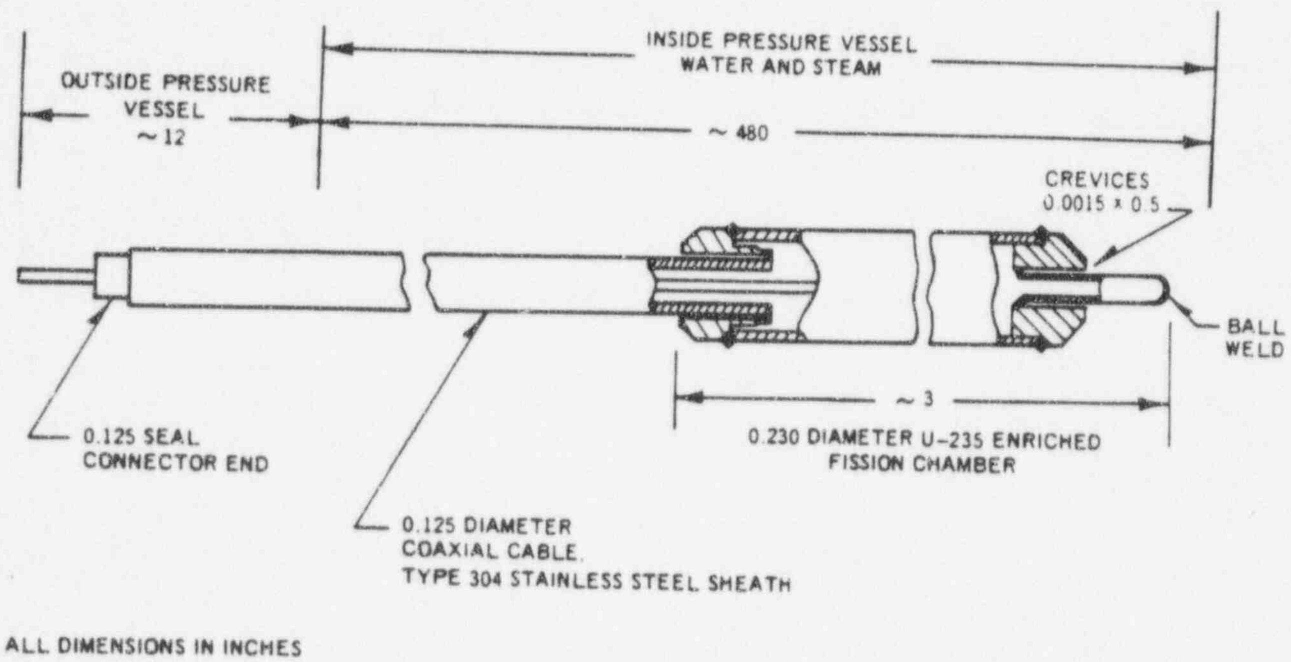


Figure 6-2.4-2. Schematic of NA200 LPRM Detector

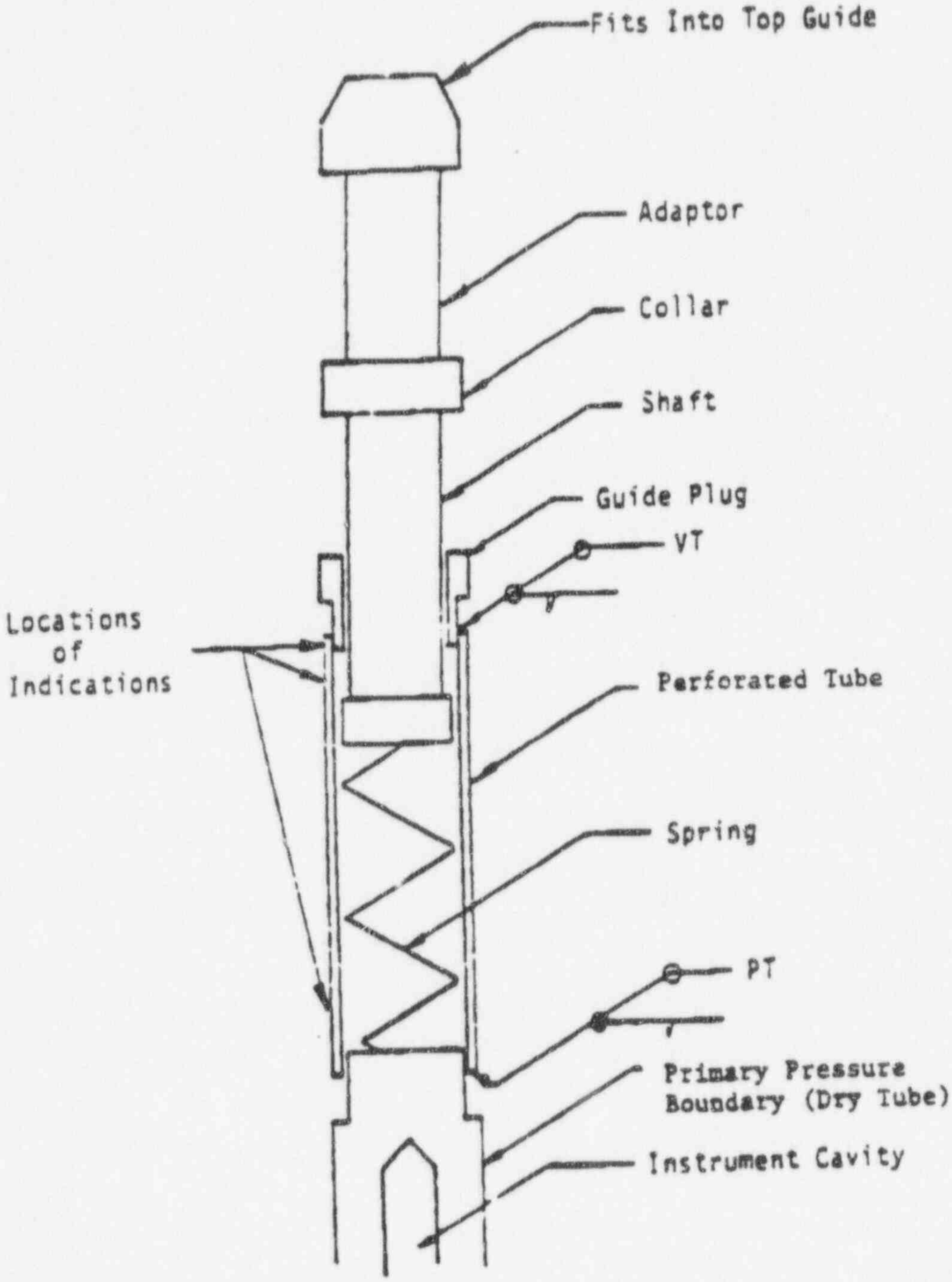


Figure 6-2 4-3. Schematic of Top Portion of Dry Tube

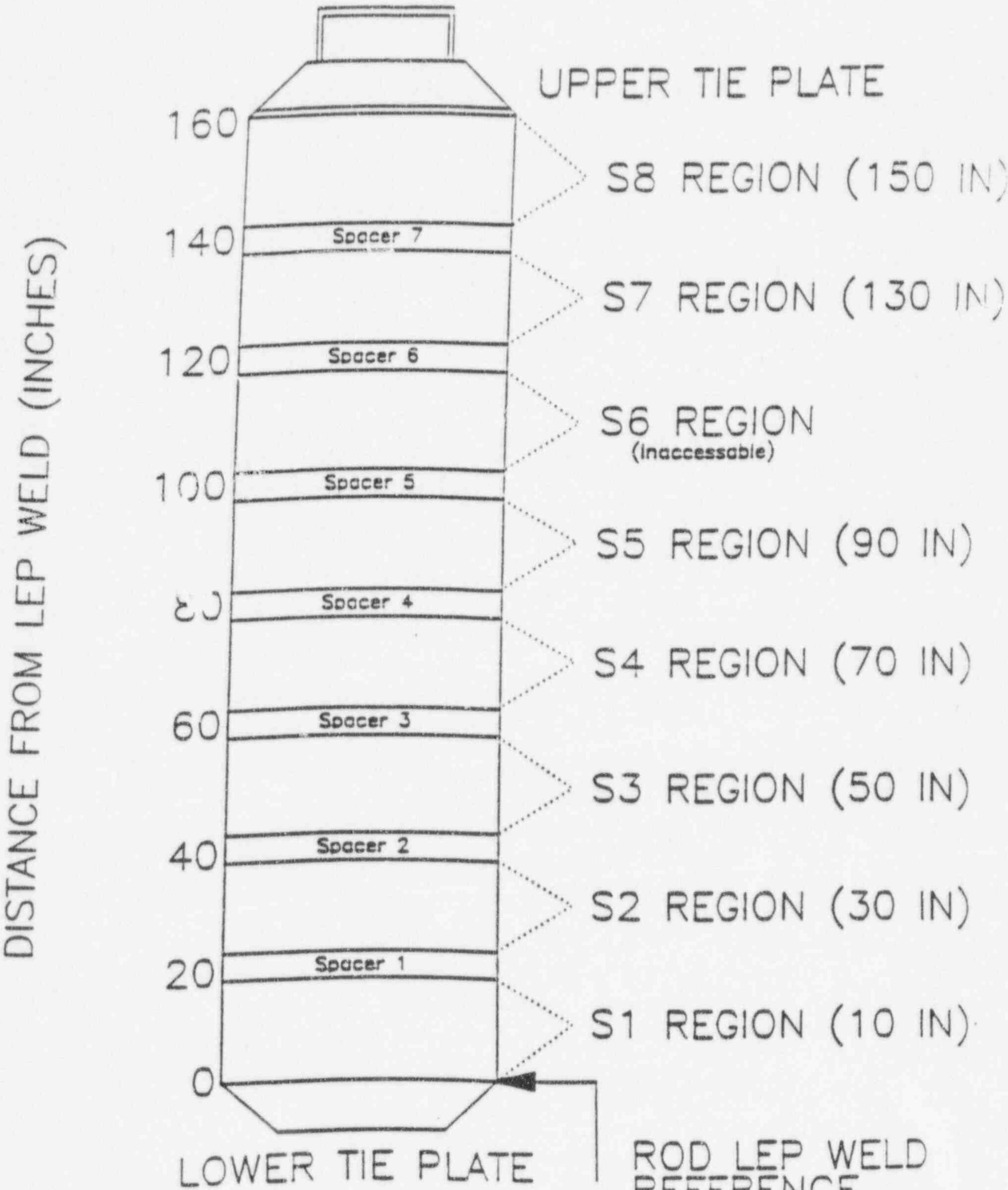


Figure 6-2.5-1. Fuel Deposit Sampling Positions

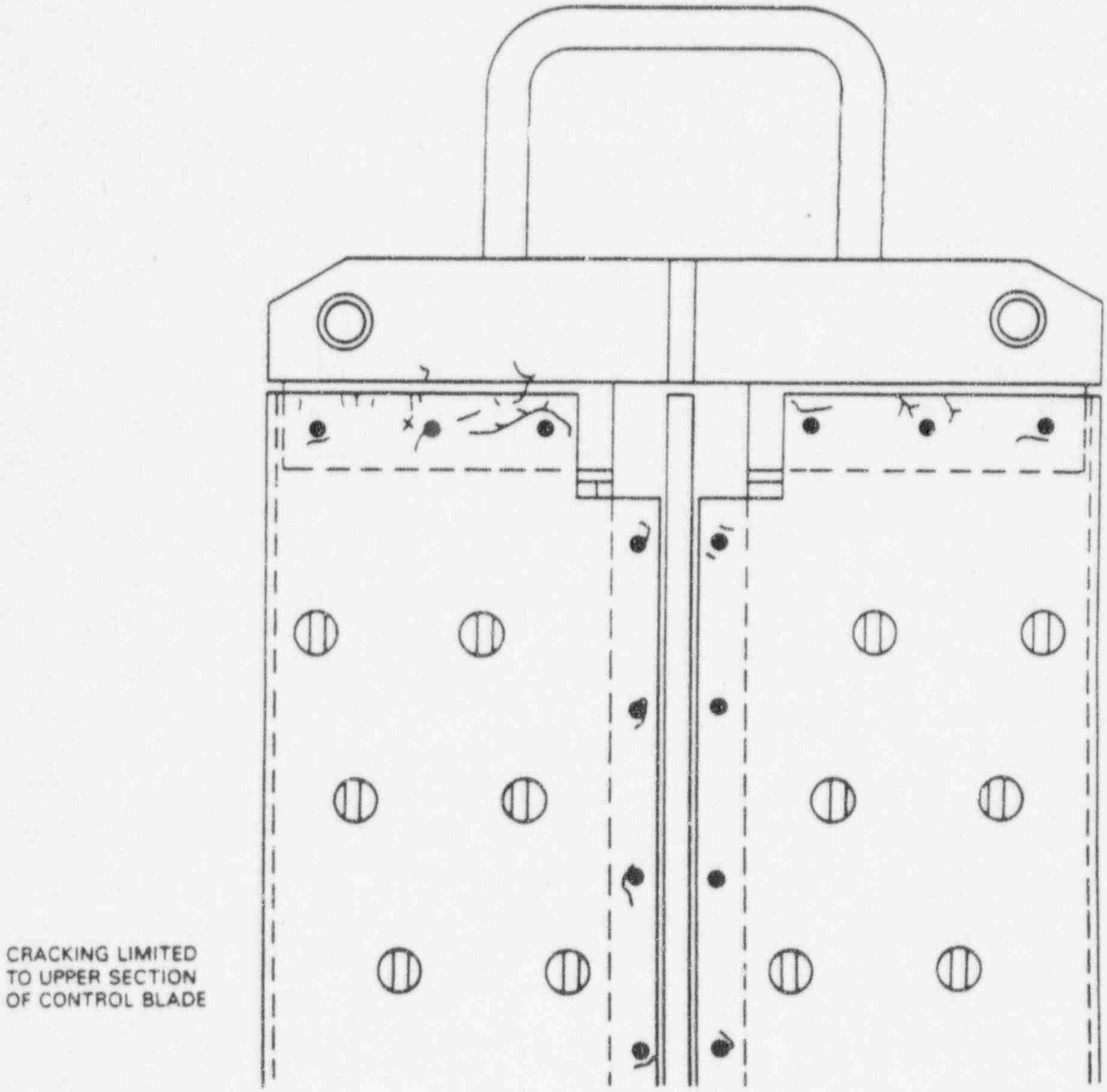


Figure 6-2.5-2. Diagram Showing Extent of Cracking in Original Equipment Control Blade Sheaths

Calculated IGSCC Depth vs. Time
[[redacted]] Model - WS Type 304 Shroud

[[redacted]]

FERMDV6A

Figure 6-3.1-1. Predicted Crack Growth from IGSCC for a Weld Sensitized Type 304 Stainless Steel Shroud (For Example Only)

Fermi 2 Calculated IGSCC Depth vs. Time
[redacted] Model - 4" Core Spray Sparger

[redacted]

[redacted]

FERMDV6.

Figure 6-3.1-2. Predicted Crack Growth for the Core Spray Sparger

Fermi 2 Calculated IGSCC Depth vs. Time [redacted] Model - 4" Core Spray Sparger

[redacted]

FERMDV7A

Figure 6-3.1-3 Predicted Crack Growth from IGSCC in the Core Spray Sparger for Two Cases of Startup Chemistry

Fermi 2 Calculated IGSCC Depth vs. Time [redacted] – Shroud to Shroud Support Weld Effect of Post-Intrusion Water Chemistry

[redacted]

FERMDVT

Figure 6-3.1-4. Predicted Crack Growth from IGSCC for Two Values of Reactor Water Conductivity and HWC

Appendix 7

CRD Component Examination

7-1 CRD Component Examination

Component and deposit samples from the Fermi 2 control rod drives were received at GE's Vallecitos Nuclear Center for examination. The following is a list of the samples received for analysis:

1. [redacted] seal segments
2. [redacted] C-spring
3. Oxide from piston tube (CRD 6177)
4. Oxide from piston tube (CRD 4572)
5. Retaining spring (from seal)

The samples were analyzed for anomalous chemical elements by plasma spectroscopy and energy dispersive spectroscopy (EDS). Optical metallography was also performed on the C-spring to characterize the surface condition.

Plasma Spectroscopy

Samples 1-4 were analyzed by plasma spectroscopy to identify the constituent elements and identify any elements that may be considered detrimental species. Table 7-1 lists the composition of the various samples tested; the compositions are normalized. The results indicated that the major constituent was iron (most likely iron oxide) with various other elements present. The composition of the samples did not indicate the presence of any detrimental species.

Energy Dispersive Spectroscopy

Samples 1, 2, and 5 were examined by EDS techniques for the presence of detrimental elements. For comparison purposes, a used [redacted] bushing from the GE CRD test facility was also examined. Sample 1 was examined in the radial direction to determine if the concentration of any detrimental species varied with the distance from the sealing surface. No trend was observed. Table 7-2 lists the average results from the EDS analysis, as well as the used graphitar bushing. The results from the analysis indicate that the seal (Sample 1) had high levels of sulfur and chlorine; however, the GE bushing (which did not see the transient event) had comparable levels. Therefore the results indicate that no detrimental species were introduced by the transient event. Samples 2 and 5 showed compositions characteristic of [redacted] with an iron oxide film, which is as expected for these components.

Optical Metallography

Sample 2 (the C-spring) was sectioned, mounted, and polished to examine the surface of the material after exposure to the transient event. Figure 7-1 is a 520X view of a typical region of the surface. No evidence of intergranular surface penetration or other degradation that would lead to failure of the spring was noted. The microstructure appeared normal fo[redacted]

Conclusion

Examination of the CRD components indicated conditions that would be expected for material that has been exposed to the BWR environment. No evidence of conditions that would lead to premature failure of the seal was found.

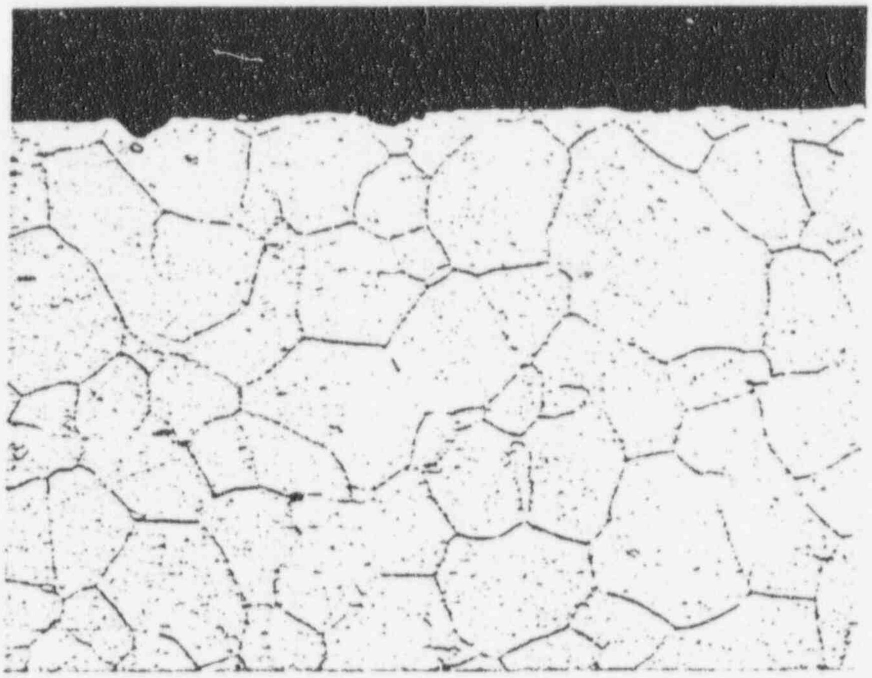


Figure 7-1 Surface of C-spring; no unusual degradation observed. (520X)