BWR Iron Control Monitoring

TR-108737

Interim Report, December 1998

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REPORT SUMMARY

This report summarizes the current state of iron control in U.S. BWRs as of July 1998 and documents the implementation and performance status of new iron control technologies. In addition, the report identifies specific plants for further in-depth analysis in order to address questions regarding field practices for dose control in the 1999 Final Report.

Background

EPRI will revise the *BWR Water Chemistry Guidelines* (TR-103515-R1) in 1999. In preparation, over the past three years EPRI undertook a series of studies on feedwater iron control to support the revision effort. The purpose of those studies, including the present work, is to determine the optimal feedwater iron level with respect to dose rate reduction from plant data and activity transport modeling and how best to achieve it in practice in a plant-specific manner. Three previous EPRI reports address these issues: *BWR Iron Control: Deep Beds* (TR-107297-V1), *BWR Iron Control: Filters* (TR-107297-V2), and *Correlative Plant Data Study of Influence of Iron on BWR Activity Transport* (TR-109566).

Objectives

To provide a ready reference for the 1999 EPRI BWR Chemistry Guidelines Revision Committee in addressing development of an improved technical basis for optimal iron control; and to provide a basis, through "lessons learned," for all BWRs to make decisions on the implementation of iron control program initiatives.

Approach

Beginning in April 1997, project managers collected detailed iron and radiation control data from 34 North American BWRs. They analyzed the data for trends in iron control performance and soluble and insoluble cobalt levels to identify optimal practices with new technologies. They grouped the plants according to condensate polishing system: deep bed only; deep bed plus pleated pre-filter; deep bed with enhanced cleaning technology; and precoated, pleated septa filter demineralizers. This study continues, with updated database development and emphasis on selected plants in which project managers expect one-on-one comparisons to provide a better understanding of how to achieve iron control optimal for radiation management.

Results

EPRI contractors collected basic data from about two thirds of the U.S. BWRs for an initial assessment of optimum feedwater iron. As expected, BRAC point dose rates correlate with increasing reactor water soluble Co-60 concentrations for all plants, although the rate of increase is lower for plants adding zinc oxide. In contrast, insoluble Co-60 does not continually decrease as feedwater iron decreases, but appears to go through a minimum for each plant. An overview of the data indicates an insoluble Co-60 minimum in the range of roughly 1-2 ppb feedwater iron.

Additional operating experience with pleated filter septa supports the statements and speculative projections made in EPRI TR-107297-V2 (1996). Useful service lives beyond two full-power service years still seem unlikely, except in the most favorable conditions.

EPRI Perspective

BWR iron control will be a major issue of debate when the next BWR Water Chemistry Guidelines Revision Committee convenes in 1999. Utilities are increasingly faced with both regulatory and economic pressure to justify their iron control programs. Two main questions arise: (1) Can a uniform, optimal feedwater iron range be specified based on current knowledge of activity transport for dose rate control?; and (2) At what cost can a utility justify meeting that optimal target? This report provides support for the concept of developing plant-specific iron control targets.

The field data provide insight into the interrelationships between feedwater iron and cobalt levels in the reactor water. The data also delineate the constraints different utilities face concerning the economic implementation of a program to achieve the optimal iron range. After a plant-specific evaluation of all issues impacting their iron program, including viability and cost of the implementation strategy available in the field, a utility may decide that operating at feedwater iron levels outside of the 0.5 to 1.5 ppb range is technically justifiable, despite somewhat higher dose rates. This report provides the industry with a metric for expected performance of different technology implementations. This type of plant-specific consideration will be proposed to the Guidelines committee for inclusion in the 1999 revision.

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Interest Categories

Chemistry
Radiation field control
Low level waste management

Key Words

BWR Chemistry
Radiation field control
Feedwater Iron Control

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1

INTRODUCTION

The initial efforts to limit iron transport to the primary system in BWR's grew out of concerns for iron deposits on the fuel that can lead to overheating and fuel damage. Today, feedwater iron is controlled to a sufficiently low level so that the impact on fuel failures is minimal.

Now, with over 30 years of commercial BWR operating experience in the United States, the main objective of optimizing feedwater iron is to control cobalt transport, thereby lowering cobalt deposition on out-of-core surfaces. Reduced cobalt deposition on piping results in lower radiation dose rates and consequently lower radiation exposure to workers, particularly during refueling outages. Lower radiation dose rates contribute to reducing BWR O&M (operating and maintenance) costs, particularly through reducing the cost and duration of refueling outages.

Current Iron Limits and Target Range

The EPRI BWR Chemistry Guidelines – 1996 Revision (1) gives an Action Level 1 limit for feedwater iron of >5 ppb at power operating conditions (>10% power). In the discussion on feedwater iron in the 1996 Guidelines, it is stated that, "It is currently believed that the optimum range is 1 ± 0.5 ppb, depending on plant-specific design issues, but work is continuing to improve the quantitative basis for this range."

Interim Report Purpose and Organization

The purpose of this Interim Report is to summarize the current state of iron control in U.S. BWR's and to document the status of new iron control technologies. This report represents the initial attempt to pull together the large amount of data collected as part of an effort that was begun in April, 1997. As the term "interim" suggests, there are gaps in the data collected so far and efforts are in progress to fill those gaps and continuing to collect new data. In addition, a process is in progress to select plants for in-depth analysis to answer questions regarding field implementation of iron and dose control approaches.

A key objective of the Interim Report is to provide input to the EPRI BWR Chemistry Guidelines Revision Committee, which will address the issue of developing an improved technical basis for optimal iron control to be included in the 1999 revision of the Guidelines. The Interim Report was organized to provide a ready reference for the Committee in addressing the optimal iron issue. An overview of the report organization is as follows:

- Section 1: Introduction
- Section 2: Description and status of data collection efforts
- Sections 3 – 37: Each section is for an individual participating plant and includes a summary of key plant design parameters and milestones, radiation data, trend plots of the power, feedwater iron and reactor water cobalt 60 data provided, and a brief discussion of the data and plant experiences reported.
- Section 38: Overview and preliminary correlations of recent industry data on iron and dose control
- Section 39: Overview of field experience with filters for iron control
- Section 40: Overview of field experience with deep beds for iron control
- Section 41: Summary and future work

Background

To consider the iron question, it is useful to review what happens to iron as it becomes part of the process water. Iron in the reactor feedwater includes contributions from:

- Iron passing through the condensate polishing system
- Corrosion of the feedwater train
- Iron in forward-pumped drains (for plants where high pressure heater drains are pumped forward)
- Iron intentionally added to the feedwater (practiced by plants where feedwater iron is judged to be too low, based on experience and literature pertaining to fuel deposit transformations which can lead to hot spots)

Most of the iron that enters the primary system rapidly forms extremely insoluble α-Fe_2O_3 on the fuel cladding surface. Therefore, the RWCU (reactor water cleanup) system plays only a small role in controlling iron which enters the reactor water. The hematite form of iron oxide is a scavenger for transition metal ions, especially cobalt and nickel, which are adsorbed on the deposit surface and incorporated as a stable mixed oxide in the ferrite form, $CoFe_2O_4$, $NiFe_2O_4$ (2). Corrosion products deposited on the fuel surface become radioactive. A list of common activated corrosion products is given in Table 1-1 (3)

Fuel deposits composed of oxides of metal ions consist of two layers, including a tenacious inner layer and a loosely attached outer layer. The relative thickness of each layer depends on the crud input from the feedwater. The activated corrosion products are released from the fuel by a number of mechanisms including dissolution and wear of the outer layer. The released corrosion products then re-distribute into soluble and insoluble forms as they are transported through the reactor water. The insoluble fraction tends to accumulate in low flow areas, creating radioactive “hot spots” while the soluble fraction is thermodynamically adsorbed into the corrosion film on the out-of-core piping surfaces.

The film on the out-of-core surfaces also forms in layers. The inner layer is composed of a fine grained, tenaciously held oxides of the form $(Fe_xCr_{1-x})_3O_4$. The outer layer has larger grains and particles. Soluble Co-60 is incorporated into the film and is also exchanged for other cations, such as zinc and nickel, in the building corrosion film.

Table 1-1
Corrosion/Erosion Product Radionuclides

Nuclide	Half Life	Precursor	Material Source
Cr-51	27.7d	Cr-50	Chromium in stainless steel; Inconel
Co-58	70.8d	Ni-58	Inconel fuel spacers, stainless steel
Mn-54	312.2d	Fe-54	Carbon steel; feedwater crud
Zn-65	244d	Zn-64	Admiralty; natural zinc oxide
Fe-59	44.6d	Fe-58	Carbon steel; feedwater crud
Co-60	5.26y	Co-59	Stellite; stainless steel; nickel alloys; feedwater crud

Under NWC (normal water chemistry) conditions, the piping corrosion film consists mainly of α-Fe_2O_3. The structure of the film undergoes a change under HWC (hydrogen water chemistry) to the spinel form and, in the process, some of the previously held cations are released to re-solubilize and be incorporated into the new film. The release of insoluble forms increases the potential for hot spots. The oxide that forms under HWC is thinner, more highly enriched in chromium, and can incorporate greater quantities of Co-60, Zn-65 and other transition metals than the film formed under NWC (1). The basis for increased dose rates under HWC is the movement of the oxide species when converting between the oxidizing and reducing environments, and the increased ability of the spinel film to incorporate transition metals. Controlling feedwater iron is a key to minimizing the corrosion film layer and keeping piping dose rates low. The significant increase in dose rates at several plants after implementing HWC placed increased emphasis on controlling feedwater iron.

Iron has traditionally been viewed as a necessary-evil contaminant in BWR reactor feedwater. As such, the focus has been on minimizing feedwater iron. As HFF (Hollow Fiber Filter) technology was applied in Japan to achieve sub-ppb levels of iron in the feedwater, data indicated that iron concentrations can also be too low and cause dose rates to increase. In the mid-1980's, the Japanese identified the iron/nickel ratio as the control parameter to limit radiation buildup. Iron/nickel ratio control is accomplished by adding iron to the feedwater in plants with condensate HFF. Recently, some U.S. plants that have achieved <0.5 ppb feedwater iron by efficient condensate filtration have also begun to add iron to the feedwater to control radiation transport.

Several U.S. BWR's have implemented zinc injection to control the thermodynamics of cobalt buildup in the piping corrosion film. This has had a measurable benefit in controlling radiation buildup on the recirculation piping. For plants applying zinc, controlling feedwater iron at the upper end of the current 0.5 – 1.5 ppb target range has been recommended to maintain a stable mixed oxide deposit on the fuel surfaces (1).

Projections of the impact of the feedwater iron concentration on piping dose rates under various chemistry regimes were performed by General Electric for EPRI (11). The starting condition for the projections was a piping dose rate of 350 mR/hr, reported as a GE BWR fleet average. The projections period was six fuel cycles, based on 18 month cycles with 35 day refueling outages.

The results for feedwater iron concentrations from 0.5 ppb to 5 ppb are summarized in Table 1-2 in terms of the percent increase in piping dose rates after six cycles. The projected increases in piping dose rates are either small or negative, depending on the chemistry regime, over the current feedwater iron target range of 0.5 - 1.5 ppb. The projected impact of feedwater iron in the 2-3 ppb range on dose rates is moderate. Therefore, depending on the cost of specific utility assigns per person-rem and the cost of depleted zinc oxide (if applicable), controlling iron in the 2-3 ppb range may be tolerable.

Table 1-2
Projected Percent Increase in Piping Dose Rates After Six Cycles (11)

FW Fe (ppb)	NWC	Zn Addition	Moderate HWC	Moderate HWC +Zn Addition	Zn Addition +NobleChem
0.5	0.86	-36.86	3.43	-20.57	-21.43
1	4.57	-32.86	7.14	-15.71	-16.86
1.5	7.71	-29.14	10.00	-11.14	-12.29
2	10.86	-25.43	13.14	-.657	-8.00
3	18.57	-17.71	20.57	2.86	0.86
5	36.00	-2.00	37.71	22.57	19.71

The iron / nickel ratio control strategy developed in Japan in the 1980's was directed at reducing the soluble Co-60 concentration in reactor water, but at the same time there was an increase in the Co-60 deposition rate on the recirculation piping. The reduction in the Co-60 concentration outweighed the deposition rate increase, and so there was a reduction in radiation buildup on piping surfaces.

However, two Japanese plants that started up in the 1990's under iron / nickel control observed higher than expected soluble Co-60. The cause was identified as the mechanically polished, non-autoclaved surface preparation of the new Zircalloy fuel cladding, which resists formation of a film to stabilize cobalt. This led to the concept called, "Ultra-Low-Crud / High Ni Control" (4). It was found that cobalt deposition on piping surfaces can be reduced by maintaining very low feedwater iron (<0.1 ppb), under which condition nickel in reactor water increases to several ppb. Under this concept, only a minimal fuel deposit is formed and most of the cobalt and nickel is removed by the reactor water cleanup system. Cobalt incorporation into the recirculation piping film is suppressed by the high concentration of nickel, which was observed in loop testing to have a similar effect on suppressing cobalt in the film as zinc. A low cobalt BWR, Onagawa 2, has taken this approach, controlling feedwater iron at $\leq$0.02 ppb and producing a reactor water nickel concentration of 2 –3 ppb. Onagawa 2 measured primary piping radiation dose rates after the first cycle to be one-third or less than those of iron / nickel ratio control plants after the first cycle.

Recent tests (5) have shown that zinc and nickel combined reduce cobalt deposition rates more effectively than either one separately. The effectiveness of zinc can be seen from the tetrahedral site preference for zinc over cobalt in the spinel structure, as illustrated in Table 1-2 (6). In addition, the octahedral site preference for nickel, compared to cobalt, in the spinel is shown in Table 1-2 and explains the zinc and nickel synergism for replacing cobalt in BWR piping films.

Table 1-3
Site Preference For Selected Ions In Spinel Structures (listed in decreasing site preference)

TETRAHEDRAL SITE	OCTAHEDRAL SITE
ZINC(II)	CHROME (III)
IRON(III)	NICKEL(II)
COBALT(II)	IRON(II)
IRON(II)	COBALT(II)
	IRON(III)

The nickel and zinc spinels that form, and exclude cobalt from the spinel structure, are shown in Table 1-3. Zinc is incorporated in the normal spinels; for example danathite ($ZnCr_2O_4$) is formed from chromite. Nickel is incorporated in the inverse spinels; for example trevorite ($NiFe_2O_4$) is formed from magnetite.

Table 1-4
Spinel Structures Showing Cobalt, Zinc, and Nickel Substitutions

NAME	**STRUCTURE***	**COBALT FORM**	**Zn/Ni FORM**
NORMAL SPINELS			
CHROMITE	$Fe^{2+}[Cr^{3+}Cr^{3+}]O_4$	$Co^{2+}[Cr^{3+}Cr^{3+}]O_4$	$Zn^{2+}[Cr^{3+}Cr^{3+}]O_4$
	$Fe^{2+}[Fe^{3+}Fe^{3+}]O_4$	$Co^{2+}[Fe^{3+}Fe^{3+}]O_4$	$Zn^{2+}[Fe^{3+}Fe^{3+}]O_4$
	$Fe^{2+}[Fe^{3+}Cr^{3+}]O_4$	$Co^{2+}[Fe^{3+}Cr^{3+}]O_4$	$Zn^{2+}[Fe^{3+}Cr^{3+}]O_4$
INVERSE SPINELS			
MAGHEMITE	$Fe^{3+}[Fe^{2+}Fe^{3+}]O_3$	$Fe^{3+}[Co^{2+}Fe^{3+}]O_4$	$Fe^{3+}[Ni^{2+}Fe^{3+}]O_4$
MAGNETITE	$Fe^{3+}[Fe^{2+}Fe^{3+}]O_4$	$Fe^{3+}[Co^{2+}Fe^{3+}]O_4$	$Fe^{3+}[Ni^{2+}Fe^{3+}]O_4$
	$Fe^{3+}[Fe^{2+}Cr^{3+}]O_4$	$Fe^{3+}[Co^{2+}Cr^{3+}]O_4$	$Fe^{3+}[Ni^{2+}Cr^{3+}]O_4$
* The metal ion preceding the bracket is in the tetrahedral site, and the metal ions in the bracket occupy the octahedral sites			

The most direct way to control cobalt-associated dose rates is to reduce the cobalt sources. Plants have aggressively replaced cobalt materials in control blade pins and rollers and valve seats, removing a significant fraction of the cobalt source term. However, the system response to these cobalt reduction efforts will not be immediate. The impact of past cobalt input will be evident for several years due to the 5.26-year half-life Co-6.

Efforts to Assess Current Field Performance

A major focus of this work is to monitor the field implementation of iron control technologies. For plants with “deep bed only” condensate polishing, iron reduction can be maximized through the use of ion exchange resins designed for enhanced crud removal, improved approaches for physical cleaning of the resins, and improved resin bed management. A major step toward iron reduction has been taken by plants which have implemented pleated filters, either as pre-filters upstream of deep bed condensate demineralizers or as precoated filters in plants designed with condensate filter demineralizers (F/D’s). Operation with pleated filters has resulted in feedwater iron <0.5 ppb, leading three plants to inject iron to the feedwater to maintain iron in the 0.5 – 1.5 ppb range. Three plants in the process of retrofitting pre-filters upstream of deep beds are providing the means for iron injection in their designs.

The initial field results with new resin and filter iron control technologies were documented in an EPRI-sponsored survey of the US BWR fleet (7, 8). At that time (1996), 22 of the 36 plants were operating outside of the current optimum feedwater iron target range of 0.5 – 1.5 ppb, with “deep bed only” plants above 1.5 ppb and some plants with pre-filters or F/D’s below the 0.5 ppb minimum.

The main objective of the performance monitoring and data evaluations is to provide a basis, through “lessons learned,” for all BWR’s to make decisions on how to implement iron control program initiatives. Details on the plants being monitored are provided in Section 2.

Application Challenge Severity Indexes

The two technologies, low crosslinked cation exchanged resins and pleated filter septa, that have clearly demonstrated benefits in reducing feedwater iron also have potential liabilities. The significance of these potential liabilities to a given plant depends on plant-specific factors. That is, in regard to potential liabilities, the severity of the challenge to the iron reduction technologies can vary from plant to plant and can be defined in terms of plant specific conditions.

Low cross-linked cation resins, used for their enhanced iron removal at plants with “deep bed only” condensate polishing, present the risk of increased sulfur release which challenges a plant’s ability to control reactor water sulfate (in addition to other ionic impurities). The potential liabilities for pleated filter septa, used with or without precoats, are rapidly declining run lengths based on differential pressure, and consequently short useful lives. For precoated pleated filter septa, an additional potential liability is unsatisfactory ion exchange performance during cooling water ingress periods.

Since the new technologies for enhanced iron removal are relatively new, potential and current users look to experiences at other plants to assist in evaluating alternative embodiments of the technologies. For this purpose, the “application challenge severity index” concept was developed as a means of ranking plants according to their vulnerability to the potential liabilities associated with the technology of interest. So far, three different index values have been developed as described as follows:

- RLI: Filter Run Length Index
- IXI: Filter Precoat Ion Exchange Index
- DSI: Deep Bed Sulfate Index

In each case, increasing index values indicate increasing challenge severity. Each index is defined and discussed below.

RLI (Filter Run Length Index)

The RLI provides an indication of the impact of plant specific conditions on filter run lengths and useful lives, and is defined as follows:

$$RLI = 100 * (F_f / (N_S * L_S))^2 * Fe_i$$

where,

F_f = Flow per Condensate Filter (gpm)

N_S = Filter Septa per Vessel

L_S = Septum Length (inches)

Fei = Inlet Insoluble Iron (ppb)

The basis for the RLI is that the pressure drop across a filter septum is a function of the quantity of filter cake deposited and the flow rate through the filter septum. For constant rate filtration, rate of cake deposition is directly proportional to flow rate. For laminar flow, pressure drop is also directly proportional to flow rate. Therefore, under these conditions, run time to a specified pressure drop is proportional to the flow rate squared. An implicit assumption in the form of the equation is that the flow through the filter media and filter cake is laminar.

It is important to recognize that the index does not take into account the characteristics of the filter septa, the cleaning method and frequency, the use of precoats, run termination criteria or temperature. All of these factors may affect the performance of the filters. In addition, with compressible cakes, the pressure drop across the filter may become a power function of flow rate as pressure drop increases.

IXI (Filter Precoat Ion Exchange Index)

The IXI is applicable to precoats on septa having outer media comprised of upright pleats. It provides an indication of the impact of unsatisfactory ion exchange performance on maintaining reactor water sulfate concentrations at or below specified limits.

$IXI = 22{,}881 * (A_t\ /\ (N * L)/(\ln[A_{rx}/A_x * F_r * 10 - 50] - 2.34))$

where,

A_t = Cooling Water Total Anions (meq/l)

A_x = Cooling Water Sulfate (ppm)

A_{rx} = Maximum Allowable Rx Water Sulfate (ppb)

F_r = RWCU Flow (gpm)

N = Number of Condensate Filter Septa In-Service

L = Filter Septum Length (inches)

The numerical value of the IXI is the precoat dose (dry lb. Precoat material/10” of septum length) required to maintain reactor water sulfate at 5 ppb with 30 day filter run lengths and a 0.1 gpm condenser leak rate. It is noted that the required precoat dose (IXI) is proportional to the required run length and is a non-linear function of the cooling water ingress rate.

A number of assumptions are inherent in the form of the IXI:

All of the condensate filter/demineralizers (CF/D) use pleated filter septa

The total condensate flow is treated via filter/demineralizers only

RWCU precoat sulfate removal efficiency = 100%

- Non-bypassed CF/D precoat anion removal efficiency = 95% @ CDI conductivity less than 0.1 µS/cm

- The CF/Ds operate as a unit; begin and end runs together
- CF/D precoat material consists of all resin with cation/anion (dry wt.) = 4/5

It should also be noted that the IXI algorithm is based on limited test data for a single type of septum with upright pleats.

DSI (Deep Bed Sulfate Index)

The DSI provides an indication of the steady state reactor water sulfate concentration (ppb) resulting from release of 0.033 mg/hr of sulfur (equivalent to 0.10 mg/hr of sulfate) per cubic foot of condensate demineralizer resin (cation and anion). The DSI is defined as follows:

$DSI = 0.44 * (N_b \times V)/F_r$

where,

N_b = Total Number of Online Condensate Demineralizer Beds

V = Total Resin Volume per Bed (ft^3)

F_r = Normal RWCU Flow (gpm)

It is assumed that 100 % sulfate in the RWCU influent is removed. The DSI does not account for differences due to characteristics of the cation and anion resins, cation/anion ratio, cleaning method and frequency, or temperature. All of these factors may affect the release of sulfur from beds.

2

DESCRIPTION OF DATA COLLECTION EFFORTS

Data on plant design, plant chemistry (including iron and activated corrosion products), resins and filters in use and radiation dose were requested from 35 US BWR units and Laguna Verde, Units 1 and 2. Big Rock Point was initially included, but has been dropped from the data collection effort since the decision was made to shut down the plant for decommissioning.

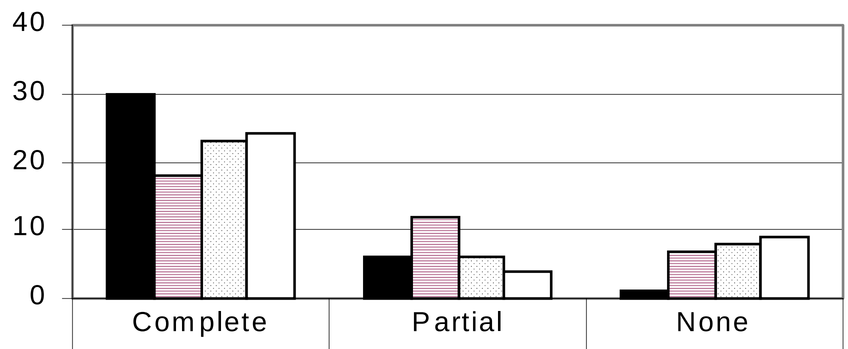
The plants being monitored are listed in Table 2-1, categorized according to the type of condensate purification system:

Table 2-1
BWR Units Included in Monitoring Program

Condensate Polishing Type		
Deep Bed Only	**Filter + Deep Bed**	**Filter Demineralizer**
Dresden 2	Brunswick 1	Browns Ferry 2
Dresden 3	Brunswick 2	Browns Ferry 3
FitzPatrick	Clinton	Cooper
Grand Gulf	Laguna Verde 1	Duane Arnold
Hope Creek (1)	Limerick 1	Fermi 2
Laguna Verde 2 (1)	Limerick 2	Hatch 1
LaSalle 1	Perry	Hatch 2
LaSalle 2		Monticello
Millstone		Peach Bottom 2
Nine Mile 1		Peach Bottom 3
Nine Mile 2		Quad Cities 1
Oyster Creek		Quad Cities 2
Pilgrim		Vermont Yankee
River Bend		WNP2
Susquehanna 1 (1)		
Susquehanna 2 (1)		
Notes: (1) Pre-Filters being installed.		

Of the 16 plants currently categorized as “deep bed only,” 4 are in the process of installing pre-filters. When these pre-filter installations are complete, there will a total of 11 “filter + deep bed” plants. Of the 14 “filter demineralizer” plants, 11 plants have some pleated filter elements that are precoated and one plant (Fermi 2) is in the process of selecting elements for a single vessel trial.

Some statistics showing the status of data collection are given in Figure 2-1. In most cases, the majority of the requested **plant design** data has been received. Most plants have also provided some or all data on which **septa and resins** are being used.



	Complete	Partial	None
Design Data	30	6	1
Septa/Resin Data	18	12	7
Chemistry Data	23	6	8
Dose/Milestone Data	24	4	9

Figure 2-1
Status of Data Collection (37 Plants)

Regarding the chemistry data, 28 plants have provided complete or partial data. The preferred data being sought are the same those being compiled by most plants for the GE Fleet database, which includes condensate, feedwater, reactor water, condensate storage, fuel pool, makeup and offgas data. However, for the purposes of BWR iron monitoring, data contributed by a plant are considered complete if they include condensate metals, feedwater metals, reactor water metals and reactor water activated corrosion products.

Of the plants that have not provided chemistry data, Hope Creek, Hatch 1, Hatch 2, Nine Mile 1 and Pilgrim have promised to provide data. Obtaining data from the remaining plants is complicated by extended plant shutdowns, including:

- Clinton (down since 9/96, projected restart 4/98)
- Millstone 1 (down since 11/95, no restart date scheduled)
- LaSalle 1 (down since 9/96, projected restart 6/98)
- LaSalle 2 (down since 9/96, no restart date scheduled).

The chemistry data are being compiled in the form of monthly averages for each plant in Microsoft Excel Workbook format. The monthly averages provide a convenient indication of current performance and trends in a manageable format. Details can then be further evaluated using the trend data as a function of date and time. Plants have been requested to provide data from the beginning of the current operating cycle through present, and then to provide updates as the data are compiled (monthly or quarterly, according to normal plant practice).

Twenty-two (22) plants have provided **dose rate data**, including BRAC point dose rates, and some have also provided personnel exposure and available piping and fuel scrapings. These plants have also provided data on important **milestone events**, such as the startup of zinc or hydrogen water chemistry, piping replacements, cobalt reductions, etc. Thirteen of the plants that have provided partial or no data, and eight have promised to provide the data requested.

Status of Data Collection on Filter Performance

Obtaining detailed performance data for the BWR Condensate Filters (CF) and Filter/Demineralizers (CF/D) using pleated filter septa is ongoing. Due to the combination of operations and chemistry data required, the data collection is challenging since the operational data are not always electronically logged in a database by the plant. The data collection efforts continue to be directed at the following units as listed in Table 2-2:

Table 2-2
Condensate Filter Performance Targeted Data Collection Efforts

Station	Application	Reason(s) for Selection
Limerick 1& 2	Non-Precoat	Most extensive and longest use of Pall BFP-4 septa
Peach Bottom 2 & 3	Precoat	Most extensive and longest use of Memtec precoated septa. Has experienced resin passage problems
Browns Ferry 2 & 3	Precoat	Highest RLI for precoated applications. Has experienced resin passage problems
Brunswick 1 & 2	Non-Preocat	Most extensive and longest use of Graver septa, and the only use of Pall septa in a non-precoat application in bottom tubesheet vessel using steady state backwash
Perry	Non-Precoat	Most extensive and longest use of Memtec non-precoat septa
Monticello	Precoat	Experience with body feed on pleated septa. Regularly logs ΔP, Flow, Conductivity and iron data. Has experienced resin passage problems
Hatch 1 & 2	Precoat	Trials of Graver, Memtec, Pall and European supplier septa. Backwash method changed from steady state to non-steady state on Unit 2 filters

At Limerick, three filters are designated for monitoring; Filters A and F of Unit 1, and Filter C of Unit 2. Data have been obtained in three forms. First, a copy of a presentation at the 1997 BWR Chemistry and Materials Workshop containing run length and ΔP rises for the first fourteen runs of Filter 1A and the first eight for Filter 1F. Second, tables of daily ΔP and flow data for Runs 18 through 26 of Filter 1A. Third, daily data for one Filter 2C run. There are indications that some ΔP data had been flow normalized before submittal; clarification is being sought. To obtain a complete history of the Pall BPF-4 septa in selected filters for both units, efforts to fill the current data gaps and obtain data for additional periods are continuing.

Peach Bottom CF/D data have been provided on a regular basis. Currently data for operations through December 31, 1997 are available for Units 2 and 3. Four filters with Memtec pleated septa are being monitored at Peach Bottom. In Unit 3, one monitored filter contains 2 μm septa, another 4 μm, and a third 10 μm septa. The only Unit 2 filter monitored has been Filter D. In September 1997, the pleated septa in this filter were replaced with yarn wound non-pleated septa because pleated septa with guide rod assemblies were not available. Monitoring of the performance of Filter 2D, with the non-pleated septa, will be continued.

Browns Ferry filter performance data have been submitted sporadically, generally related to specific aberrant filter performance. The filters designated for monitoring are Filters 2B and 2C in Unit 2, and 3A and 3H in Unit 3. The most recent data received are for Filters 2B and 2C, covering operations from October to December 1997. Browns Ferry personnel periodically provide verbal reports on approximate run lengths and specific problems encountered with the pleated septa. The pleated septa in Filter 2B have been replaced twice and filters have been replaced once each in Filters 2C and 3B because of resin passage. A revised strategy for monitoring filters at Browns Ferry is being considered because of the aborted septa lives, and the possible difficulty in retrieving historical data.

Brunswick flow and ΔP data for the Condensate Filters of Units 1 and 2 have been provided for operations through November 30, 1997. In addition to covering the performance of the original pleated septa, the data also cover the performance of new sets of Graver pleated septa that went into service in Unit 1 Filters 1D and 1C in May and July of 1997, respectively. In Unit 1 Filters 1B and 1A, Pall BPF-4 septa that replaced Graver septa were placed into service during January and February of 1998, respectively. Continued performance monitoring will be focused on the new Graver septa in Filter 1D and the Pall septa in Filter 1B.

Perry has provided daily flow and ΔP data for the three filters being monitored; Filters C, D and H. The data covers initial operations, as early as May 1995, up to January 14, 1998. The data available includes an operating period during which Heater Drains were not pumped forward as they normally are at Perry. Monitoring of the three filters is being continued.

Monticello has provided daily ΔP and effluent conductivity data, and periodic effluent iron data. Daily influent conductivity and periodic effluent iron data, precoat and body feed quantities have also been included in transmittals. These data are for two filters, A and E, and cover the period from the initial use of the pleated septa to December 31, 1997 inclusive. Average flows over each run, rather than daily flow rates, are reported. Therefore, normalization of ΔP readings and run days are approximate.

Hatch conditions, flow rates per unit length of septa and influent iron concentrations, present the least severe challenge for the application of precoated pleated septa. Nonetheless, because septa from all three domestic suppliers and a European supplier are undergoing side-by-side trials, performance data from Hatch has great potential value. Efforts are continuing to obtain daily flow and ΔP data or summaries of run lengths and average flows for the various pleated filter septa in service at Hatch.

Status of Data Collection on Deep Bed Performance

Of the "deep bed only" plants, FitzPatrick, Grand Gulf, River Bend and Oyster Creek are being monitored because they appear to have the capability to achieve or approach the current target feedwater iron range of 0.5 - 1.5 ppb. FitzPatrick and River Bend employ standard resins and URC (Ultrasonic Resin Cleaner) to periodically clean resins. Grand Gulf has retrofitted the ARC (Advanced Resin Cleaner) and also uses standard resins. Oyster Creek has added the JRC (Japanese Resin Cleaning) method and has tried a bed of Dow C-500 cation resin (10% crosslinked, 500 microns uniform size) and SBR-C anion resin, which has demonstrated enhanced crud removal.

Dresden 2 and 3 are also being monitored to follow results with their continued application of low crosslinked cation resins for enhanced crud removal. Dresden is also planning to retrofit an Advanced Resin Cleaner as part of an EPRI Tailored Collaboration project. Nine Mile 2 has also installed one bed (a second is planned) of low crosslinked resins under an EPRI Tailored Collaboration project, and its performance will be monitored.

3

BROWNS FERRY UNIT 2

Table 3-1
Browns Ferry 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	3/75
Capacity (MWe)	1097
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Browns Ferry Unit 2 Milestones

Milestone events for Browns Ferry Unit 2 are given in Table 3-2. The following additional data and information are noteworthy:

The condenser was re-tubed and a chemical decontamination of the recirculation piping was performed in 1991 prior to restart. In the same outage, the recirculation piping safe ends and risers were replaced.

Table 3-2
Browns Ferry 2 Milestone

Browns Ferry – Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser				X						
Recirc. Pipe Replacement				X						
RWCU Pipe Replacement						X				
Extraction Steam Pipe Replacement										
Chem. Decon				X		X				
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										10/97
Iron Injection										
Crud Resins										
Pleated Filters										3/97

Radiation Data

Recirculation System dose rates are summarized in the Table 3-3.

Table 3-3
Browns Ferry 2 Recirculation System Dose Rates

Browns Ferry Unit 2 – Recirculation System Dose Rates (mR/hr)									
	May-91	Oct-91	Feb-92	Sep-92	Jan-93	May-93	Oct-94	Mar-96	Sep-97
EFPY					pre decon	post decon			
BRAC	55			300	349	34	360	296	425
A Suction	50	120	220	300	400	40	400	350	500
B Suction	50			300	350	90	500	400	400
A Discharge	25			300	325	4	250	225	400
B Discharge	95			300	320	3	290	210	400
Avg Risers									

Trend Data

Trend data for Browns Ferry 2 for power and feedwater iron are presented in Figures 3-1 and 3-2. Cobalt 60 data were not provided.

Feedwater Iron Control

In the 1996 –1997 period, Browns Ferry 2 maintained feedwater iron concentrations between about 1.5 and 3 ppb. Although total iron concentrations are similar for Browns Ferry Unit 2 and Unit 3 due to the predominance of the insoluble iron, the average soluble iron concentrations are significantly different for the two units. Brown's Ferry 2 soluble feedwater iron values are reported as <0.01 ppb, while the reported Brown's Ferry 3 soluble feedwater iron concentrations in the range of about 0.094 ppb are among the highest industry values.

Recirculation Piping Dose Rates

The historical BRAC data for Browns Ferry 2 show dose rates in the high range among U.S. BWR's, reaching 300 mR/hr after a year of operation in 1991, and recontaminating to 300 mR/hr one year after a chemical decontamination in 1993. No reactor water metals or isotopic data was available assess the causes of this trend. These dose rates are also high in comparison to those of Browns Ferry Unit 3, where reported values were less than 100 mR/hr after at least one year of operation after restart. The major difference between the two units is that Unit 3 began injection of depleted zinc oxide in 1995, while Unit 2 had not implemented zinc injection.

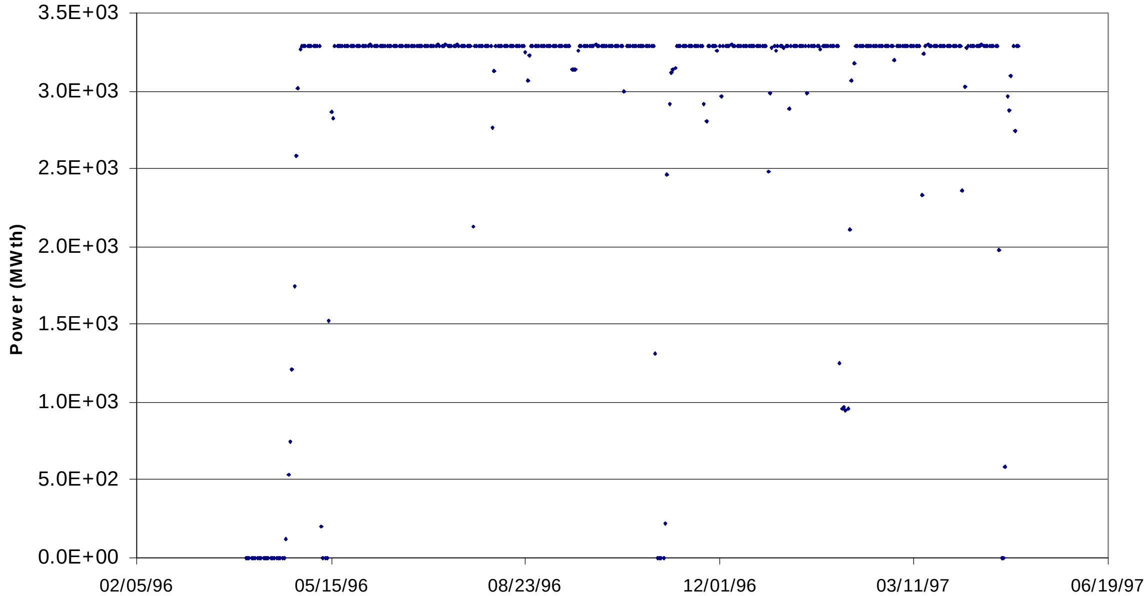


Figure 3-1
Power History, Browns Ferry Unit 2

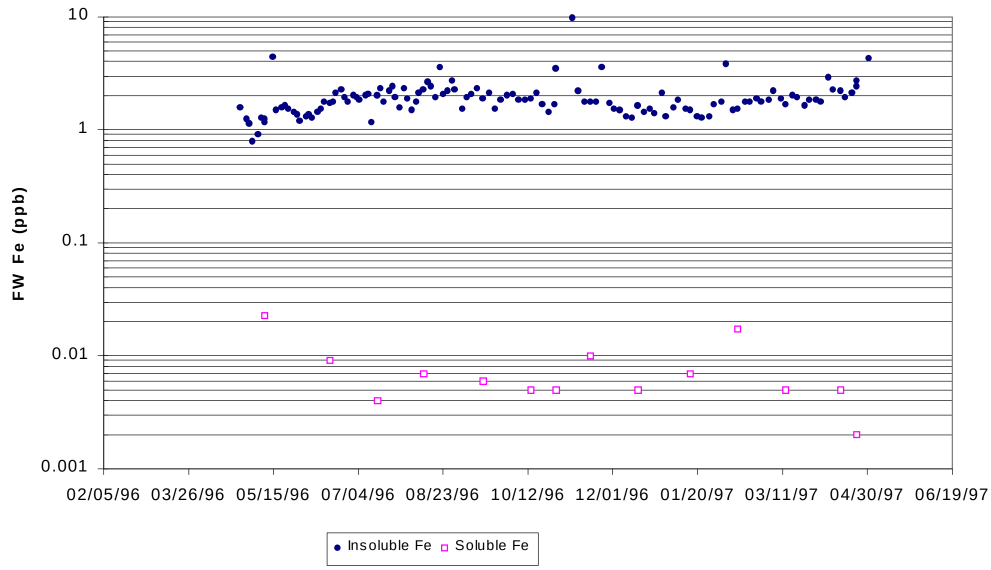


Figure 3-2
Feedwater Iron, Browns Ferry Unit 2

Browns Ferry Preocat Pleated Filter Septa Performance

Browns Ferry conditions, flow rates per unit length of septa and influent iron concentrations, present the most severe challenge for the application of precoated pleated septa. Pleated septa are used in four of the nine Condensate Filter/Demineralizers (CF/Ds) in each of the two Browns Ferry units. Initial run lengths in excess of seventy (70) days were reported. Thereafter, run lengths generally have been less than forty days, and at times as low as fifteen days. Runs have often been terminated at ΔP values of 8 psi and greater.

The earliest use of pleated septa was in Filter B of Unit 2, starting in May 1996. Since that time, Filter 2B's septa have been replaced twice, first in April 1997 and again in October 1997. Both replacements were because of resin trap plugging. Resin trap plugging also prompted replacement of the original pleated septa in Filter 2C in October 1997, after about six months service time, and in Filter 3B in early 1998 after about one year of service. Currently, the oldest septa are those installed during December 1996 in Unit 3 Filters 3A, 3H and 3J.

Figure 3-3 shows the vessel and resin trap ΔPs, and service flow for the latter part of the run during which Filter 2B's resin trap reached the 10 psi alarm level that initiated the septa replacement. A steady and significant rise in the resin trap ΔP is clearly evident. The resin trap ΔP alarm point was reached at about the 50^{th} day of the run.

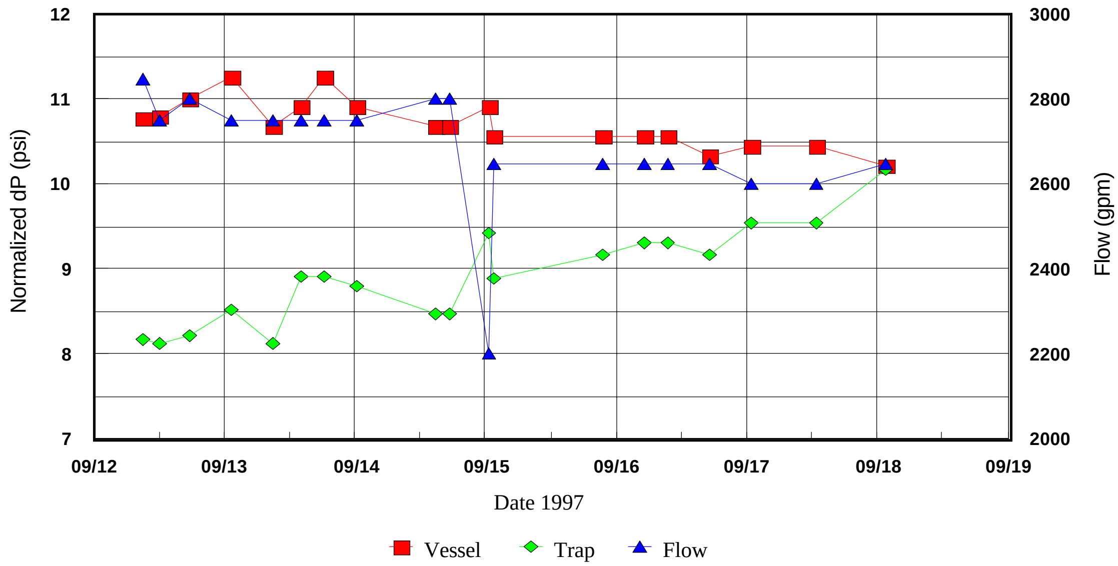


Figure 3-3
Filter 2B Performance, Browns Ferry Unit 2

Filter 2C's resin trap ΔP alarm occurred immediately upon placing the filter in service after a new precoat had been applied. Figure 3-4 shows the vessel and resin trap ΔPs, and service flow for the latter part of the run which preceded the precoat application. The resin trap ΔP behavior is reasonably stable compared to that of Filter 2B shown in Figure 3-3.

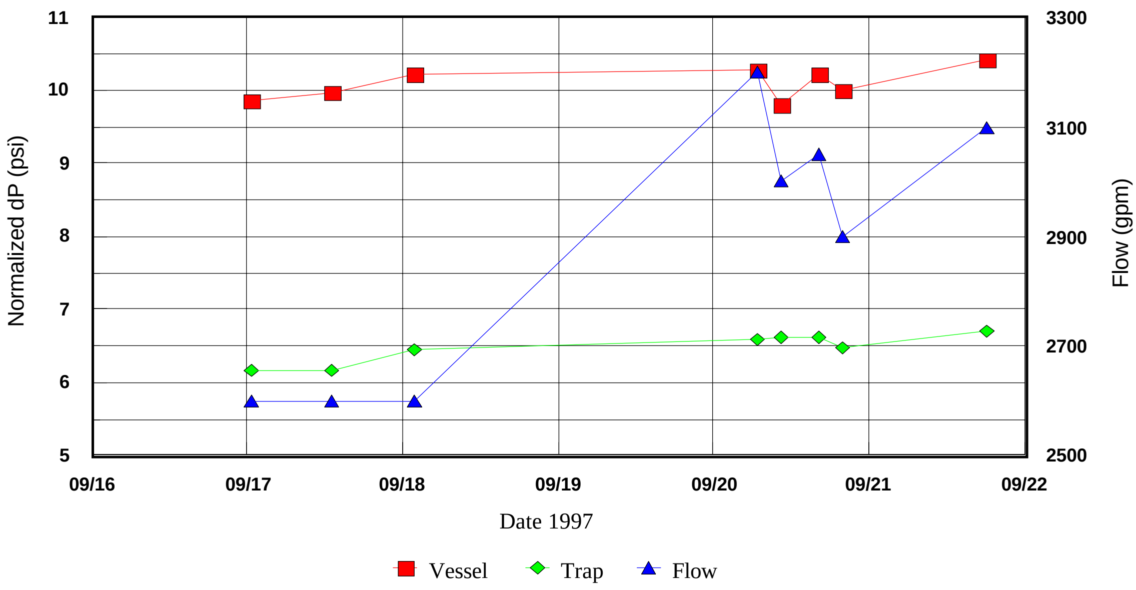


Figure 3-4
Filter 2C Performance, Browns Ferry Unit 2

Two commonalties in Figures 3-3 and 3-4 may be significant to the septa failures in both filters. First, the septa in both filters were exposed to normalized ΔPs in excess of 10 psi. Second, for each filter there was at least one significant flow rate change during the operating period preceding the resin trap alarm.

In all three trap plugging incidents, the septa were found to be properly latched. Only during the October 1997 replacements were springs on the attachment hardware found to be at less than the prescribed compression. One hundred and three (103) of the 302 septa removed from Filter 2C during October 1997 were closely examined for filter media damage by observing air release from submerged septa. Suspicious releases were seen from 27 septa, always from the two lowest cartridges, and usually from the lowest. Patches of filter media were cut from five suspicious bubble release locations. A visual examination found narrow slits about 1/8th inches long through the filter media in two of the five patches.

Figures 3-5 and 3-6 are plots of the vessel and resin trap flow normalized ΔPs during the first three runs following the septa replacements in Filters 2B and 2C, respectively. The base flow used for normalization is 3150 gpm. New or recently cleaned resin traps have 6 to 6.5 psi ΔPs at 3150 gpm.

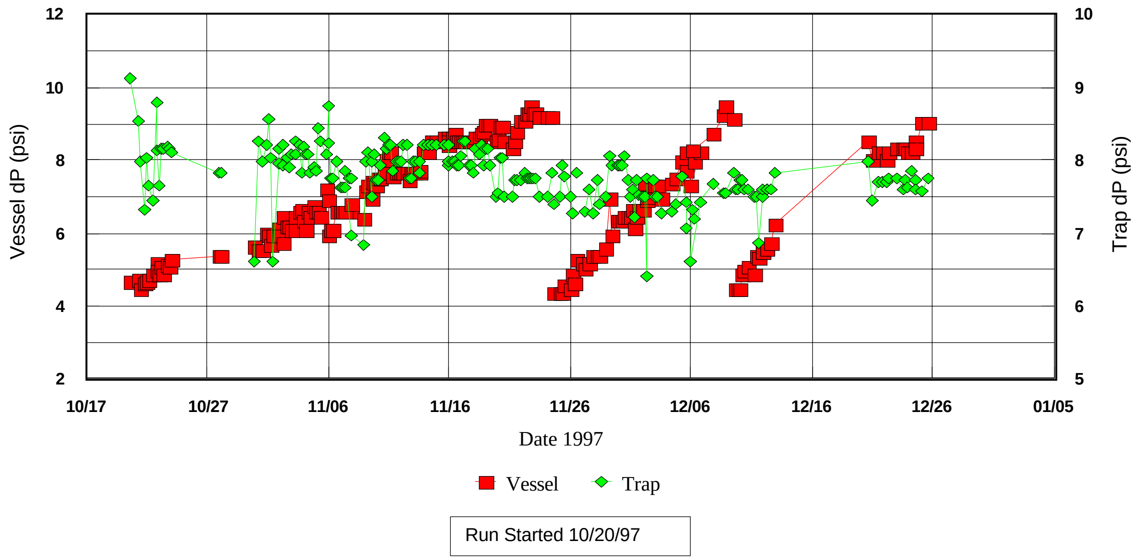


Figure 3-5
Filter 2B Flow Normalized Differential Pressure, Browns Ferry Unit 2

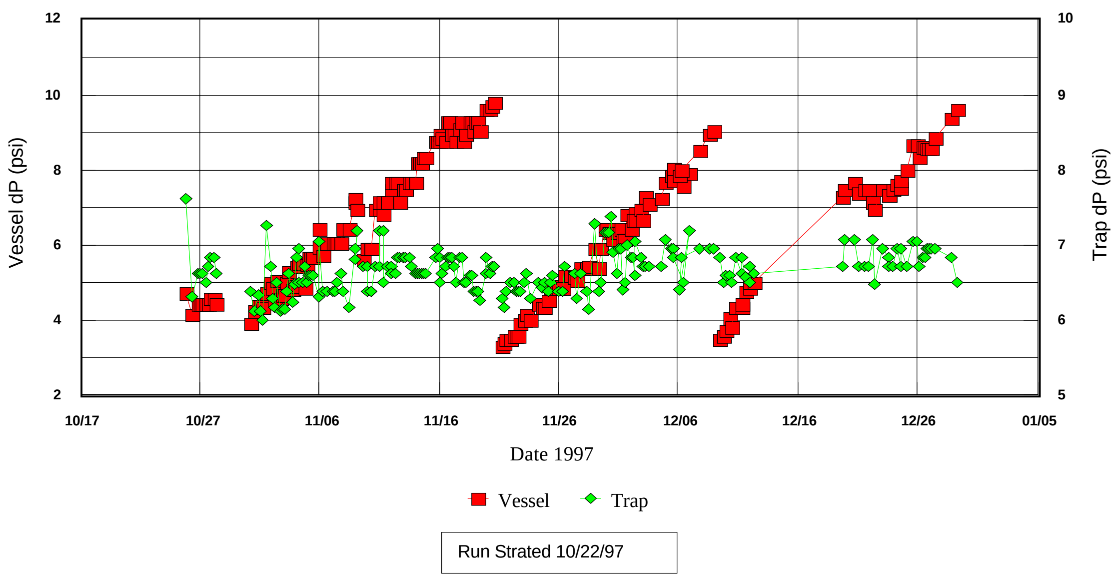


Figure 3-6
Filter 2C Flow Normalized Differential Pressure, Browns Ferry Unit 2

The new pleated septa (10 μm) installed in Filter 2C during October 1997 achieved an initial run length of about a 25 days, and about 20 days for the second and third runs. The new pleated septa (10 μm) installed in Filter 2B during October 1997 achieved run lengths of about 34, 16 and 16 days for the first, second and third runs respectively. All of the runs of Filters 2C and 2B were terminated at normalized ΔPs of 8 psi or greater.

Cyclic variations in run lengths are seen with pleated and yarn wound septa at Browns Ferry. TVA personnel suspect, based on historical data, that run lengths decrease during transitions from warm to cold weather and increase after the transition is completed.

A precoat dose of 0.033 dry lb / 10 inches of septum length is normally used. However, on a few occasions higher doses have been used. All powdered resin precoat materials have always been used with the pleated septa, except for one unsuccessful trial of a resin and fiber mixture material to reduce resin passage.

4

BROWNS FERRY UNIT 3

Table 4-1
Browns Ferry 3 Plant Design Parameters

Parameter	**Value**
Commercial Operation Date	3/77
Capacity (MWe)	1097
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Browns Ferry Unit 3 Milestones

Milestone events for Browns Ferry Unit 3 are given in Table 4-2. The following additional data and information are noteworthy:

The condenser was retubed, a chemical decontamination of the recirculation system was performed and the recirculation piping ring header, safe ends, and risers were replaced in 1995 prior to startup.

Table 4-2
Browns Ferry 3 Milestones

Browns Ferry – Unit 3										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser								X		
Recirc. Pipe Replacement								X		
RWCU Pipe Replacement								X		
Extraction Steam Pipe Replacement										
Chem. Decon								X		
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO								12/95	→	→
Iron Injection										
Crud Resins										
Pleated Filters									11/96	

Radiation Data

Recirculation System dose rates are summarized in Table 4-3:

Table 4-3
Browns Ferry 3 Recirculation System Dose Rates

Browns Ferry Unit 3 – Recirculation System Dose Rates (mR/hr)									
	May-96	Sep-96	Feb-97						
EFPY									
BRAC	29	41	70						
A Suction	40	50	90						
B Suction	25	60	80						
A Discharge	50	30	60						
B Discharge	30	25	50						
Avg Risers									

Trend Data

Trend data for Browns Ferry 3 for power and feedwater iron are presented in Figures 4-1 and 4-2. Cobalt 60 data were not provided.

Feedwater Iron Control

Brown's Ferry 3 feedwater total iron concentrations varied between 1.5 and 3.2 ppb for the data provided, which is similar to the range for Unit 2. As noted in the Browns Ferry 2 summary, the soluble feedwater iron concentrations for the two units differ significantly. The Browns Ferry 3 soluble feedwater iron concentration is among the highest reported, exceeding 0.1 ppb. While plants reporting the highest soluble feedwater iron concentrations (>0.1 ppb) also appear to have higher recirculating pipe dose rates, Brown's Ferry 3 and Vermont Yankee are exceptions to this trend. Both Browns Ferry 3 and Vermont Yankee have significant zinc input to the primary system (Vermont Yankee's zinc is from materials of construction, while Browns Ferry 3 injects DZO).

Recirculation Pipe Dose Rates

The Browns Ferry 3 dose rates are much lower than those at Unit 2. The most recent dose rates are less than 100 mR/hr at Unit 3. Unit 3 has not been in operation as long as Unit 2. However, the rate of increase in dose rate is also slower for Unit 3. The obvious difference between the two units is the start of depleted zinc oxide injection at Unit 3 in 1995, while Unit 2 has not implemented zinc injection. The Unit 3 reactor water soluble zinc concentration was maintained in the range of 3 - 7 ppb. No reactor water metals data, except zinc, or isotopic data were available for review.

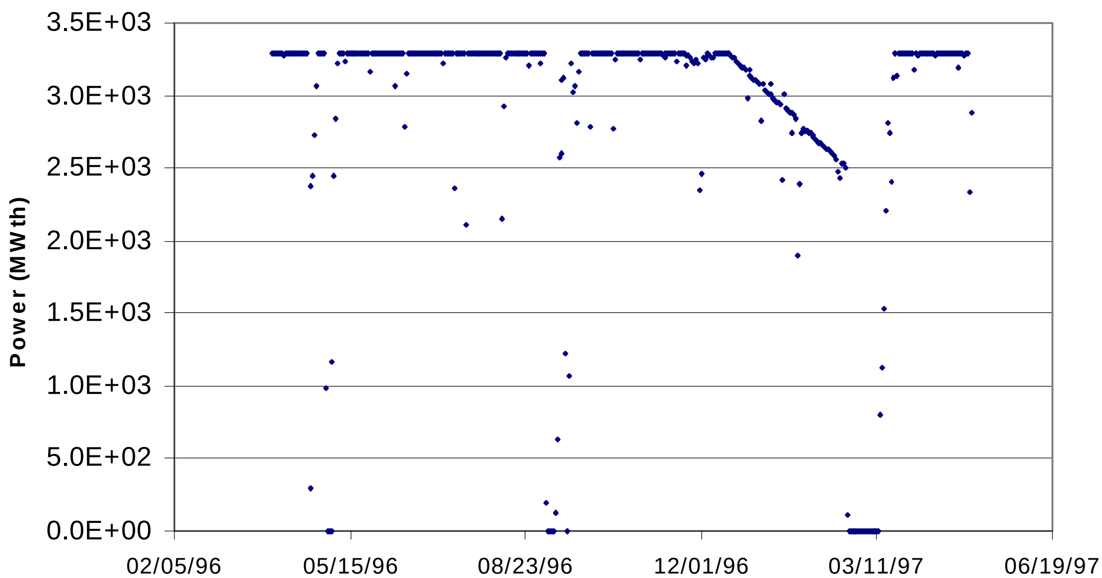


Figure 4-1
Power History, Browns Ferry Unit 3

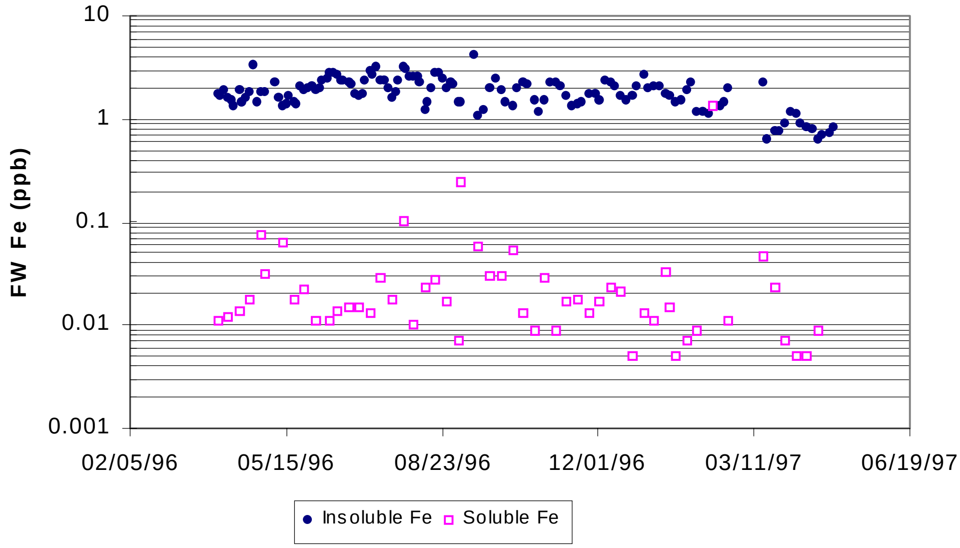


Figure 4-2
Feedwater Iron, Browns Ferry Unit 3

Browns Ferry Preocat Pleated Filter Septa Performance

See Browns Ferry Unit 2 for a discussion of septa performance at Unit 2 and Unit 3.

5

BRUNSWICK UNIT 1

Table 5-1
Brunswick Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	3/77
Capacity (MWe)	770
BWR Type	4
Drains Path	Forward Pumped
Condensate Polishing	Filter + Deep Bed
RWCU Capacity (% Feedwater Flow)	1%

Brunswick Unit 1 Milestones

Milestone events for Brunswick Unit 1 are given in Table 5-2. The condenser was retubed with stainless steel in 1983. The original tube material was copper/nickel. The recirculating pipe was replaced in 1990. The decontamination of the recirculation pipe in 1993 removed 31.3 curies; the decontamination in 1995 removed 16.7 curies.

Table 5-2
Brunswick Unit 1 Milestones

Brunswick - Unit 1										
Milestone	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Power Uprate										
Retube Condenser	1983									
Recirc. Pipe Replacement			X							
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.						X		X		
HWC (scfm)			10-18	→	→	→	35	→	→	39
Noble Metals Coating										
NZO										
DZO								5/95	→	→
Iron Injection										
Crud Resins										
Pleated Filters							8/94	→	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 5-3:

Table 5-3
Brunswick Unit 1 Recirculation System Dose Rates

Brunswick Unit 1 - Recirculation System Dose Rates (mR/hr)											
	Feb-87	Mar-87	Oct-90	Nov-90	May-92	Apr-93	Apr-93	Apr-95	Apr-95	Oct-96	Nov-97
EFPY											
BRAC	212	61.7	343.8	82.5	216.3	177.5	23.8	1525	693.8	417.5	550
A Suction			300	85	250	200	20	1500	350	220	300
B Suction	160	60	400	120	225	150	10	1900	1200	750	800
A Discharge	225	80	300	45	195	110	15	1400	575	400	350
B Discharge	250	45	375	80	195	250	50	1300	650	300	750
Avg Risers	185	22.2	687.5	40.5	90	69	4.8	1112.5	80	218.75	237.5

Trend Data

Trend data for Brunswick 1 are presented in Figures 5-1, 5-2 and 5-3.

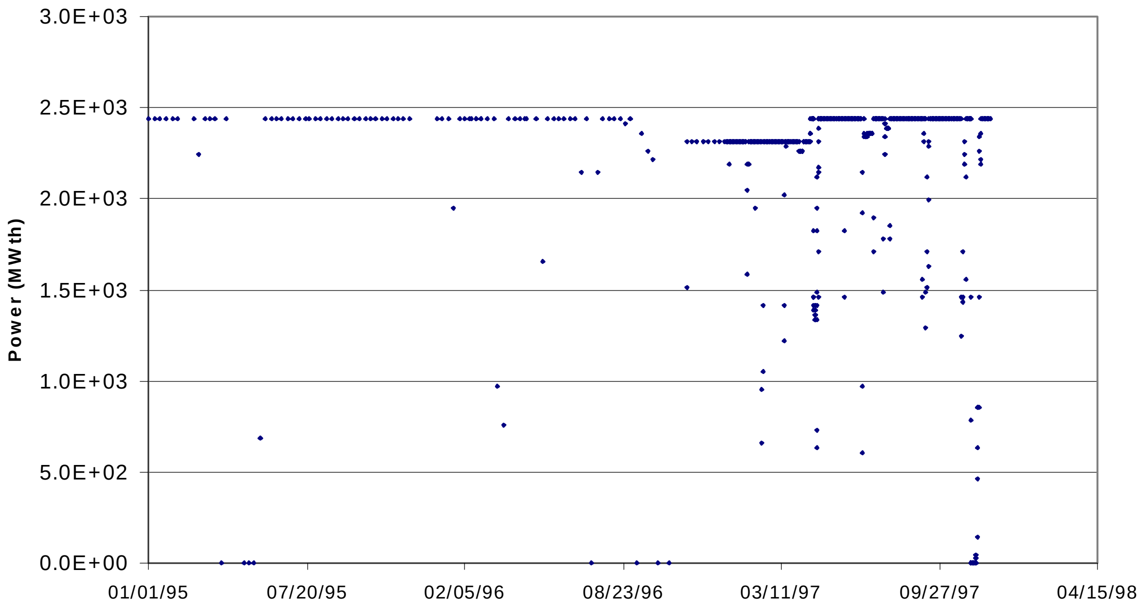


Figure 5-1
Power History, Brunswick Unit 1

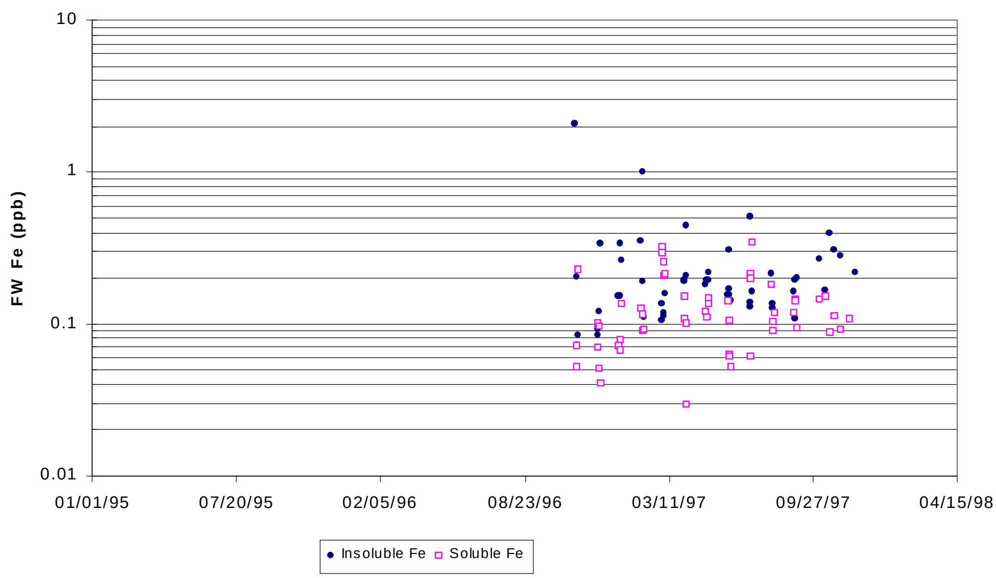


Figure 5-2
Feedwater Iron, Brunswick Unit 1

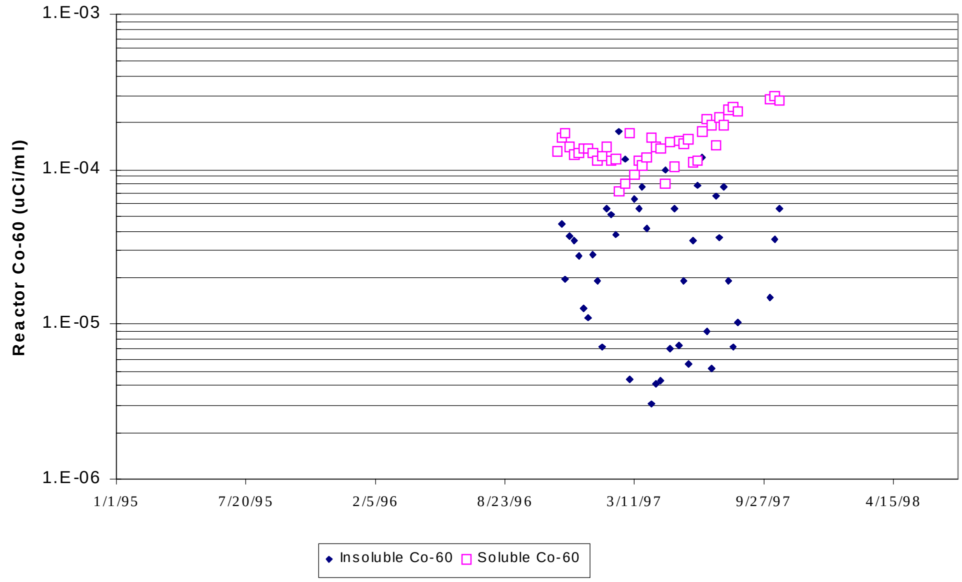


Figure 5-3
Reactor Water Cobalt 60, Brunswick Unit 1

Feedwater Iron Control

Brunswick's original plant design included filter demineralizers followed by deep beds for condensate polishing. Feedwater iron concentrations at Unit 1 are routinely < 0.5 ppb, which are among the lowest in the industry. At the same time, reactor water iron was in the 1 to 30 ppb range, chromium in the 1 to 5 ppb range and copper in the 3 to 7 ppb range. In the second quarter 1997, the reactor water insoluble metals trended lower than in previous months, with iron < 2 ppb, chromium around 1 ppb, and copper about 1 ppb. Both Brunswick units have feedwater Ni/Fe of < 0.2; however the (Ni+Zn)/Fe is much greater than 0.2.

Unit 1 has an average soluble feedwater iron concentration of about 0.14 ppb, which is among the higher values reported by BWR's. The ratio of soluble to insoluble feedwater iron is also high compare to other plants.

Recirculating Pipe Dose Rates

Reactor water soluble Co-60 typically exceeds 1.0E-4 uCi/ml. The most significant increases in drywell dose rates are clearly related to hydrogen injection, although it is not clear if the increases were due to operation at moderate HWC conditions of 1 ppm H_2 in the feedwater, or frequent cycling of hydrogen injection. Dose rates tended to stabilize at approximately 200 mR/hr without hydrogen injection. Addition of depleted zinc oxide was implemented after a chemical decontamination in 1995. With both zinc addition and moderate hydrogen injection applied, dose rates appear to have returned to the 200 mR/hr range.

Pipe Gamma Scan Data

A gamma scan of the recirculating pipe in 1990, before the chemical decontamination was performed, indicated the corrosion film had approximately 18 uCi/cm^2 of total activity with about 80% of the activity made up of Co-60.

Brunswick Non-Precoated Pleated Septa Performance

By December 1997, CDI iron concentrations at Brunswick Unit 1 had declined to about 6 ppb. Station personnel speculate that the decline may be a consequence of recent pipe replacements. Previously average CDI iron concentrations reported had been in the range of 8 to 11 ppb. At a 6 ppb CDI iron concentration, the application challenge severity for the pleated filter septa at Brunswick would be among the lowest among BWR plants using pleated septa, with or without precoats.

Unit 1 power has been uprated by 5 percent. Because of high ΔPs across the Condensate Filters with the original Graver pleated septa, some installed almost three years ago, at the higher condensate flow only 3 of the 4 Condensate Filters can be on-line because of system ΔP limits.

The original Graver pleated filter septa in all four Condensate Filters of Unit 1 have been replaced. Pall BPF-4 septa replaced the Graver septa in Filters 1A and 1B, and were first placed in service on February 13, 1998 and January 31, 1998, respectively. The original Graver pleated septa in Filters 1C and 1D were replaced with new Graver septa that were first placed in service on July 6, 1997 and May 26, 1997 respectively. The new Graver septa are claimed to have about 18% more filtration area than the septa replaced.

As of March 10, 1998, the Pall septa in Filter 1B had completed one 30-day cycle with a 5 psi rise over the clean ΔP. The first run with Pall septa in Filter 1A was in progress.

Early runs with new Graver septa were disappointing. There was a significant (42 to 56%) decrease in run length following long initial run lengths. This was followed by a more gradual decrease in run lengths. The average run length for the first three runs with the new septa in Filter 1C was about 42.5 equivalent base flow days. For the new septa in Filter 1D, the average for the first five runs was about 36.1 equivalent base flow days per run. Subsequently, run lengths improved, and the early disappointing performance is attributed to particularly arduous service conditions as Unit 1 returned to stable full power. In the future, Brunswick personnel are considering the use of minimum precoats during startup periods when high crud concentrations and bursts are encountered. An alternative countermeasure would be to limit run lengths and/or final ΔPs during startup periods.

As of this writing, none of the original pleated septa in Unit 2 Condensate Filters have been replaced. However, replacement of original septa in all filters is expected to occur during 1998.

Run length and longevity statistics for the pleated septa monitored at Brunswick are shown in Table 5-4.

Table 5-4
Brunswick Non-Precoat Pleated Septa Performance

Filter	**1C**	**1D**	**2C**
Septa Particle Rating (μm)	1	1	1
Total Elapsed Days Since Initial Service	899.0	1005.0	862.0
Total Operating Time (Actual Days)	644.0	631.0	740.0
Total Operating Time (Base Flow Days)	612.2	595.1	704.7

6

BRUNSWICK UNIT 2

Table 6-1
Brunswick Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	11/72
Capacity (MWe)	770
BWR Type	4
Drains Path	Forward Pumped
Condensate Polishing	Filter + Deep Bed
RWCU Capacity (% Feedwater Flow)	1%

Brunswick Unit 2 Milestones

Milestone events for Brunswick Unit 2 are given in Table 6-2. The condenser was retubed with stainless steel in 1984. The original material was copper/nickel. The recirculating piping was replaced in 1989.

The chemical decontamination of the recirculation piping in 1991 removed 76 curies; the 1994 chemical decontamination removed 25.3 curies; the decon in 1996 removed 281 curies.

Table 6-2
Brunswick Unit 2 Milestones

Brunswick Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser	1984									
Recirc. Pipe Replacement		X								
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.				X			X		2/96	
HWC (scfm)		10→0	12-15	→	→	20	35	→	→	→
Noble Metals Coating										
NZO										
DZO									3/96	→
Iron Injection										
Crud Resins										
Pleated Filters							12/94	→	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 6-3.

Table 6-3
Brunswick Unit 2 Recirculation System Dose Rates

Brunswick Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Jan-86	Apr-87	Apr-88	Sep-89	Oct-89	Aug-90	Jan-91	Apr-91	Sep-91
EFPY									
BRAC	350	172.5	142.8	247.5	58.8	468.8	243.8	906.3	275
A Suction				190	75	450	275	700	300
B Suction				150	45	425	200	700	350
A Discharge				150	60	500	300	825	250
B Discharge				500	55	500	200	1400	200
Avg Risers		170	144	201	7.1	942.5	990	2020	740

Brunswick Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Oct-91	May-92	Mar-94	Mar-94	Jun-94	Feb-96	Feb-96	Sep-97	
EFPY									
BRAC	14.5	60	981.3	612.5	625	2175	38.8	325	
A Suction	20	90	975	600	500	2200	40	350	
B Suction	18	80	1100	600	600	2500	65	350	
A Discharge	10	35	950	675	600	2000	20	300	
B Discharge	10	35	900	575	800	2000	30	300	
Avg Risers	438.5	535.5	1652.5	1912.5		1283	31		

Trend Data

The Brunswick trend data for power, feedwater iron, and reactor water cobalt 60 are presented in Figures 6-1, 6-2 and 6-3, respectively.

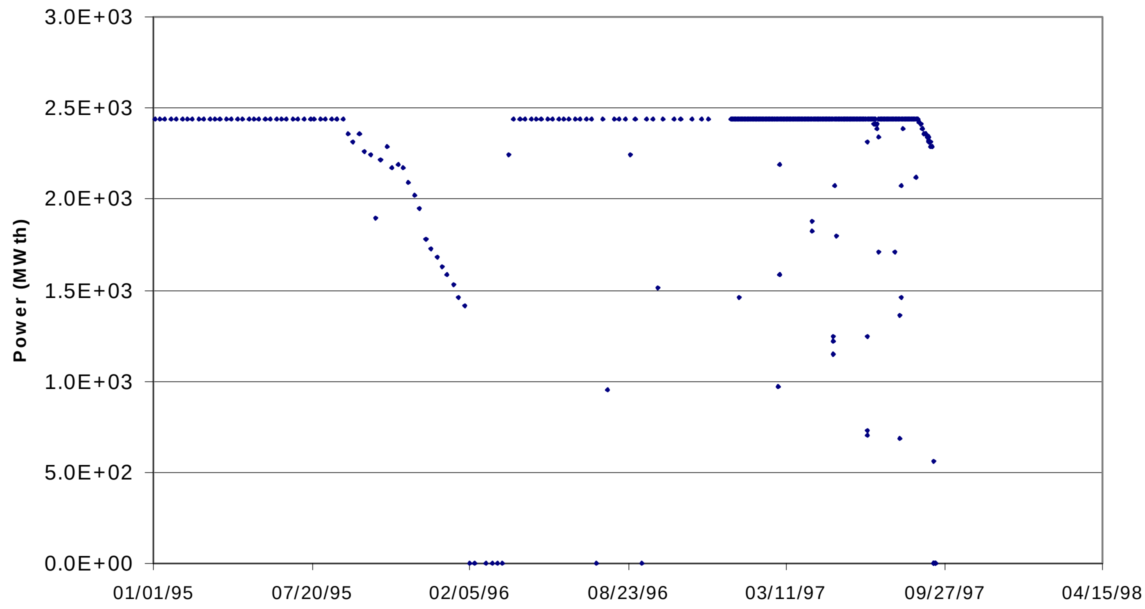


Figure 6-1
Power History, Brunswick Unit 2

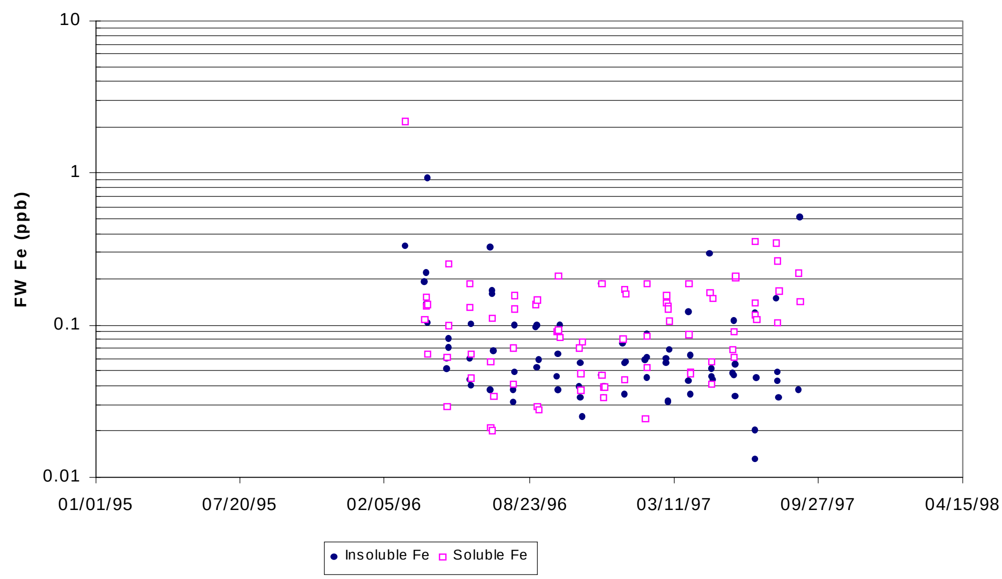


Figure 6-2
Feedwater Iron, Brunswick Unit 2

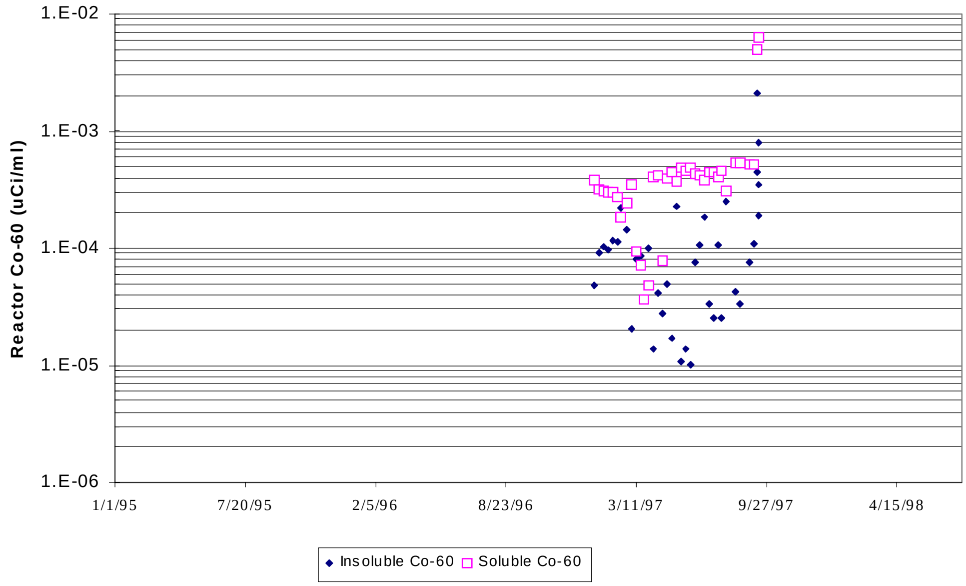


Figure 6-3
Reactor Water Cobalt 60, Brunswick Unit 2

Feedwater Iron Control

Feedwater insoluble iron concentrations at Unit 2 were typically <0.1 ppb. Feedwater soluble iron concentrations averaged 0.135 ppb, exceeding the feedwater insoluble iron concentration. Reactor water insoluble iron concentrations ranged from 5 -15 ppb, which insoluble chromium was in the 3 ppb range and insoluble copper was in the 4 ppb range. In the second quarter 1997, the reactor water insoluble metals trended lower than in previous months with iron about 1 ppb, chromium <1 ppb, and copper about 1 ppb.

Recirculation Piping Dose Rates

Brunswick 2 has the highest reported average reactor water soluble Co-60 at 4.99E-4 uCi/ml. The industry data indicate that those plants with higher reactor water soluble Co-60 tend to have higher recirculation pipe dose rates.

Past increases in drywell dose rates are clearly related to hydrogen injection operation, although it is not clear if the increases were due to operation at moderate HWC conditions of 1 ppm feedwater H_2, or frequent cycling of hydrogen injection. Prior to hydrogen injection, dose rates tended to stabilize at less than 200 mR/hr.

The plant started depleted zinc oxide addition after a chemical decontamination in 1996. The next dose rate survey, after operation with zinc addition and hydrogen injection, indicated a BRAC value of approximately 300 mR/hr. This is higher than dose rates measured at Brunswick Unit 1 after operating with both zinc addition and hydrogen injection.

Pipe Gamma Scan Data

A gamma scan of the recirculating pipe before the chemical decontamination in 1991 indicated the corrosion film had approximately 23 uCi/cm^2 total activity on the suction piping and 11 uCi/cm^2 total activity on the discharge piping. Co-60 accounted for between 65 and 80% of the total activity while Co-58 accounted for an additional 20% of the activity.

Stellite™ Reduction

Brunswick has replaced some valves and control rod blades with Stellite™ hardfacing with cobalt-free materials in both units. Approximately 4.2% of the initial Stellite surface area of 330 square feet has been replaced with alternative materials.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997	608 person-Rem
1996	799 person-Rem
1995	851 person-Rem
1994	831 person-Rem
1993	758 person-Rem
1992	983 person-Rem
1991	1371 person-Rem
1990	1694 person-Rem

Brunswick Non-Precoated Pleated Septa Performance

Experience with non-precoated condensate filter septa at Brunswick are reported in the Brunswick Unit 1 section.

7

CLINTON

Table 7-1
Clinton Plant Design Parameters

Parameter	Value
Commercial Operation Date	4/87
Capacity (MWe)	980
BWR Type	6
Drains Path	Cascaded
Condensate Polishing	Filter + Deep Bed
RWCU Capacity (% Feedwater Flow)	1%

Clinton Milestones

Milestone events for Clinton are given in Table 7-2.

Table 7-2
Clinton Milestones

Clinton										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										
Pleated Filters								7/95	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 7-3:

Table 7-3
Clinton Recirculation System Dose Rates

Clinton – Recirculation System Dose Rates (mR/hr)									
	Dec-97								
EFPY									
BRAC	335								
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Radiation Exposure

The station radiation exposure for 1997 was 173 person-Rem.

Clinton Non-Precoated Pleated Septa Performance

As of March 31, 1998, the Clinton station remains shutdown. The RLI values for the second sets of Memtec, Graver and Pall pleated septa at Clinton are 47, 65 and 71, respectively. The differences in the values result primarily from the differences in the number of septa per vessel each supplier elected to use; the septa from all suppliers have 2.5 inch nominal ODs.

The replacement sets of Graver, Memtec and Pall pleated filter septa have been installed in the three original CF vessels. When the three additional CF vessels will be installed is uncertain.

Only the Graver and Pall replacement septa have been subjected to any flow. The Pall BPF-4 septa were used for three runs before the plant shutdown. Pall has recommended limiting run lengths to 30 days. The first run lasted 33 days and ΔP increased from 0.4 to 1 psi over that period. Runs 2 and 3 were terminated by plant problems and lasted twelve and seven days respectively.

The Graver septa were also used before the plant shutdown, and are the only septa also used during Long Path flow cleanup while the plant was shutdown. The first run lasted 31 days during which the ΔP increased from 0.26 to 5 psi. By the fourth run the initial ΔP had increased to 0.58 psi. The fourth run lasted only 9 days to 10 psi. As a consequence of service during Long Path cleanup at 2800 gpm with an average influent iron of 20 ppb and bursts of higher concentrations, the Graver septa performance degraded significantly. As of August 14, 1997, the initial ΔP had increased to 7.5 psi and run lengths were about 24 hours to a 15 psi endpoint. The Graver septa will be replaced with Pall BPF-4 septa, drawn from the inventory of septa for the three additional CF vessels to be installed at a later date.

8

COOPER NUCLEAR

Table 8-1
Cooper Plant Design Parameters

Parameter	Value
Commercial Operation Date	7/74
Capacity (MWe)	801
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Cooper Milestones

Milestone events for Cooper are given in Table 8-2. The recirculation pipe was replaced during 1984 – 1985. The original material was 304 stainless steel, while the new material is seamless, electropolished and passivated 316L.

Table 8-2
Cooper Milestones

Cooper										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement	1984 - 1985									
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										
Pleated Filters										12/97

Radiation Data

Recirculation System dose rates are summarized in the following Table 8-3:

Table 8-3
Cooper Recirculation Dose Rates

Cooper – Recirculation System Dose Rates (mR/hr)							
	Oct-85	Oct-86	Mar-88	Apr-89	Oct-91	Mar-93	Mar-97
EFPY							
BRAC	9	70	95	95	160	175	230
A Suction	8	60	80	70	155	180	225
B Suction	6	60	90	95	165	170	200
A Discharge	17	85	90	110	160	200	300
B Discharge	9		110	105	160	155	200
Avg Risers							

Trend Data

Trend data presented for Cooper include power, feedwater iron and reactor water cobalt 60 in Figures 8-1, 8-2 and 8-3, respectively.

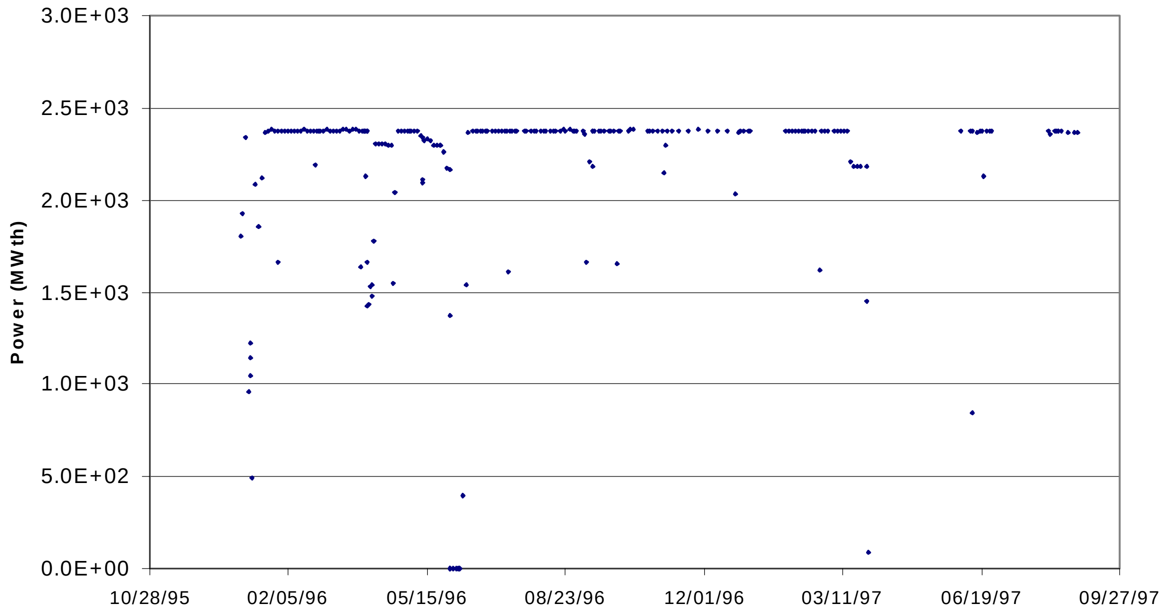


Figure 8-1
Power History, Cooper Nuclear Station

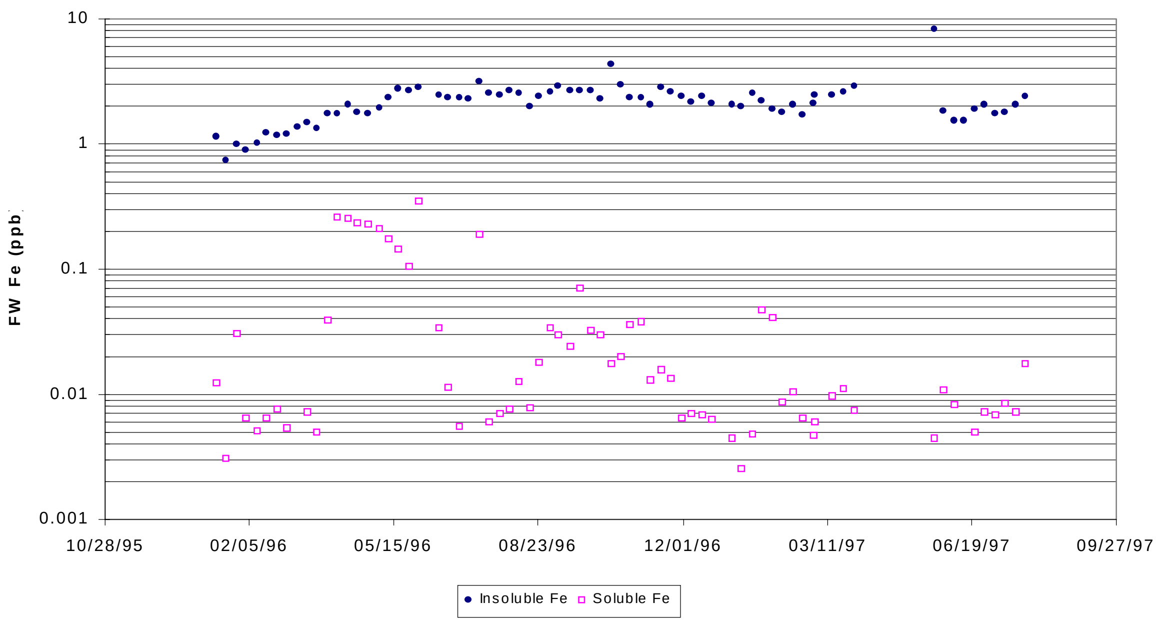


Figure 8-2
Feedwater Iron, Cooper Nuclear Station

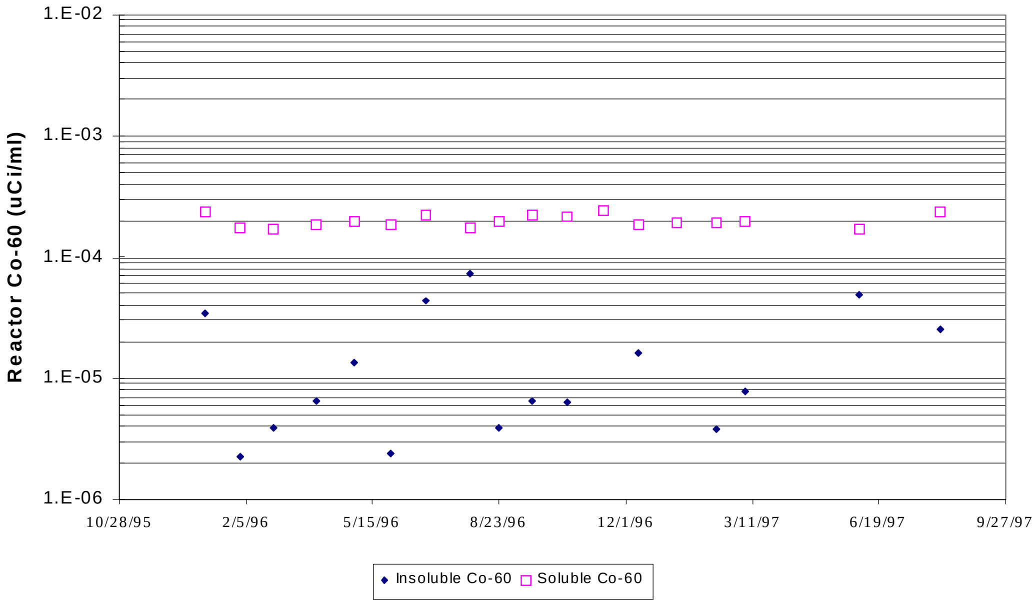


Figure 8-3
Reactor Water Cobalt 60, Cooper Nuclear Station

Feedwater Iron Control

The feedwater iron during 1996 and 1997 remained in the range of 1 to 2.5 ppb. Cooper does not inject either hydrogen or zinc oxide. There were some significant changes in monthly average insoluble Co-60 concentrations, with the values ranging from 4 E-6 uCi/ml to 5 E-5 uCi/ml, while the soluble Co60 remained relatively constant. No reactor water metals data were available for review.

Recirculation Piping Dose Rates

Since 1984 when the 304SS recirculation piping was replaced with 316L SS, the piping dose rates have been steadily increasing and are currently at 230 mR/hr. Soluble reactor water Co-60 is relatively high, at 2E-4 uCi/ml with no zinc in the system. Reported data indicates that plants with Co-60 greater than 1E-4 uCi/ml tend to have higher dose rates than those plants with soluble Co-60 less than 1E-4 uCi/ml.

Piping Gamma Scan Data

A gamma scan of the recirculation pipe was performed in 1997. The total activity was approximately 14 uCi/cm^2 with Co-60 accounting for 54% of the activity. Mn-54 accounts for an additional 38% of the total activity.

Stellite Reduction

The plant indicated that no significant stellite reduction has been performed.

Radiation Exposure

Station dose exposure three year rolling averages are as follows:

1997	151 person-Rem
1996	119 person-Rem
1995	234 person-Rem
1994	182 person-Rem
1993	289 person-Rem

Cooper Nuclear Precoated Pleated Filter Septa Performance

The RLI at Cooper Nuclear is 28, about 11% below the average of the two Peach Bottom units. The IXI, the challenge severity index for ion exchange, is 0.234, the highest value of BWR units using or planning to use precoated pleated filter septa in condensate applications. The next highest value at units now using pleated septa is 0.023 at Monticello and Quad Cities.

Currently 3 of the 7 Condensate Filter/Demineralizers are using Memtec 10 μm pleated septa. The first set of pleated were placed in service on February 20, 1998.

9

DRESDEN UNIT 2

Table 9-1
Dresden 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	6/70
Capacity (MWe)	830
BWR Type	3 - Mark I
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	3%

Dresden Unit 2 Milestones

Milestone events for Dresden 2 are given in Table 9-2. The RWCU piping was replaced in 1997 with 316L stainless steel; the original material was 304 stainless steel. The extraction steam piping was replaced with chrome-moly.

Table 9-2
Dresden 2 Milestones

Dresden 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										4/97
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)	47 (1983)	→	→	→	→	→	→	→	→	→
Noble Metals Coating										
NZO										
DZO									12/96	→
Iron Injection										
Crud Resins								12/95	→	→
Pleated Filters										
Oxygen Injection									10/96	→

Radiation Data

Recirculation System dose rates are summarized in the Table 9-3:

Table 9-3
Dresden 2 Recirculation System Dose Rates

Dresden Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Dec-97								
EFPY									
BRAC	100								
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Trend Data

Trend data for Dresden 2, including power history, feedwater iron and reactor water cobalt 60, are presented in Figures 9-1, 9-2 and 9-3, respectively.

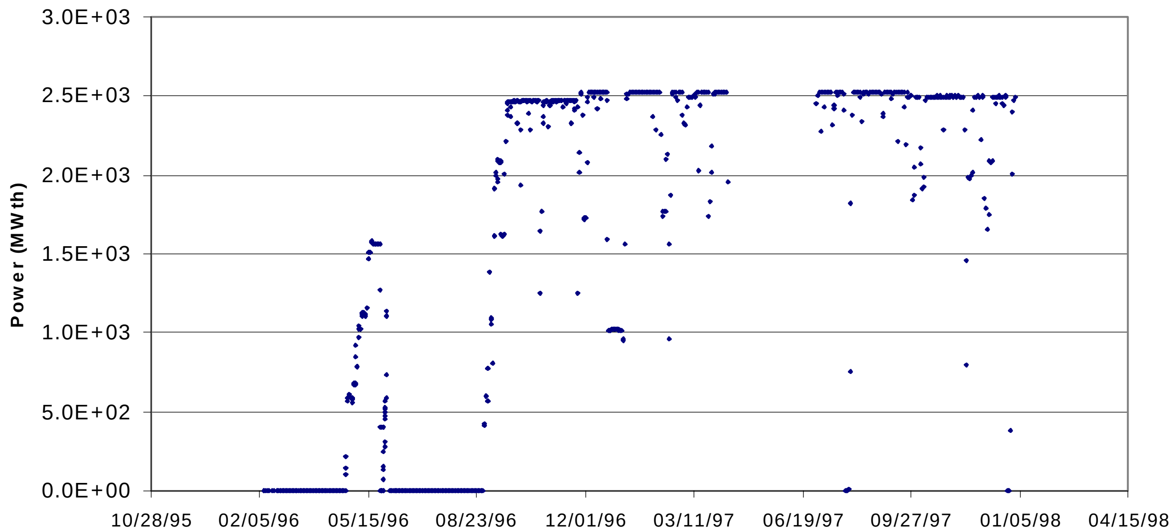


Figure 9-1
Power History, Dresden Unit 2

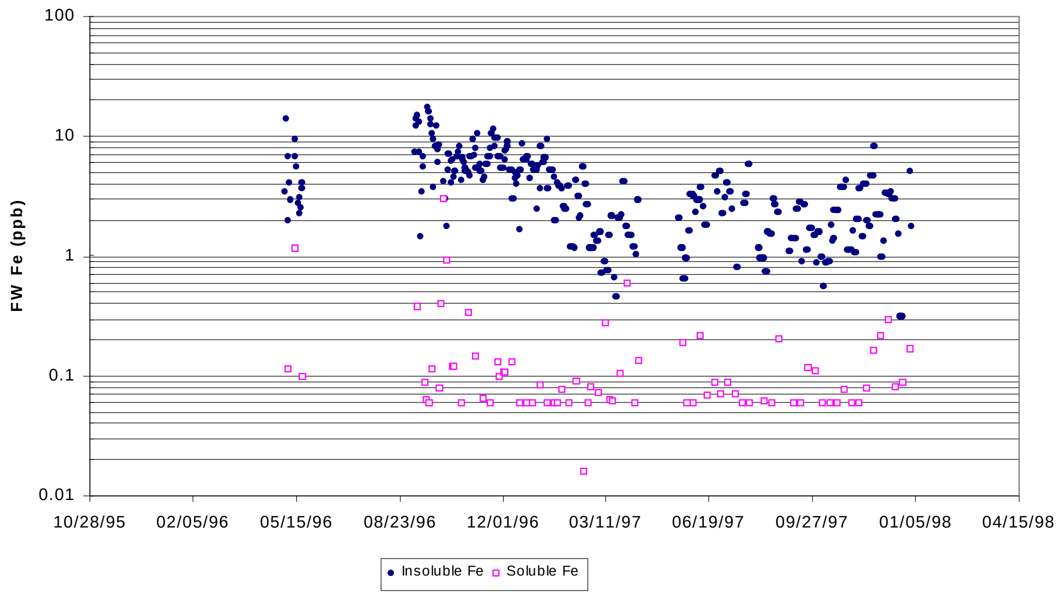


Figure 9-2
Feedwater Iron, Dresden Unit 2

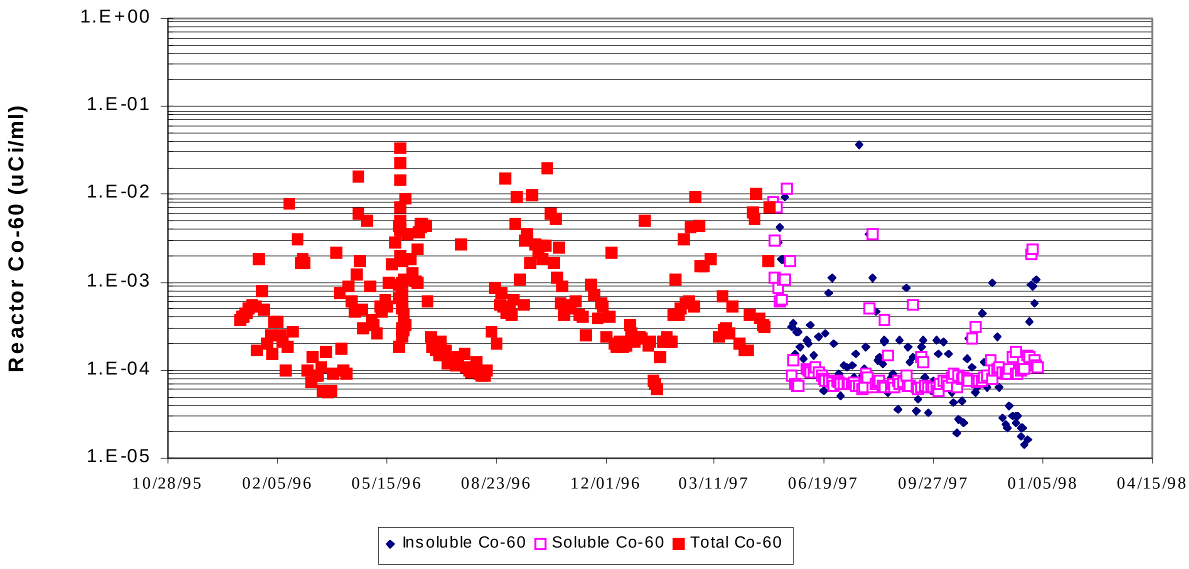


Figure 9-3
Reactor Water Cobalt 60, Dresden Unit 2

Feedwater Iron Control

Dresden 2 has continued to use some low crosslinked resins to improve feedwater iron control. The station has not reported adverse effects on reactor water quality, particularly sulfate, attributable to the use of these reins. The feedwater iron concentration in 1996 was in the range of 4 to 7 ppb. In February, 1997 the iron concentration decreased, averaging approximately 2.5 ppb. Reactor water total Co-60 was high compared to the rest of the industry, averaging approximately 1.5 E-3 uCi/ml. Soluble Co-60 averaged greater than 1E-4 uCi/ml in 1997, with activity peaks associated with power changes.

Recirculation Piping Dose Rates

Dresden 2 is currently injecting both hydrogen and depleted zinc oxide. The zinc injection started in December, 1996. The BRAC dose rate reported for December, 1997 was 100 mR/hr.

10

DRESDEN UNIT 3

Table 10-1
Dresden Unit 3 Plant Design Parameters

Parameter	Value
Commercial Operation Date	11/71
Capacity (MWe)	810
BWR Type	3 - Mark I
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	3%

Dresden Unit 3 Milestones

Milestone events for Dresden 3 are given in Table 10-2. The recirculation piping was replaced in 1985 with 316NG stainless steel; the original material was 304 stainless steel. The RWCU piping was replaced in 1997 with 316L stainless steel; the original material was 304 stainless steel.

The extraction steam piping was replaced with chrome-moly.

Table 10-2
Dresden Unit 3 Milestones

Dresden 3										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement	1985									
RWCU Pipe Replacement										6/97
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										6/97
Pleated Filters										
Oxygen Injection									10/96	→

Radiation Data

Recirculation System dose rates are summarized in Table 10-3:

Table 10-3
Rec Dresden Unit 3 Recirculation System Dose Rates

Dresden Unit 3 – Recirculation System Dose Rates (mR/hr)									
	Dec-97								
EFPY									
BRAC	60								
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Trend Data

Trend data for Dresden Unit 3 for power, feedwater iron and reactor water cobalt 60 are presented in Figures 10-1 and 10-2 and 10-3, respectively.

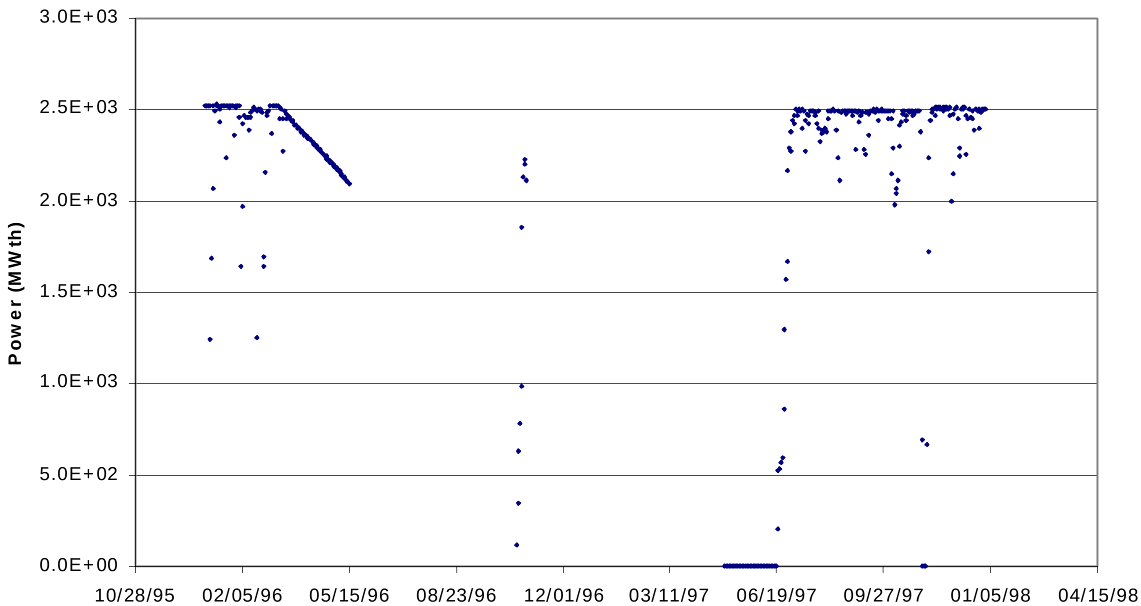


Figure 10-1
Power History, Dresden Unit 3

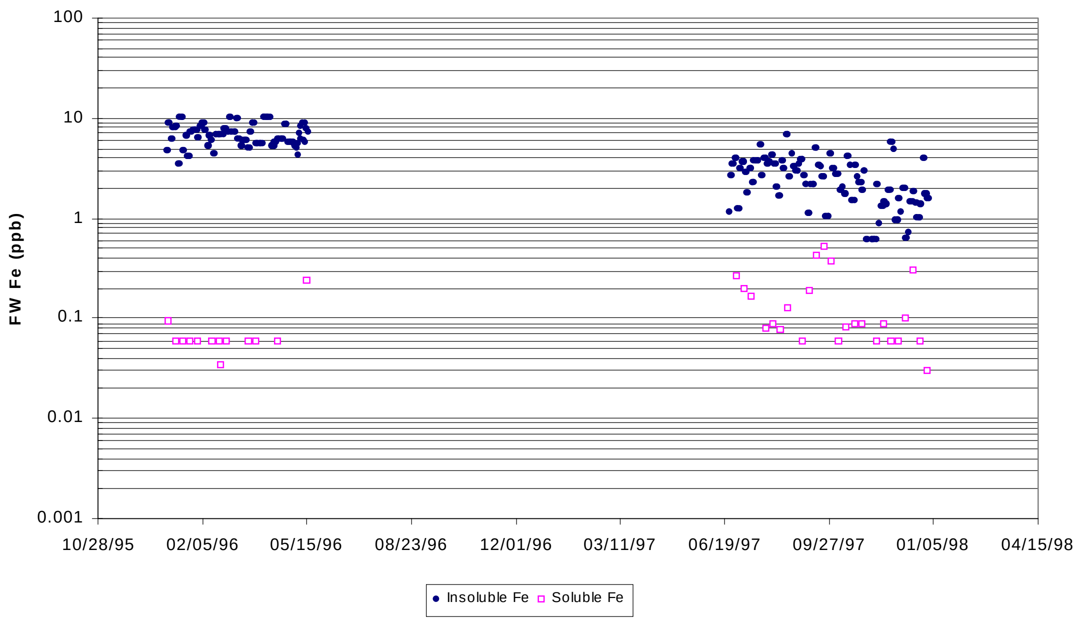


Figure 10-2
Feedwater Iron, Dresden Unit 3

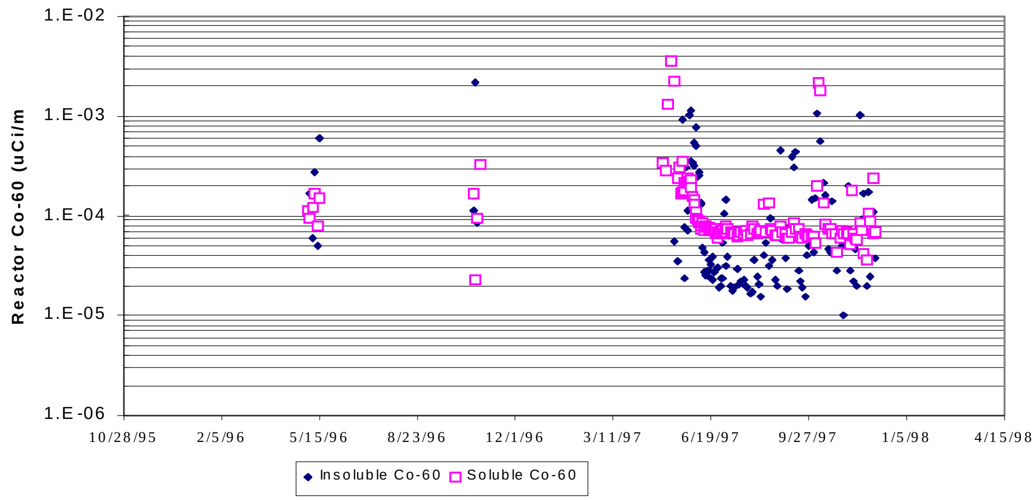


Figure 10-3
Reactor Water Cobalt 60, Dresden Unit 3

Feedwater Iron Control

Dresden 3 has installed some low crosslinked resin beds in 1997 to improve feedwater iron control. Insoluble and soluble feedwater iron were approximately 7 ppb and 0.06 ppb, respectively, in 1996.

Recirculation Piping Dose Rates

Unlike Dresden 2, Dresden 3 does not inject either hydrogen or zinc oxide. The other major operating difference between these units is the recirculation piping at Unit 3 is 316 SS while that at Unit 2 is 304 SS. BRAC dose rates reported at the end of 1997 were 60 mR/hr for Unit 3.

11

DUANE ARNOLD

Table 11-1
Duane Arnold Plant Design Milestones

Parameter	Value
Commercial Operation Date	2/75
Capacity (MWe)	545
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Duane Arnold Milestones

Milestone events for Duane Arnold are given in Table 11-2.

Table 11-2
Duane Arnold Milestones

Duane Arnold										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)	15 (1987)	→	→	→	→	→	→	→	→	→
Noble Metals Coating										X
NZO										
DZO								1995	→	→
Iron Injection										
Crud Resins										
Pleated Filters								3/95	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 11-3:

Table 11-3
Duane Arnold Recirculation System Dose Rates

Duane Arnold – Recirculation System Dose Rates (mR/hr)									
EFPY									
BRAC									
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Trend Data

Duane Arnold trend data for power, feedwater iron and reactor water cobalt 60 are presented in Figures 11-1, 11-2 and 11-3, respectively.

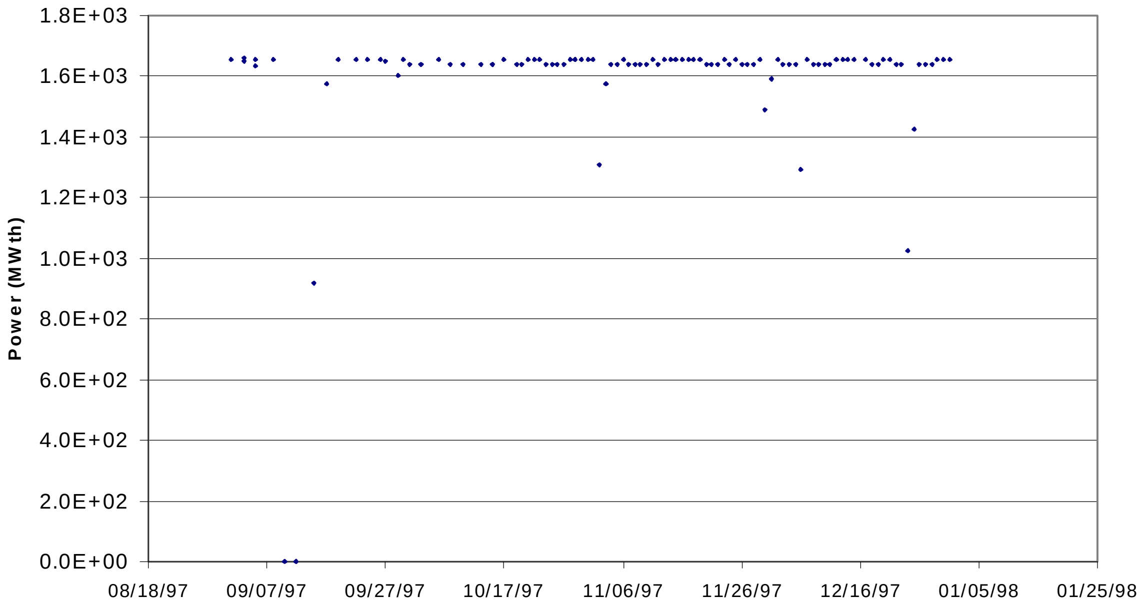


Figure 11-1
Power History, Duane Arnold

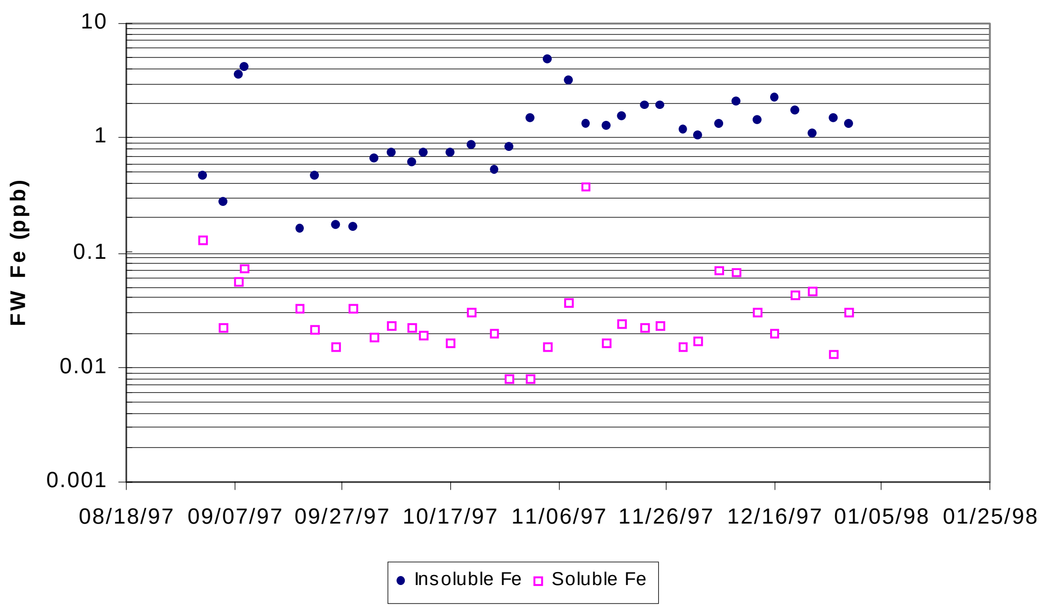


Figure 11-2
Feedwater Iron, Duane Arnold

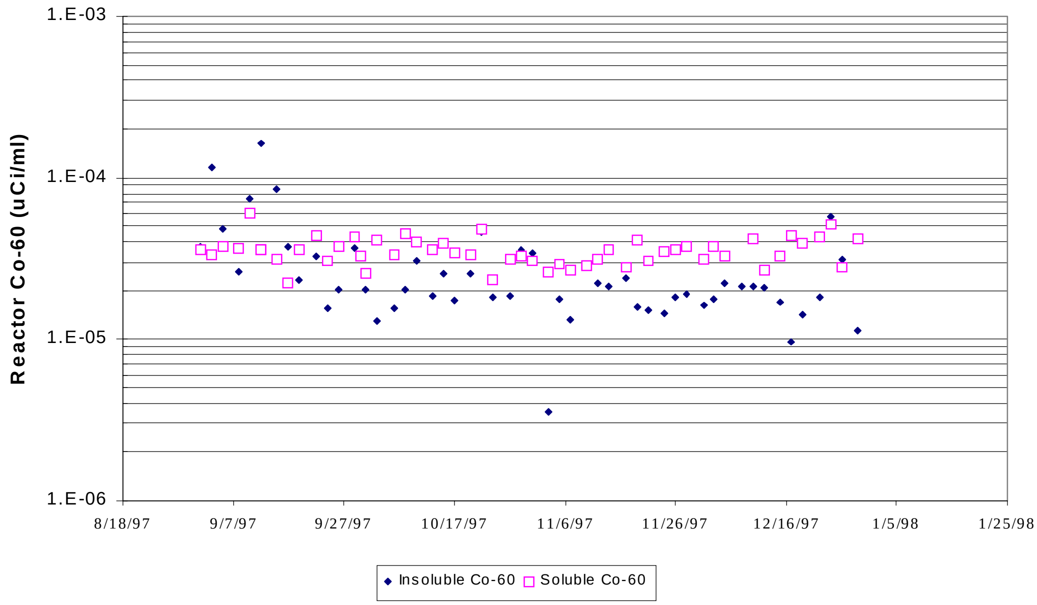


Figure 11-3
Reactor Water Cobalt 60, Duane Arnold

Feedwater Iron Control

Feedwater insoluble iron increased from a range of 0.6 to 0.7 ppb in September 1996 to 1 to 2 ppb in November, 1996. The soluble feedwater iron remained constant at this time at 0.02 to 0.05 ppb.

Recirculation Pipe Dose Rates

Soluble Co-60 for Duane Arnold in 1997 averaged about 3.5E-5 uCi/ml, which was in the low range in comparison to the industry,. Plants with lower soluble Co-60 (<1E-4 uCi/ml) tend to have lower recirculation pipe dose rates. However, there were no radiation dose rate data provided for review.

Duane Arnold Precoated Pleated Filter Septa Performance

Pall polyaramid pleated septa are used in one of the CF/D vessels. The pleated septa have 2 inch outside diameter. The septa were installed in December 1994, and initial use was in March, 1995. As of October 1997, the septa were still in service. The pleated septa have a RLI of 26.5, about 16% less than the Peach Bottom RLI.

The pleated septa have been removed from the CF/D vessel twice and cleaned with an ultrasonic cleaning system. The initial run lengths with new and out-of-vessel cleaned septa have been about 25 days. After the initial use and following the first out-of-vessel cleaning, run lengths declined to 15 days in about 12 months. In October, 1997, the reported run length decline appeared to be more rapid after the second out-of-vessel cleaning, and the Pall polyaramid septa would likely be replaced by another type of pleated septa.

The Pall pleated septa have been precoated with a fiber and ion exchange resin mixture at a dosage of about 0.09 dry pounds per 10 inches of septum length. The dosage used at Duane Arnold is about three times the dosage used at Peach Bottom and Browns Ferry, where all ion exchange resin precoats are used on the Memtec pleated septa.

Upon removal of the septa for the first out-of-vessel cleaning, it was found that the joint between the 48-inch and 9-inch segments of one septum had failed. The joint failed on four additional septa after removal when subjected to a bending test. After the second removal of septa for cleaning, no failed points were found. However, two or three septa failed the bending test after the second removal.

12

FERMI 2

Table 12-1
Fermi 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	1/88
Capacity (MWe)	1150
BWR Type	4
Drains Path	Forward Pumped
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Fermi 2 Milestones

Milestone events for Fermi 2 are given in Table 12-2. The plant electrical capacity was increased in 1992 from 1093 MWe to 1139 MWe, and again in 1996 to 1150 MWe. The plant was in an extended shutdown following the turbine blade failure on December 25, 1993 which resulted in a large ingress of main condenser cooling water into plant systems.

The condenser was retubed with titanium in 1991; the original material was admiralty brass. Approximately 150 ft of extraction steam piping to the #5 heater was replaced in 1992. The original extraction steam piping material was carbon steel, and the new material is chrome-moly.

Table 12-2
Fermi 2 Milestones

Fermi 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate					9/92				11/96	
Retube Condenser				X						
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement					X					
Chem. Decon.										
HWC (scfm)										9/97
Noble Metals Coating										
NZO										
DZO								X	→	→
Iron Injection										
Crud Resins										
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 12-3.

Table 12-3
Fermi 2 Recirculation System Dose Rates

Fermi 2 – Recirculation System Dose Rates (mR/hr)									
	11/88	4/91	10/92	3/94	11/96	10/97			
EFPY									
BRAC	43	91	133	162.5	127.5	125			
A Suction	40	90	160	190	140	120			
B Suction	25	95	50	60	40	80			
A Discharge	46	90	120	200	150	150			
B Discharge	60	90	200	200	180	150			
Avg Risers	119	164	339	424	296	223			

Trend Data

Fermi 2 trend data for power, feedwater iron and reactor water cobalt 60 are presented in Figures 12-1, 12-2 and 12-3, respectively.

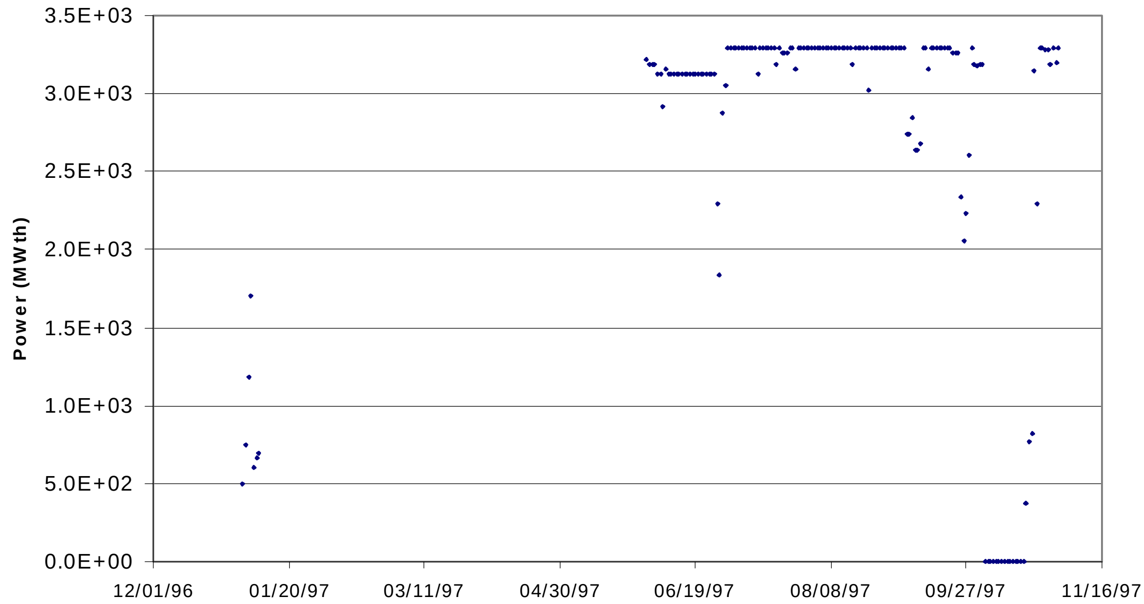


Figure 12-1
Power History, Fermi 2

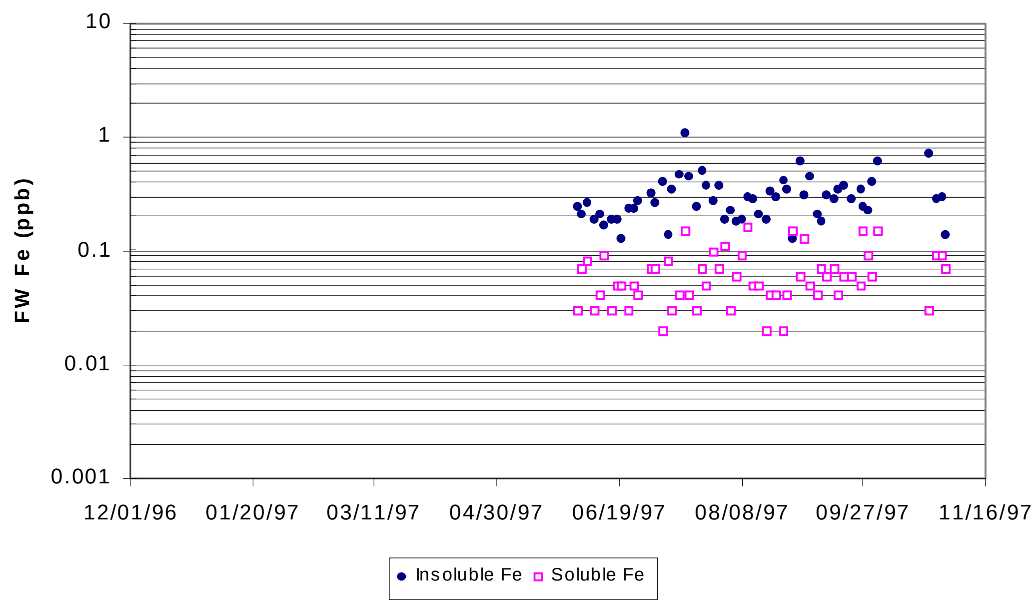


Figure 12-2
Feedwater Iron, Fermi 2

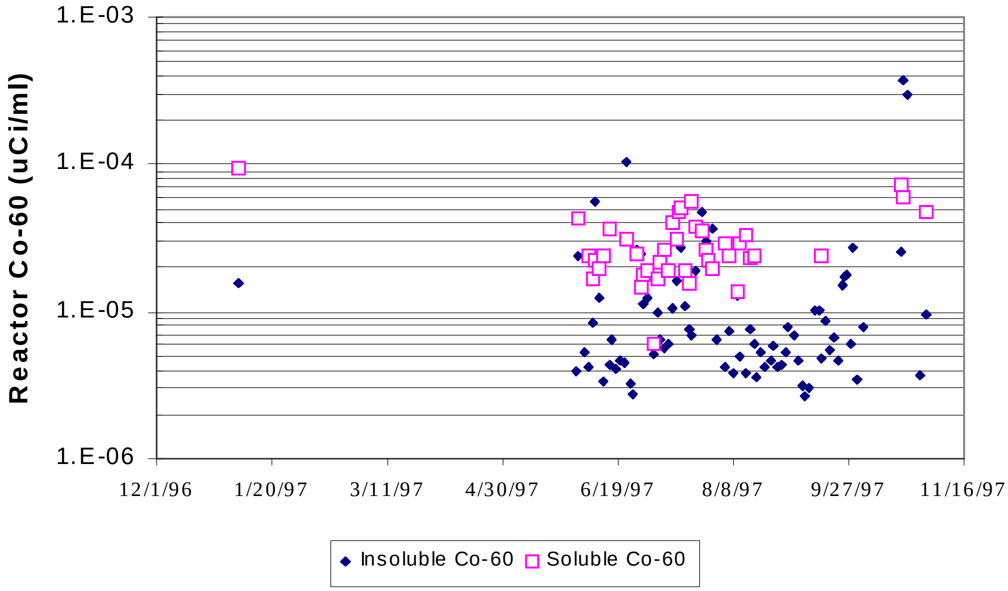


Figure 12-3
Reactor Water Cobalt 60, Fermi 2

Feedwater Iron Control

The feedwater insoluble iron concentration was approximately 0.3 ppb during the first part of 1997, and soluble iron averaged 0.06 ppb. Therefore, total feedwater iron is below the current target range minimum of 0.5 ppb. Fermi is actively pursuing a set of pleated septa for one condensate filter demineralizer vessel to reduce radwaste generation. The new septa are expected to drive feedwater iron concentrations lower.

Recirculating Pipe Dose Rates

Pipe dose rates had shown gradual increases from the start of plant operation until 1994, when the dose rates reached 162 mR/hr. Surveys taken after 1994 indicate the dose rates have stabilized at approximately 130 mR/hr. Fermi started adding DZO to the feedwater in 1995 and consistent moderate hydrogen injection was implemented in late 1997. Fermi reports low soluble Co-60 activity, in the range of 3.1E-5 uCi/ml.

Pipe Gamma Scan Data

Plant gamma scan data are recorded in counts per second, which provides and indication for Fermi of relative changes between measurements, but does not allow comparison of Fermi data with that of other plants.

Radiation Exposure

Station radiation exposure three year rolling averages are as follows:

1997 78 person-Rem

1996 132 person-Rem

1995 92 person-Rem

1994 159 person-Rem

1993 159 person-Rem

1992 175 person-Rem

1991 176 person-Rem

Fermi 2 Precoated Pleated Filter Septa Performance

Memtec pleated filter septa will be installed in one CF/D vessel (Filter H), as a trial, in the last quarter of 1998. The average feedwater (FW) iron concentration at Fermi 2 is about 1.5 ppb. Therefore, the main interest in pleated septa is their potential to reduce the annual cost of precoat material purchases and disposals.

The Memtec bundle will contain 310 septa, with a particle retention rating of 4 μm. At an average CDI iron concentration of about 12 ppb, the application challenge severity at Fermi will be moderate; about the same as at Peach Bottom and slightly less than at Monticello. With only one of eight CF/Ds using pleated septa, ion exchange performance of precoats on the pleated septa is not a concern. Nonetheless, the trial period will include operations with body feed as part of an effort to determine the maximum number of vessels that could use pleated septa without encountering ion exchange run length limitations during periods of minor condenser leaks.

13

FITZPATRICK

Table 13-1
FitzPatrick Plant Design Parameters

Parameter	Value
Commercial Operation Date	7/75
Capacity (MWe)	860
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

FitzPatrick Milestones

Milestone events for James A. FitzPatrick Nuclear Power Plant are given in Table 13-2. The main condenser was retubed in 1994; the replacement tubes are admiralty brass, the same as the original material. The chemical decontamination of the RWCU and recirculation piping in 1988 removed 63 curies, while the decon in 1992 removed 49 curies and the 1994 the decon removed 37 curies. The power was uprated to 2536 MWth in January, 1997.

Table 13-2
FitzPatrick Milestones

J A FitzPatrick										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										1/97
Retube Condenser							12/94			
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.	10/88				2/92		12/94			
HWC (scfm)	11	→	13.5	→	→	→	→	18.5	→	→
Noble Metals Coating										
NZO		1/89	→	→	→	→	→	→		
DZO									4/96	→
Iron Injection										
Crud Resins										
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in the following Table 13-3.

Table 13-3
FitzPatrick Recirculation System Dose Rates

FitzPatrick – Recirculation System Dose Rates (mR/hr)

	Sep-88	Oct-88	Sep-89	Apr-90	Mar-91	Jan-92	May-92	Mar-93	Nov-93
EFPY	8.5	8.5	9.3	9.7	10.3	10.6	10.6	10.7	11.2
BRAC	168	43	116	116	120	113	10	34	90
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers	525	53	279	275	295	266	6	50	112

FitzPatrick (continued) – Recirculation System Dose Rates (mR/hr)

	Apr-94	May-95	Mar-96	Sep-96	Oct-96	Nov-96	May-97	Dec-97	
EFPY	11.5	12.5	13	13.5	13.60		14	14.5	
BRAC	112	42.5	90	96	85	78	68	92	
A Suction						70			
B Suction						85			
A Discharge						70			
B Discharge						85			
Avg Risers	154	70	140	145	164	265	125	165	

Trend Data

Trend data for FitzPatrick are presented in Figures 13-1, 13-2 and 13-3 for power, feedwater iron and reactor water cobalt 60, respectively.

Feedwater Iron Control

FitzPatrick has been one of the more successful plants with “deep bed only” condensate polishing in controlling feedwater using standard resins and URC for resin cleaning. The 1997 average feedwater total iron concentration was about 1.68 ppb, with iron dropping below 1 ppb for extended periods at steady state. Reactor water zinc is maintained between 4 and 6 ppb using passive DZO addition.

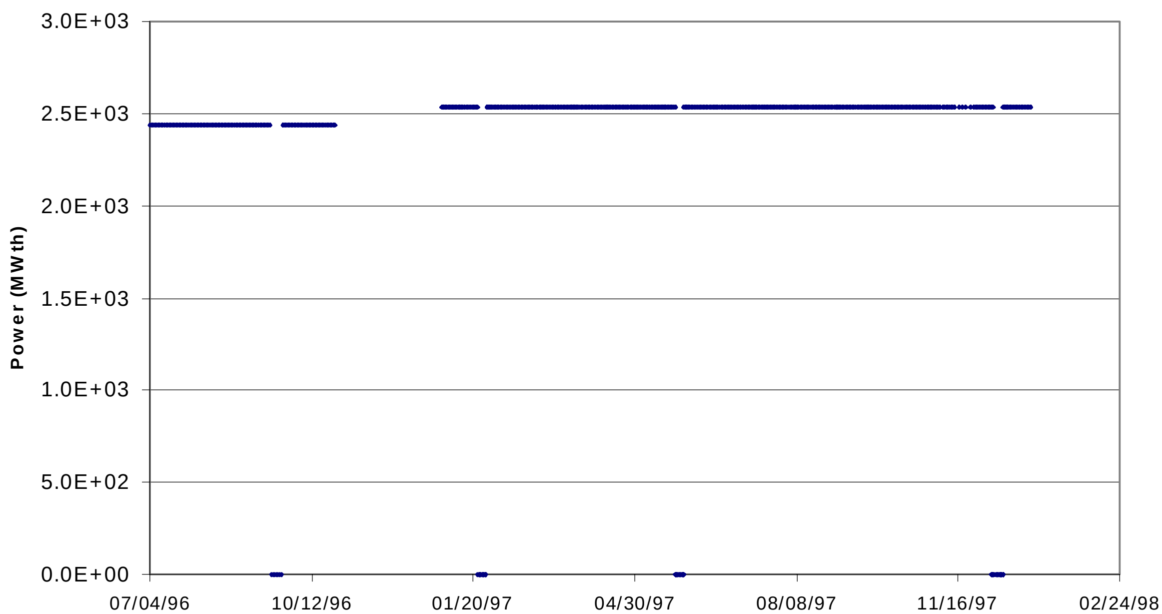


Figure 13-1
Power History, FitzPatrick

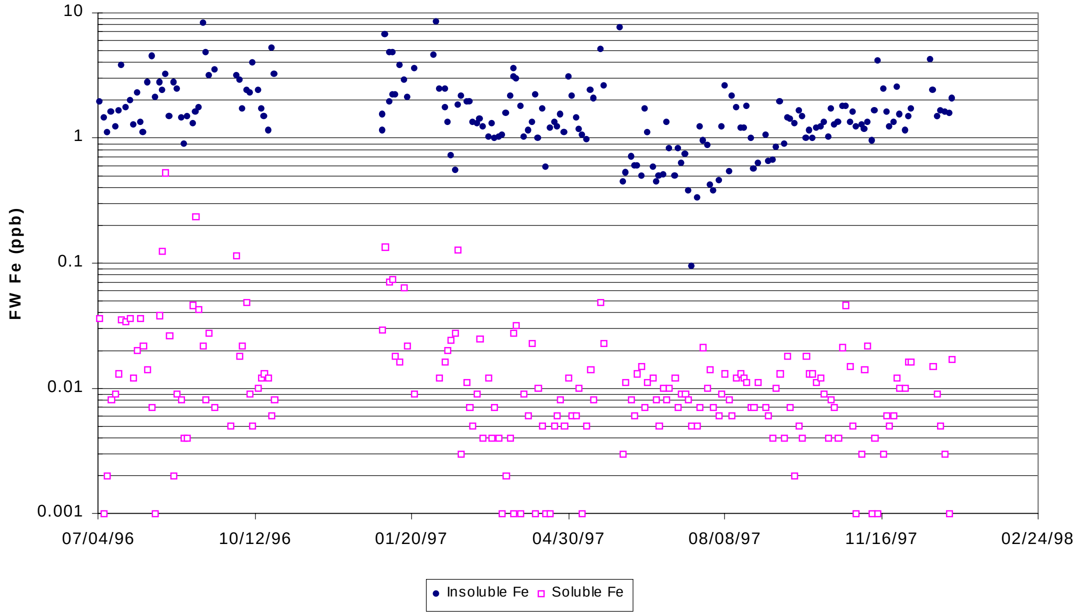


Figure 13-2
Feedwater Iron, FitzPatrick

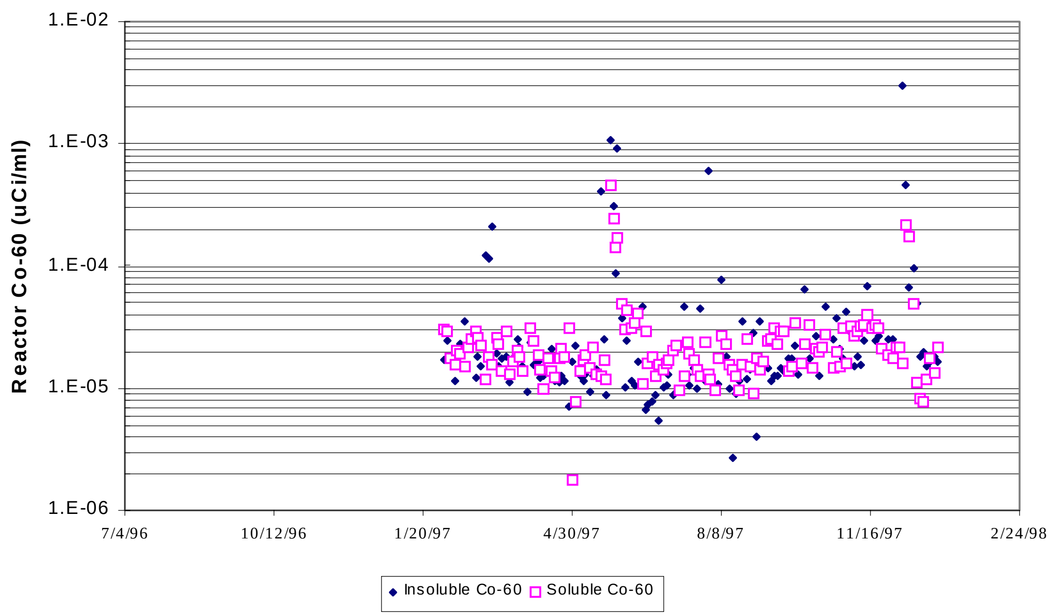


Figure 13-3
Reactor Water Cobalt 60, FitzPatrick

Recirculation Piping Dose Rates

Pipe dose rates had increased to 168 mR/hr in 1988, before the plant started natural zinc injection 1989. Two chemical decontaminations were performed on the recirculating piping after starting natural zinc injection. The last chemical decontamination was performed in 1994, and BRAC dose rates have stabilized between 68 and 96 mR/hr. DZO addition was started in April, 1996. Reactor water soluble Co-60 are low, averaging 2.95E-5 uCi/ml in 1997.

Pipe Gamma Scan Data

Gamma scan results from 1994 (after the start of natural zinc injection) indicated the pipe corrosion film had about 10 uCi/cm^2 total activity with 40 - 60 % due to Co-60, about 25 % due to Mn-54 and 10% due to Zn-65. A gamma scan performed in 1996, 5 months after the start of DZO, indicated that the total activity was between 4 and 7 uCi/cm^2, with 40 % due to Co-60, 25% from Mn-54 and 19% from Zn-65.

Radiation Exposure

Station dose exposure three-year rolling averages are as follows:

1997	258 person-Rem
1996	336 person-Rem
1995	294 person-Rem
1994	410 person-Rem
1993	400 person-Rem

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GRAND GULF

Table 14-1
Grand Gulf Plant Design Parameters

Parameter	Value
Commercial Operation Date	7/85
Capacity (MWe)	1250
BWR Type	6
Drains Path	Forward Pumped
Condensate Polishing	Deep Beds &F/D*
RWCU Capacity (% Feedwater Flow)	1%

* Filters only used for plant startups

Grand Gulf Milestones

Milestone events for Grand Gulf are given in Table 14-2. The LOMI process was used for the recirculation piping chemical decontaminations performed in 1992 and 1995. The 1995 decon of the recirculation piping removed 24.1 curies. A new resin cleaning process, the ARCS (Advanced Resin Cleaning System), was installed in 1995 as a replacement for the original URC (Ultrasonic Resin Cleaner). The ARCS was initially in use from 12/13/95 to 8/7/96, at which time it was shut down for modifications and the URC was used. ARCS operations resumed on 10/11/96.

Table 14-2
Grand Gulf Milestones

Grand Gulf										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.					5/92			4/95		
HWC (scfm)										4/88
Noble Metals Coating										
NZO										
DZO										1/88
Iron Injection										
Crud Resins						11/93	X			
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 14-3.

Table 14-3
Grand Gulf Recirculation System Dose Rates

Grand Gulf – Recirculation System Dose Rates (mR/hr)									
	Oct-86	Dec-87	Apr-89	Nov-90	May-92	Nov-93	Apr-95	Nov-96	
EFPY									
BRAC	145	nd	175	235	220	310	425	417	
A Suction	143		170	230	220	320	400	450	
B Suction	154		180	260	240	320	500	420	
A Discharge	153		180	230	200	300	300	400	
B Discharge	129		170	220	220	300	500	400	
Avg Risers	173	196	293	296	288	407	408	445	

Trend Data

Trend data for Grand Gulf are presented in Figures 14-1, 14-2 and 14-3 for power, feedwater iron and reactor water cobalt 60, respectively.

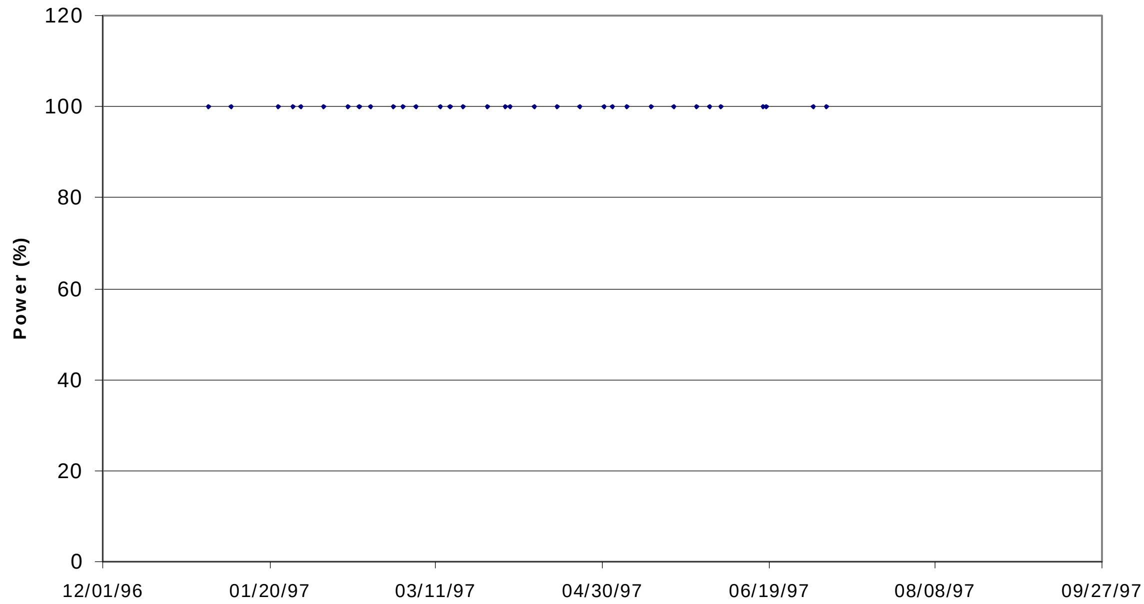

Figure 14-1
Power History, Grand Gulf

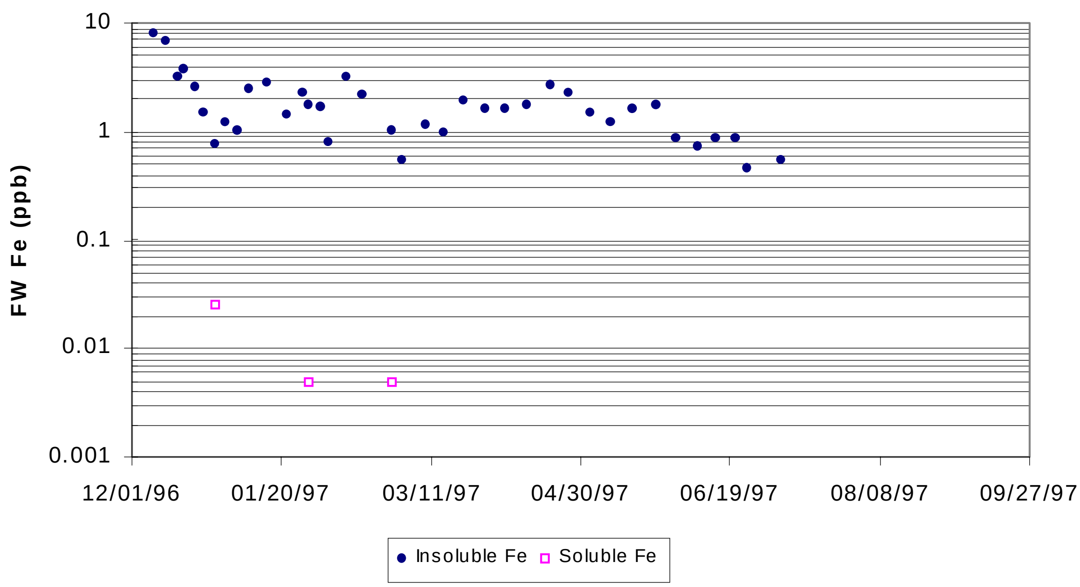

Figure 14-2
Feedwater Iron, Grand Gulf

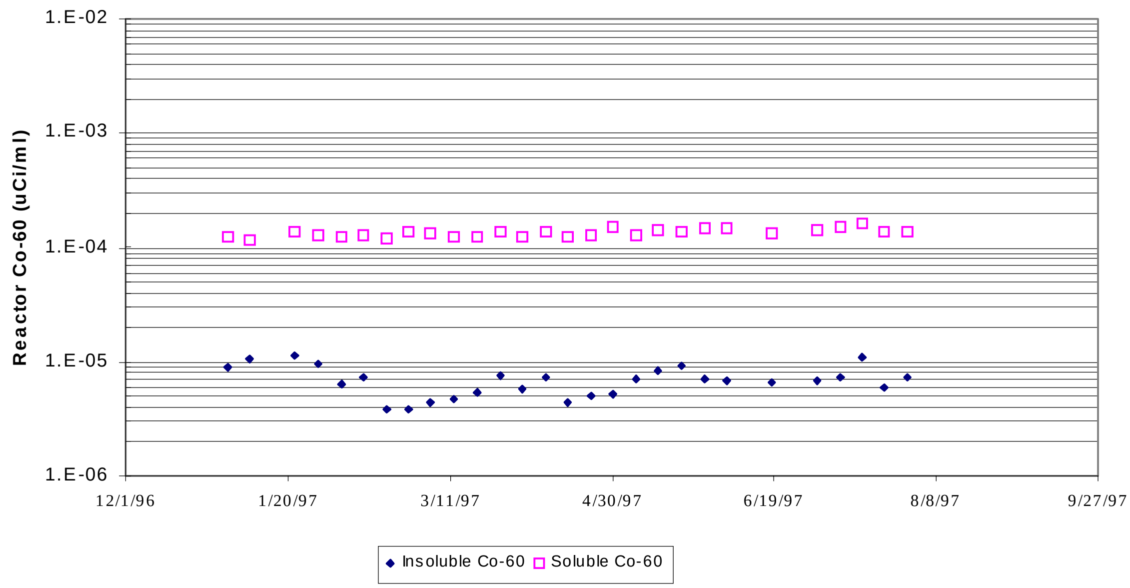

Figure 14-3
Reactor Water Cobalt 60, Grand Gulf

Feedwater Iron Control

Feedwater insoluble iron concentrations are currently between 1 and 3 ppb, which is in the low range for a BWR with "deep bed only" condensate polishing. Feedwater iron data were provided only for the first half of 1997. Grand Gulf does have condensate filters, but these are used only during startup to minimize crud transport. This design feature enables the plant to reduce the amount of crud loading on the deep bed resins during startups. Grand Gulf tried using low crosslinked resins for enhanced crud removal in 1993 and 1994, but these were removed due to unacceptable reactor water chemistry. The plant now relies on standard resins and the new resin cleaning system to control feedwater iron.

Recirculation Piping Dose Rates

Even with a chemical decontamination of the recirculation piping in 1995, the piping has recontaminated to give BRAC dose rates in the range of 400 mR/hr. The dose rates prior to the chemical decontamination in 1995 were 425 mR/hr, and a survey taken in 1996 indicated the dose rates had returned to 417 mR/hr. Soluble reactor water Co-60 averages about 1.3E-4 uCi/ml. Grand Gulf is expecting to start both DZO and hydrogen injection in 1998.

Pipe Gamma Scan Data

Recirculation piping gamma scan data in 1992 indicated the total activity of the corrosion film was approximately 18 uCi/cm^2, with 65% of the activity due to Co-60 and 30% due to Mn-54.

Radiation Exposure

Station radiation exposure three year rolling averages are as follows:

1997 268 person-Rem

1996 251 person-Rem

1995 243 person-Rem

1994 291 person-Rem

1993 307 person-Rem

1992 357 person-Rem

15

HATCH UNIT 1

Table 15-1
Hatch Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/75
Capacity (MWe)	838
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Hatch Unit 1 Milestones

Milestone events for Hatch Unit 1 are given in Table 15-2. The condenser was retubed in 1990 with titanium; original condenser material was admiralty brass. The recirculation piping chemical decontamination in 1991 removed 72.2 curies; the decon in 1996 removed 72.9 curies.

Table 15-2
Hatch Unit 1 Milestones

Hatch Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser			6/90							
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.				10/9 1					3/96	
HWC (scfm)	9/87 @ 22	→	→	→	→	30	45	50	45	→
Noble Metals Coating										
NZO			8/90	→	→	→				
DZO							2/94	→	→	→
Iron Injection										
Crud Resins										
Pleated Filters								1/95	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 15-3.

Table 15-3
Hatch Unit 1 Recirculation System Dose Rates

Hatch Unit 1 – Recirculation System Dose Rates (mR/hr)									
	Nov-86	Mar-87	Sep-88	Feb-90	Feb-91	Sep-91	Nov-91	Apr-92	Mar-93
EFPY									
BRAC	113	118	135	161	184	320	38	118	200
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Hatch Unit 1 – Recirculation System Dose Rates (mR/hr)									
	Dec-93	Sep-94	Mar-96	Apr-96					
EFPY									
BRAC	133	203	268	153					
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers			492	7					

Trend Data

No power, feedwater iron or reactor water cobalt 60 data were provided.

Recirculation Piping Dose Rates

Hatch 1 started natural zinc injection in August, 1990 and DZO in February, 1994. Since the start of zinc addition, two chemical decontaminations have been performed to reduce dose rates. Prior to the 1991 decon, the BRAC average dose rate had increase to 320 mR/hr. Prior to the 1996 decon, the BRAC dose rate had increased 268 mR/hr. Hatch 1 is performing hydrogen injection at moderate levels for vessel internals protection.

Piping Gamma Scan Data

Pipe gamma scans show an increase in total corrosion film activity, with the specific activity and percent contributions from the major isotopes summarized in Table 15-4. The fraction of the corrosion film attributable to Zn-65 should decrease since the plant switched to DZO in 1994.

Table 15-4
Hatch Unit 1 Recirculation Piping Gamma Scan Results

Date	9/92	3/93	10/94	3/96
Total Activity (uCi/cm^2)	17	17	18	28.75
% Co-60	48	25	31	30
% Mn-54	14	10	11	3
% Zn-65	26	60	49	56

Stellite Reduction

Hatch 1 reported replacement of all original control rod blades over the period from 1990 through 1996.

Hatch Pleated Filter Septa Performance

Several types of pleated filter septa have undergone trials at Hatch, and trials of additional types are underway and planned. Several types of precoat materials have also been tried on both pleated and non-pleated filter septa used in the CF/Ds. The average RLI of both Hatch units is 25.4.

- The Pall polyaramid pleated septa installed in Unit 1 CF/D-D during January 1995 were replaced with Memtec 4 μm pleated septa on September 12, 1996. Four additional Unit 1 CF/Ds will receive pleated filter septa during the October-November, 1997 re-fueling outage. After these installations, five of the seven CF/Ds will have pleated filter septa. Memtec, Pall BPF-4, and Graver DualGuard septa will each be used in single vessel trials. Pleated septa manufactured in Germany from an Italian supplier are scheduled for trials in two vessels.

- Unit 2 has trials of pleated septa from two suppliers in progress, two vessels with Memtec pleated septa and one with Graver's DualGuard septa. Pall's APF-2 non-pleated polypropylene septa are also being used in a vessel trial.

Prior to the current fuel cycle (started April, 1997), the Graver air surge backwash system was added to Unit 2. Early indications are that with this backwash system run lengths have improved for the conventional non-pleated Graver yarn wound septa but, have decreased for the vessels with pleated filter septa. Of the pleated septa, run lengths of the Graver DualGuard septa were reported as the shortest as of September 1997. The air surge was added despite the bottom plenum liquid volume being below Graver's normal design criteria.

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HATCH UNIT 2

Table 16-1
Hatch Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/79
Capacity (MWe)	852
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Hatch Unit 2 Milestones

Milestone events for Hatch Unit 2 are given in Table 16-2. The condenser was retubed in 1989 with titanium; original condenser material was admiralty brass. The original 304 stainless steel recirculation piping was replaced with 316 stainless steel in 1984.

Table 16-2
Hatch Unit 2 Milestones

Hatch Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser		12/89								
Recirc. Pipe Replacement	8/84									
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)			8/90 @ 17	→	→	30	36	40-45	→	→
Noble Metals Coating										
NZO			8/90	→	→					
DZO						12/93	→	→	→	→
Iron Injection										
Crud Resins										
Pleated Filters										1/97

Radiation Data

Recirculation System dose rates are summarized in the Table 16-3.

Table 16-3
Hatch Unit 2 Recirculation System Dose Rates

Hatch Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Sep-86	Feb-88	Sep-89	Apr-91	Jan-92	Sep-92	Oct-92	Nov-92	Mar-93
EFPY									
BRAC	65	80	86	158	140	213	194	160	295
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Hatch Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Nov-93	Apr-94	Sep-95	Mar-97					
EFPY									
BRAC	281	250	209	193					
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Trend Data

No power, feedwater iron or reactor water cobalt 60 data were provided.

Recirculation Piping Dose Rates

Hatch 2 initiated natural zinc addition in 1990, and started switched to DZO addition during 12/93. Through 1997, there have been no chemical decontaminations of the recirculation piping performed at Hatch 2. BRAC dose rates showed a steadily increasing trend through March, 1993 when the average dose rate peaked at 295 mR/hr. Since then, BRAC dose rates show a gradual decreasing trend, with an average reading of 200 mR/hr logged in 3/97.

Piping Gamma Scan Data

Pipe gamma scan data for Hatch 2 are summarized in Table 16-4. The corrosion film total activity shows a similar trend as that for the BRAC dose rates, with the peak activity recorded in 1993 before the plant began adding DZO. The contribution due to Zn-65 shows a gradual decreasing trend after the 10/93 gamma scan as expected due to the decay of the Zn-65 inventory and the switch to DZO

Table 16-4
Hatch Unit 2 Recirculation Piping Gamma Scan Results

Date	3/91	10/92	10/93	4/94	4/95	10/95	3/97
Total Activity (uCi/cm^2)	12.4	15.1	27.6	17.6	18.4	15.1	13.9
% Co-60	49	38	30	42	45	53	44
% Mn-54	17	17	6	7	7	8	14
% Zn-65	19	36	56	45	36	27	21

Stellite Reduction

Hatch 2 has replaced 114 of 137 control blades between 1992 and 1995.

Radiation Exposure

Station dose exposure three year rolling averages for the two unit plant are as follows:

1996 600 person-Rem / year

1995 676 person-Rem / year

1994 695 person-Rem / year

1993 793 person-Rem / year

Hatch Pleated Filter Septa Performance

The pleated filter performance for Hatch 1 and 2 are discussed under Hatch Unit 1.

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HOPE CREEK

Table 17-1
Hope Creek Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/86
Capacity (MWe)	1100
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

Hope Creek Milestones

Milestone events for Hope Creek are given in Table 17-2. Hope Creek applied various types of crud resins from 1991 through 1995 in the condensate polisher deep beds to control iron. Addition of natural zinc oxide was started in 1986. The plant switched to DZO addition after observing significant increases in Zn-65 activity in various plant systems. Hydrogen injection was started in 1993.

Table 17-2
Hope Creek Milestones

Hope Creek										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe										
Chem. Decon.										
HWC (scfm)						21 (1993)	→	→	→	→
Noble Metals Coating										
NZO	1986	→	→	→	→	X				
DZO						1993	→	→	→	→
Iron Injection										
Crud Resins				1991	→	→	→	X		
Pleated Filters										

Radiation Data

Data on recirculation piping dose rates were not provided.

Trend Data

Power, feedwater iron and reactor water cobalt 60 data were not provided.

Feedwater Iron Control

Hope Creek applied low crosslinked resins for enhanced crud removal for 3 years before returning to conventional resins. The use of crud resins was discontinued due to increased reactor waster sulfate concentrations. The plant is in the process of installing full flow condensate pre-filters upstream of the deep bed polishers to reduce feedwater iron concentrations.

Hope Creek Non-Precoat Pleated Filter Septa Performance

Initially it was hoped the CFs would be installed and operated for a short time prior to the November, 1997 outage. Currently, the installation and startup of the filters is scheduled for the second quarter of 1998.

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LAGUNA VERDE UNIT 1

Table 18-1
Laguna Verde Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	7/90
Capacity (MWe)	654
BWR Type	5 Mark II
Drains Path	Forward Pumped
Condensate Polishing	Filters + Deep Beds
RWCU Capacity (% Feedwater Flow)	0.85

Laguna Verde Unit 1 Milestones

Milestone events for Laguna Verde Unit 1 are given in Table 18-2. Only the Reactor Water Clean-Up System was chemically decontaminated in 1994, during the third refueling outage. Condensate Pre-filters were installed and were phased in to service over several months starting in 3/97.

Table 18-2
Laguna Verde Unit 1 Milestones

Laguna Verde Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.							X (rwcu)			
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										
Pleated Filters										3/97

Radiation Data

Recirculation System dose rates are summarized in Table 18-3.

Table 18-3
Laguna Verde Unit 1 Recirculation System Dose Rates

Laguna Verde Unit 1 – Recirculation System Dose Rates (mR/hr)									
End of Cycle	1	2	3	4	5	6			
EFPY	0.212	1.262	1.936	3.003	3.963				
BRAC	7.9	90.4	105	200	298	215			
A Suction	4.5	88.0	126	342	165	400			
B Suction	6.7	83.3	76	211	860	220			
A Discharge	10.5	88.4	100	122	85	185			
B Discharge	9.9	102.0	120	146	94	57			
Avg Risers									

Trend Data

Laguna Verde 1 power history, feedwater iron and reactor water cobalt 60 data are presented in Figures 18-1, 18-2 and 18-3, respectively. Note that the Co-60 data were reported in units of uCi/kg, rather uCi/ml as reported by U.S. plants.

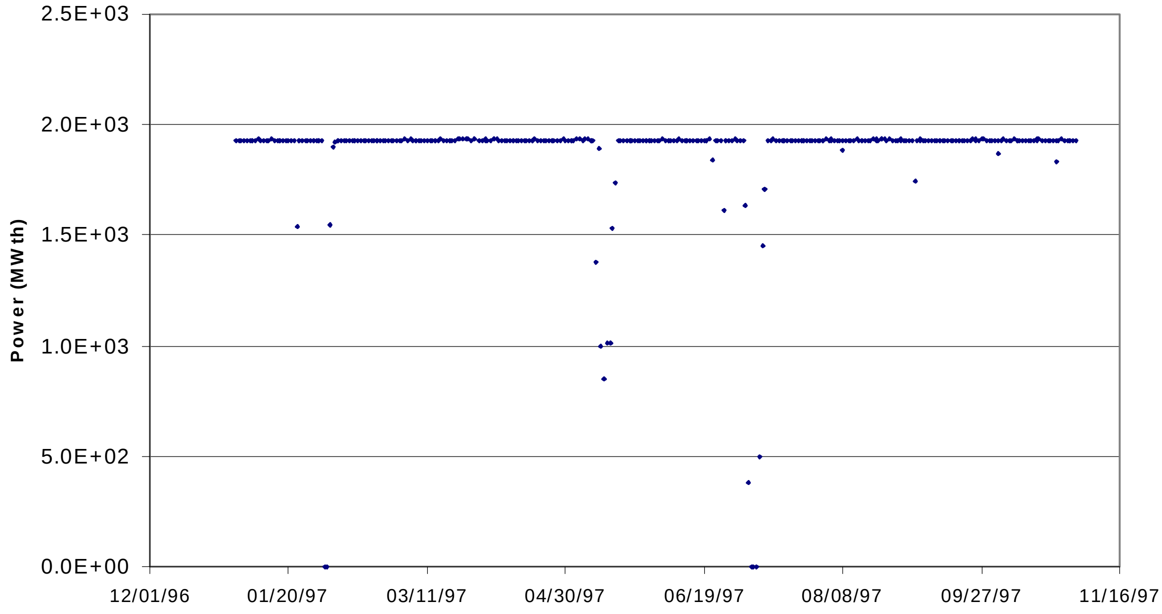

Figure 18-1
Power History, Laguna Verde Unit 1

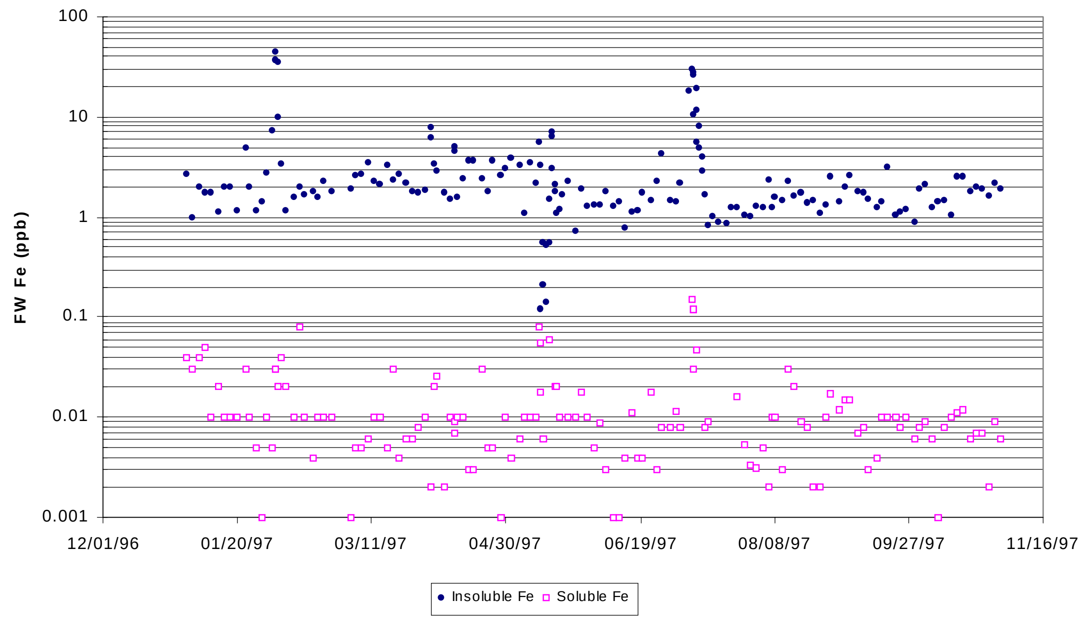

Figure 18-2
Feedwater Iron, Laguna Verde Unit 1

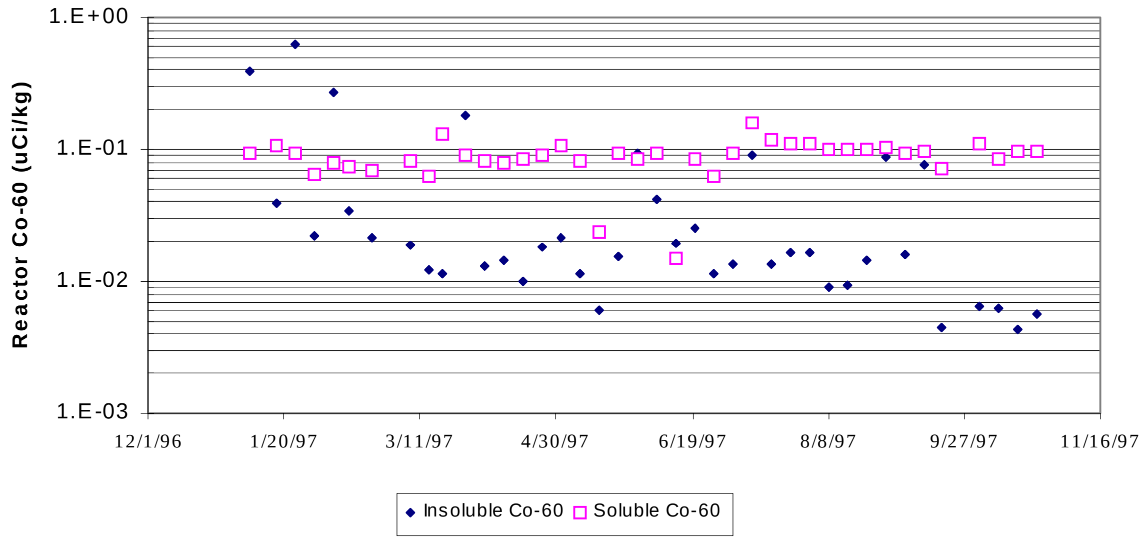

Figure 18-3
Reactor Water Cobalt 60, Laguna Verde Unit 1

Feedwater Iron Control

Laguna Verde 1 began phasing into service the condensate pre-filters in March, 1997. Prior to implementing the pre-filters, the feedwater iron showed an increasing trend as the cycle progressed, until it appeared to level out in the 3 – 4 ppb range. By mid-summer, 1997, when full flow condensate pre-filtration was available, final feedwater iron was in the 1 – 2 ppb range. The condensate polisher system effluent iron was actually very low, in the <0.1 ppb range. The forward pumped drains at Laguna Verde 1 have total iron in the range of 4 – 7 ppb and thus contribute roughly 1 – 2 ppb to the final feedwater. The 1997 average feedwater total iron concentration was 3.75 ppb. Soluble feedwater iron concentrations are low, averaging 0.01 ppb.

Recirculation Piping Dose Rates

The most recent pipe dose rate was 215 mR/hr. Dose rates at this unit seem to be stable around 200 mR/hr. The next dose rate measurement should show the effect of the new condensate filters.

Soluble reactor water Co-60 averaged about 8.9E-5 uCi/ml (8.95E-2 uCi/kg), which is less than the average soluble cobalt activity in Unit 2 and is at the approximate concentration which divides high BRAC dose rate plants from low BRAC dose rate plants.

Laguna Verde Non-Precoat Pleated Filter Septa Performance

Condensate Filters with pleated filter septa have been retrofitted to both units at Laguna Verde. The Unit 1 filters went into service during March 1997. The filters of Unit 2 are scheduled to be placed in service during the first quarter of 1998.

Unit 1 has an RLI of 23.5 based on its current average CDI iron concentration of 11.1 ppb. The RLI for Unit 2 is 73.3 based on its current average CDI iron concentration of 34.6 ppb. It is curious that during the Unit 1 fuel cycle preceding the CF installation, the average CDI iron was 22.5 ppb.

Initial runs on all of the Unit 1 CFs were long. However, succeeding runs have been significantly shorter. Filters F and G are egregious examples of this behavior. The first run of Filter G started on March 19, 1997 with an initial ΔP of 0.71 psi and ended on August 14, 1997 with a final ΔP of 4.55 psi for a run length of 149 days. The second run started with a 1.28 psi ΔP and lasted 22 days to a final ΔP 4.41 psi. The third run started on September 9, 1997 with a 1.28 psi ΔP, by the next day the ΔP was 1.85 psi.

The first run of Filter G lasted 106 days during which the ΔP increased from 0.57 to 4.12 psi. The second run started with a ΔP of 1.28 psi and after 23 days the ΔP was 3.56 psi with the run in progress.

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LAGUNA VERDE UNIT 2

Table 19-1
Laguna Verde Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	4/95
Capacity (MWe)	654
BWR Type	5 Mark II
Drains Path	Forward Pumped
Condensate Polishing	Filters + Deep Beds
RWCU Capacity (% Feedwater Flow)	0.85

Laguna Verde Unit 2 Milestones

Milestone events for Laguna Verde Unit 2 are given in Table 19-2. Condensate pre-filters were added as a retrofit, and the first filter vessel was place in service in 2/98.

Table 19-2
Laguna Verde Unit 2 Milestones

Laguna Verde Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										
Pleated Filters										2/98

Radiation Data

Recirculation System dose rates are summarized in Table 19-3.

Table 19-3
Laguna Verde Unit 2 Recirculation System Dose Rates

Laguna Verde Unit 2 – Recirculation System Dose Rates (mR/hr)									
End of Cycle	1	2	3	4	5	6	7	8	
EFPY									
BRAC	4.2	219	253						
A Suction									
B Suction	4.3	205	250						
A Discharge	3.7	375	410						
B Discharge	4.5	77	98						
Avg Risers	3.0	88	345						

Trend Data

Laguna Verde 2 power history, feedwater iron and reactor water cobalt 60 data are presented in Figures 19-1, 19-2 and 19-3, respectively. Note that the Co-60 data were reported in units of uCi/kg, rather uCi/ml as reported by U.S. plants.

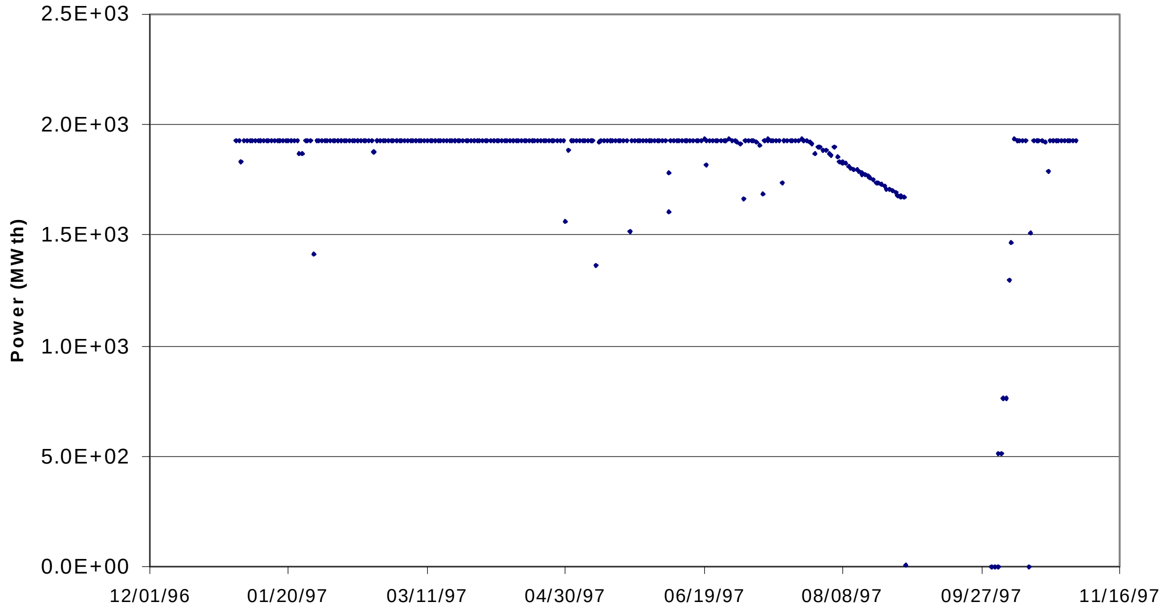

Figure 19-1
Power History, Laguna Verde Unit 2

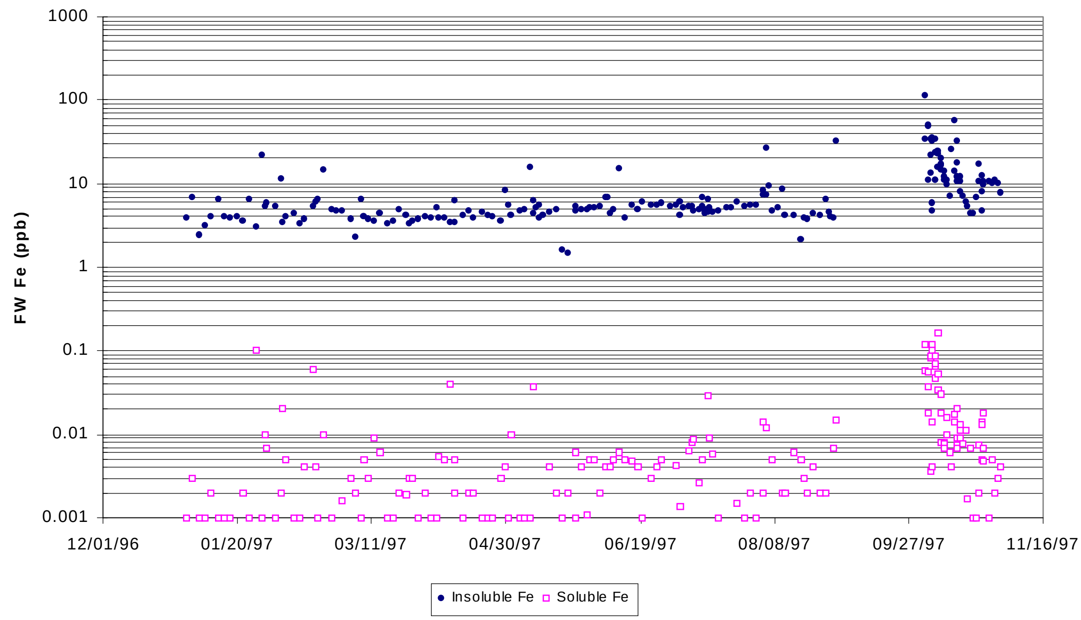

Figure 19-2
Feedwater Iron, Laguna Verde Unit 2

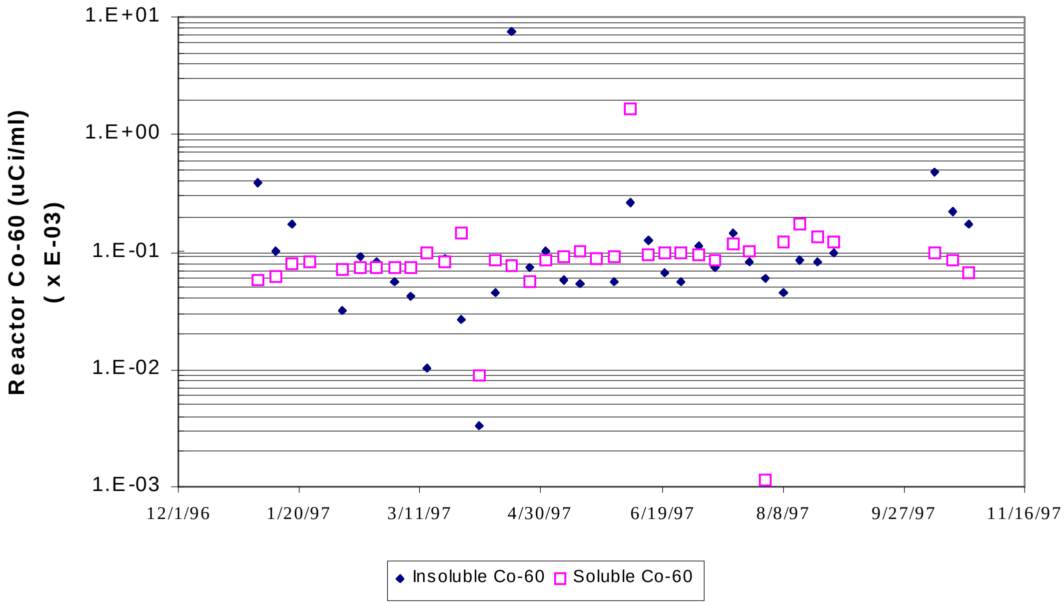

Figure 19-3
Reactor Water Cobalt 60, Laguna Verde Unit 2

Feedwater Iron Control

The Laguna Verde 2 condensate pre-filters were installed in 1997 are the first filter was placed in service during 2/98. The remaining filters are scheduled to be phased into service during the first half of 1998. Therefore, the 1997 final feedwater iron concentrations during 1997, which were in the 5 - 7 ppb range, were representative of "deep bed old" condensate polishing. The soluble feedwater iron averaged 0.01 ppb. There is a significant iron contribution to the final feedwater from the forward pumped drains. It is also noted that the average reactor water conductivity of approximately 0.11 uS/cm is in the high range among BWR's, and there appears to be a significant contribution from reactor water soluble chromium and copper.

Recirculation Piping Dose Rates

The Laguna Verde 2 piping dose rates show an increasing trend. The reactor water soluble Co-60 activity averaged 1.3E-4 uCi/ml in 1997.

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LASALLE UNIT 1

Table 20-1
LaSalle Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	10/84
Capacity (MWe)	1110
BWR Type	5
Drains Path	Forward Pumped
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

LaSalle Unit 1 Milestones

Milestone events for LaSalle Unit 1 are given in Table 20-2. The recirculation piping was decontaminated in 1990 and 1994. In 1994 decon, 85.99 curies were removed. LaSalle has been in a shutdown condition since 9/96.

Table 20-2
LaSalle Unit 1 Milestones

LaSalle Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.	3/88		1/90				3/94			
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO							6/94	→	→	→
Iron Injection										
Crud Resins							X	X		
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 20-3.

Table 20-3
LaSalle Unit 1 Recirculation System Dose Rates

LaSalle Unit 1 – Recirculation System Dose Rates (mR/hr)									
	May-84	Oct-85	Mar-88	Jun-88	Jan-90	Feb-91	Oct-92	Jun-94	Jul-94
EFPY									
BRAC	100	205	288	50	50	223	420	460	65
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

LaSalle Unit 1 – Recirculation System Dose Rates (mR/hr)									
	Feb-96								
EFPY									
BRAC	82								
A Suction	42.5								
B Suction	67.5								
A Discharge	65.5								
B Discharge	152.5								
Avg Risers									

Feedwater Iron Control

LaSalle Unit 1 has been shut down since 9/96, and no chemistry data were available for review.

Recirculation Piping Dose Rates

Dose rates steadily increased after the 1988 chemical decontamination from 50 mR/hr to 460 mR/hr in 1994, prior to another decon. After the 1994 decon, LaSalle began adding DZO. Since DZO addition began and up to the 9/96 shutdown, the BRAC dose rates have not increased.

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LASALLE UNIT 2

Table 21-1
LaSalle Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	1/84
Capacity (MWe)	1110
BWR Type	5
Drains Path	Forward Pumped
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

LaSalle Unit 2 Milestones

Milestone events for LaSalle Unit 2 are given in Table 21-2. The 1995 chemical decontamination of the recirculation piping removed 88.5 curies. The plant has been in cold shutdown since 9/96.

Table 21-2
LaSalle Unit 2 Milestones

LaSalle Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.		1/89						3/95		
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO								6/95	→	→
Iron Injection										
Crud Resins							X	X		
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 21-3:

Table 21-3
LaSalle Unit 2 Recirculation System Dose Rates

LaSalle Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Apr-85	Feb-89	Jan-92	Mar-95	Apr-95	Nov-96			
EFPY									
BRAC	53	25	425	618	34	110			
A Suction						180			
B Suction						50			
A Discharge						110			
B Discharge						100			
Avg Risers									

Trend Data

Power and feedwater iron data are plotted in Figures 21-1 and 21-2. No power history data were provided for LaSalle 2.

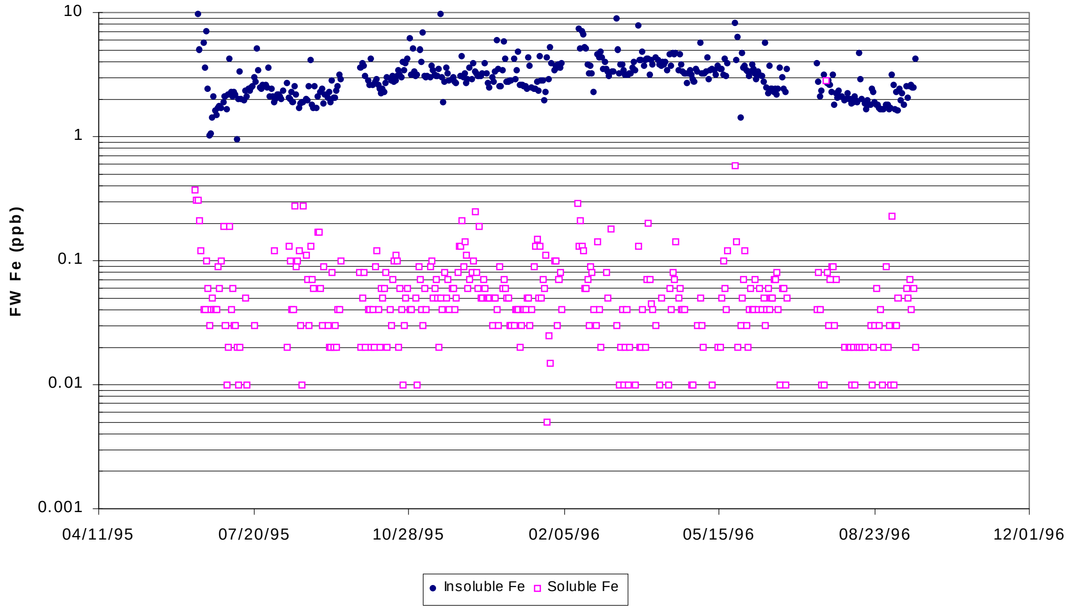

Figure 21-1
Feedwater Iron, LaSalle Unit 2

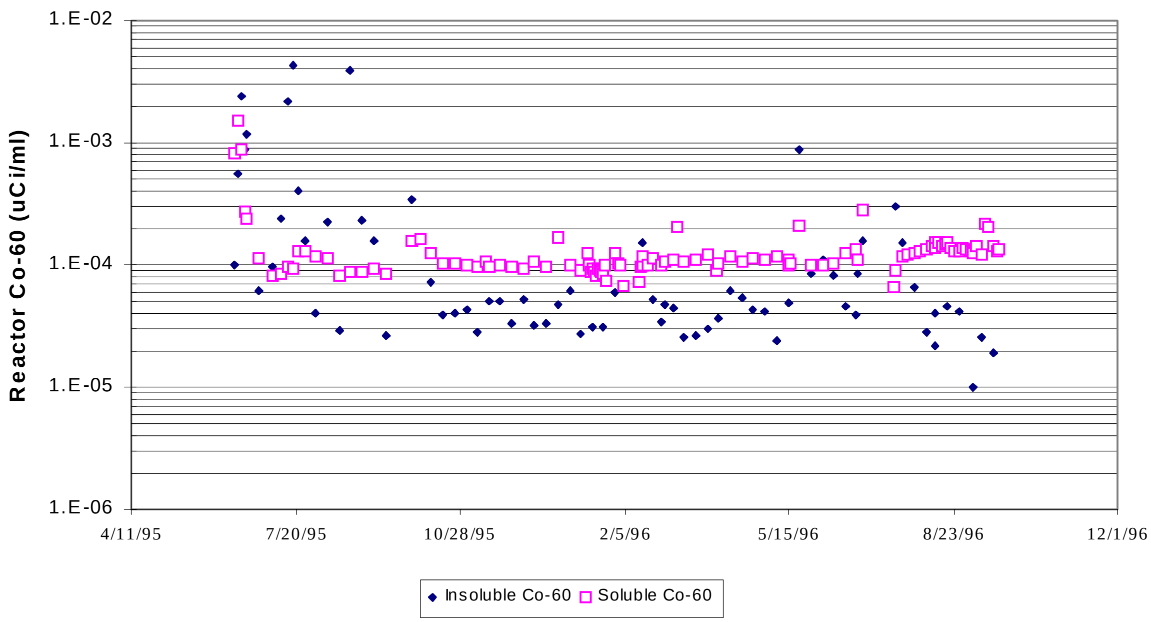

Figure 21-2
Reactor Water Cobalt 60, LaSalle Unit 2

Feedwater Iron Control

The last operating period for LaSalle 2 was during 1995 - 1996. Feedwater iron concentrations ranged from 2 to 4 ppb at this time. Insoluble iron averaged 3.36 ppb and soluble iron averaged 0.07 ppb.

Recirculation Piping Dose Rates

Dose rates increased from 25 mR/hr after the 1989 decon to 425 mR/hr just prior to the 1995 decon. LaSalle started DZO injection after the 1995 decon, and BRAC average dose rate measured in 11/96 was 110 mR/hr. During periods of constant power operations, insoluble Co-58 and insoluble Co-60 gradually decreased while the soluble species of these isotopes remained approximately constant. The average soluble Co-60 activity in 1996 was 1.2E-4 uCi/ml.

Piping Gamma Scan Data

Gamma scan measurements made during November, 1996 showed 8.3 uCi/cm^2 total activity, with 47% from Co-60 and 42% from Mn-54.

Radiation Exposure

Station radiation exposure three-year rolling averages for LaSalle 1 and LaSalle 2 are as follows:

1997 551 person-Rem/year

1996 685 person-Rem/year

1995 699 person-Rem/year

1994 917 person-Rem/year

1993 944 person-Rem/year

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LIMERICK UNIT 1

Table 22-1
Limerick Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	2/86
Capacity (MWe)	1160
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	Filters + Deep Beds
RWCU Capacity (% Feedwater Flow)	1.2%

Limerick Unit 1 Milestones

Milestone events for Limerick Unit 1 are given in Table 22-1. In 1995 Limerick 1 implemented a power uprate to 105% of the original design rating. Full flow deep beds were installed downstream of the original condensate filter/demineralizers in 1992 to control copper from the condenser tubes.

Table 22-2
Limerick Unit 1 Milestones

Limerick Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate								X		
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO					X	→	→	→	→	
DZO										5/97
Iron Injection										2/97
Crud Resins										
Pleated Filters							10/94	→	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 22-3:

Table 22-3
Limerick Unit 1 Recirculation System Dose Rates

Limerick Unit 1 – Recirculation System Dose Rates (mR/hr)									
	Jan-94	Feb-96							
EFPY									
BRAC	137.5	109							
A Suction	140	118							
B Suction	160	126							
A Discharge	130	103							
B Discharge	120	90							
Avg Risers	374	223							

Trend Data

Power history, feedwater iron and reactor water cobalt 60 trend plots for Limerick 1 are provided in Figures 22-1, 22-2 and 22-3, respectively.

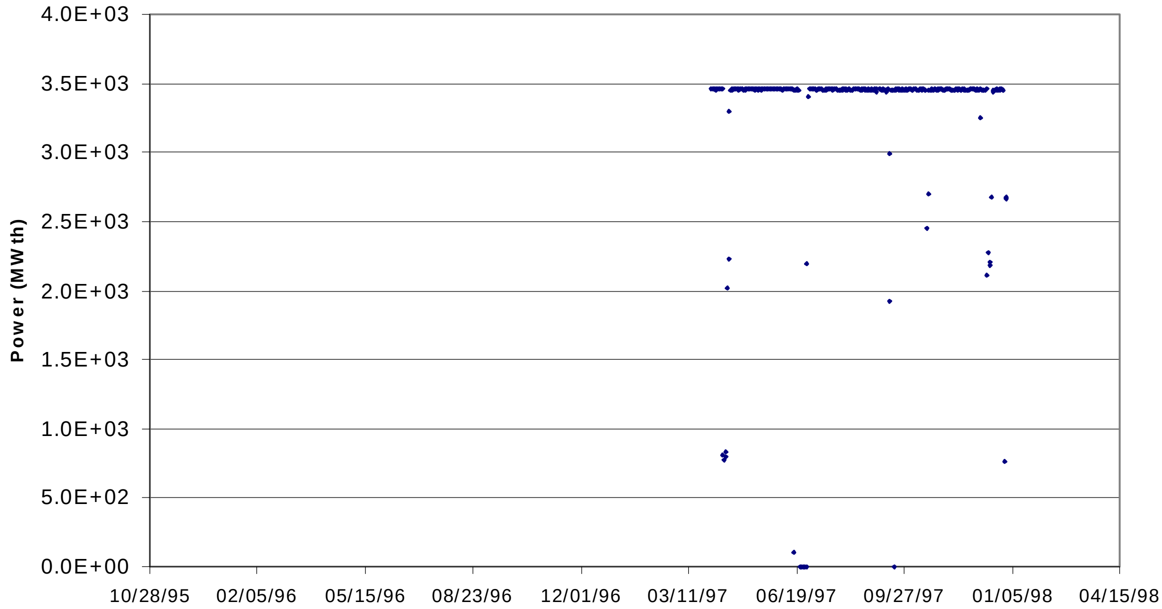

Figure 22-1
Power History, Limerick Unit 1

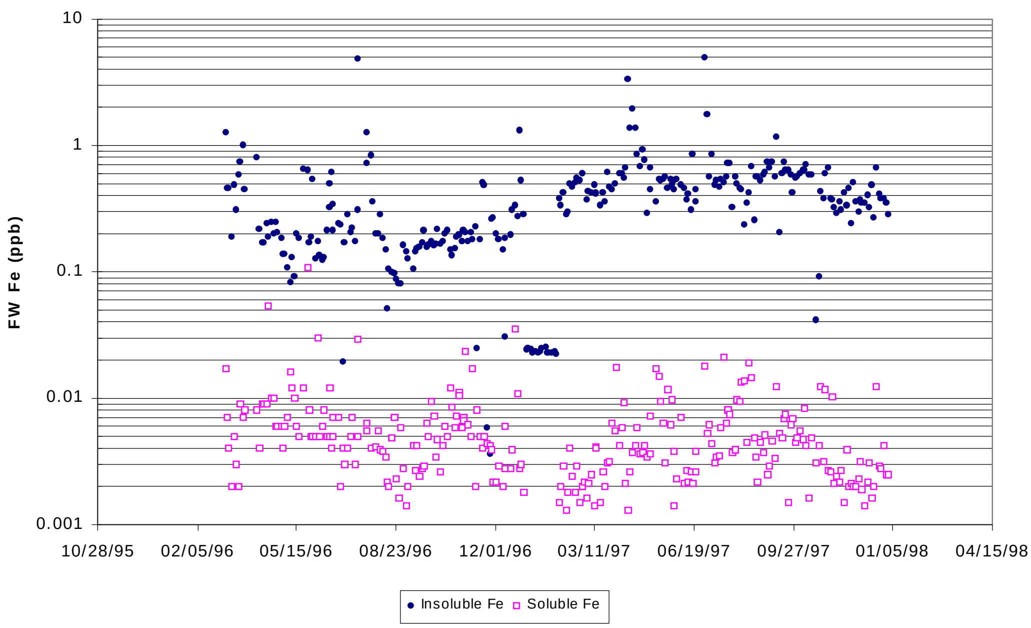

Figure 22-2
Feedwater Iron, Limerick Unit 1

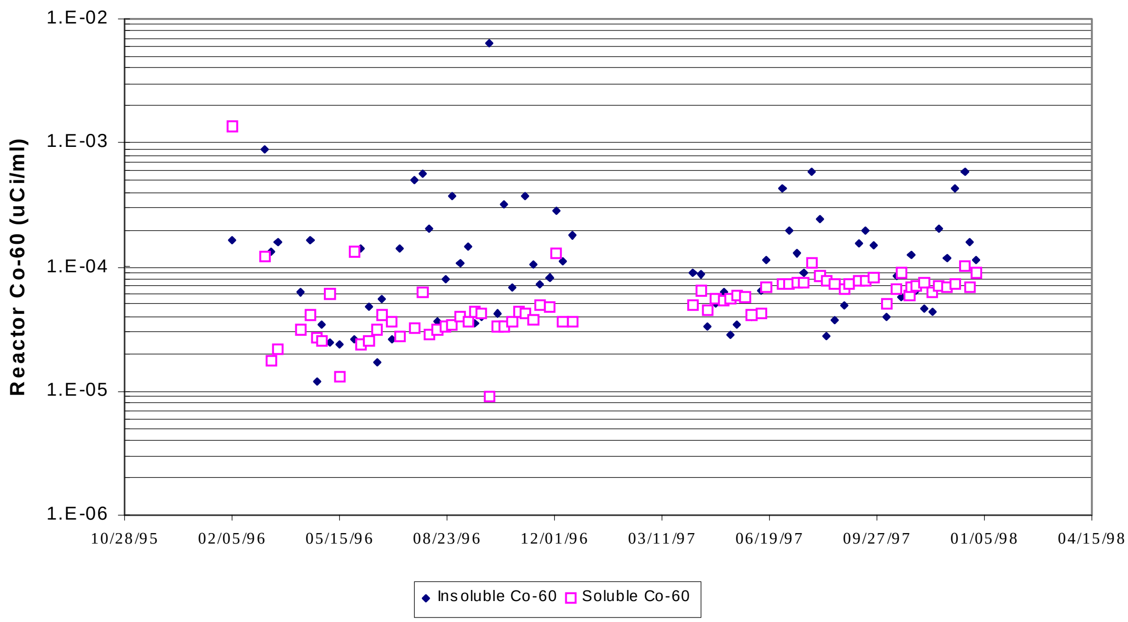

Figure 22-3
Reactor Water Cobalt 60, Limerick Unit 1

Feedwater Iron Control

In 1992, Limerick 1 added deep beds downstream of the original condensate filter/demineralizers to improve the removal of copper from the condenser tubes. In 1994, the plant started installing pleated filter septa in the filters and operated them in a non-precoat mode, eliminating burial volumes from condensate precoat materials and also providing greater removal of insoluble iron. The deep bed resins used for this application do not have to be cleaned, allowing the resin bed and the developed ion exchange zone to remain undisturbed throughout the bed's useful life. With non-precoat pleated pre-filter elements installed, feedwater iron concentrations decreased to about 0.2 ppb. In 1997, Limerick 1 started injecting iron oxide into the feedwater to maintain a minimum feedwater iron in the range of 0.5 – 1 ppb to control insoluble Co-60 transport in the primary system. The insoluble feedwater iron concentration averaged 0.53 ppb and soluble iron averaged 0.005 ppb during 1997.

Recirculation Piping Dose Rates

Two BRAC data points were reported, with the dose rates decreasing significantly from 137 mR/hr in 1994 to 109 mR/hr in 1996. Limerick 1 originally had a significant input of zinc to the primary system from the admiralty condenser tubes and due to incomplete zinc removal by the original filter/demineralizers. When the deep beds were started up in 1992, Limerick 1 began adding natural zinc oxide, and then switched to DZO in 1997. Reactor water zinc concentrations range from 5 to 8 ppb. Soluble reactor water Co-60 was low in 1997, averaging 6.9E-5 uCi/ml.

Pipe Gamma Scan Data

Limerick 1 has performed numerous gamma scans of the recirculation piping. Some representative results are summarized in Table 22-4.

Table 22-4
Limerick Unit 1 Recirculation Piping Gamma Scan Results

Date	5/87	1/89	9/90	3/92	2/94	2/96
Total Activity (uCi/cm^2)	8	7	7	10	11	13
% Co-60	22	30	42	41	42	36
% Co-58	34	16	18	15		
% Mn-54			31	33	42	32
% Zn-65	39	42	9	7		20

The piping total activity has gradually increased, and the isotopic composition of the film has changed significantly. While Co-60 remains the major contributor to the total activity, Mn-54 has become significant. An increase in Zn-65 was also detected in the 1996 gamma scan.

Limerick Non-Precoated Pleated Septa Performance

Currently, Pall BPF-4 pleated filter septa are being used in all of the Condensate Filters at Limerick. The use of this type filter with polyolefin filter media at Limerick started in December, 1995. The Pall pleated septa at Limerick face the highest application challenge severity for pleated filter septa among BWRs now operating with pleated septa in condensate applications. The Pall septa at Hope Creek and at Clinton, and the Memtec septa at Susquehanna will face higher application challenge severities.

The operating strategy at Limerick has been to limit run lengths to 30 days. For much of the septa lives, the terminal ΔP was considerably less than 10 psi, often less than 7 psi. By late 1997, 10 psi ΔPs were being reached. In the case of Filter A of Unit 1, the septa that started service on December 13, 1995 were reaching 10 psi ΔP in about 24 days by September 1997. As of January 11, 1998, the septa of Filter A were attaining 20 day runs to a 10 psi endpoint, about 2 years after being first placed into service.

Limerick personnel have decided to limit the ΔP to 10 psi with all eight CF/Ds in service. Currently, when only seven vessels are in service because of backwashing or maintenance, the ΔP across some vessels exceeds 10 psi.

23

LIMERICK UNIT 2

Table 23-1
Limerick Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	1/90
Capacity (MWe)	1160
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	Filters + Deep Beds
RWCU Capacity (% Feedwater Flow)	1.2%

Limerick Unit 2 Milestones

Milestone events for Limerick Unit 2 are given in Table 23-2. In 1995 Limerick 2 implemented a power uprate to 105% of the original design. Limerick 2 installed full flow deep beds downstream of the original condensate filter/demineralizers in 1993 to control copper from the condenser tubes. Iron addition was started in 1997 using iron oxide and injecting it into the feedwater using the zinc original injection skid.

Table 23-2
Limerick Unit 2 Milestones

Limerick Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate								X		
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO					X	→	→	→	→	
DZO										5/97
Iron Injection										3/97
Crud Resins										
Pleated Filters									6/96	→

Radiation Data

Recirculation System dose rates are summarized in Table 23-3.

Table 23-3
Limerick Unit 2 Recirculation System Dose Rates

Limerick Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Jan-95	Jan-97							
EFPY									
BRAC	164	107.5							
A Suction	160	110							
B Suction	180	120							
A Discharge	160	100							
B Discharge	155	100							
Avg Risers	241	147							

Trend Data

Power, feedwater iron and reactor water cobalt 60 data are plotted in Figures 23-1, 23-2 and 23-3, respectively.

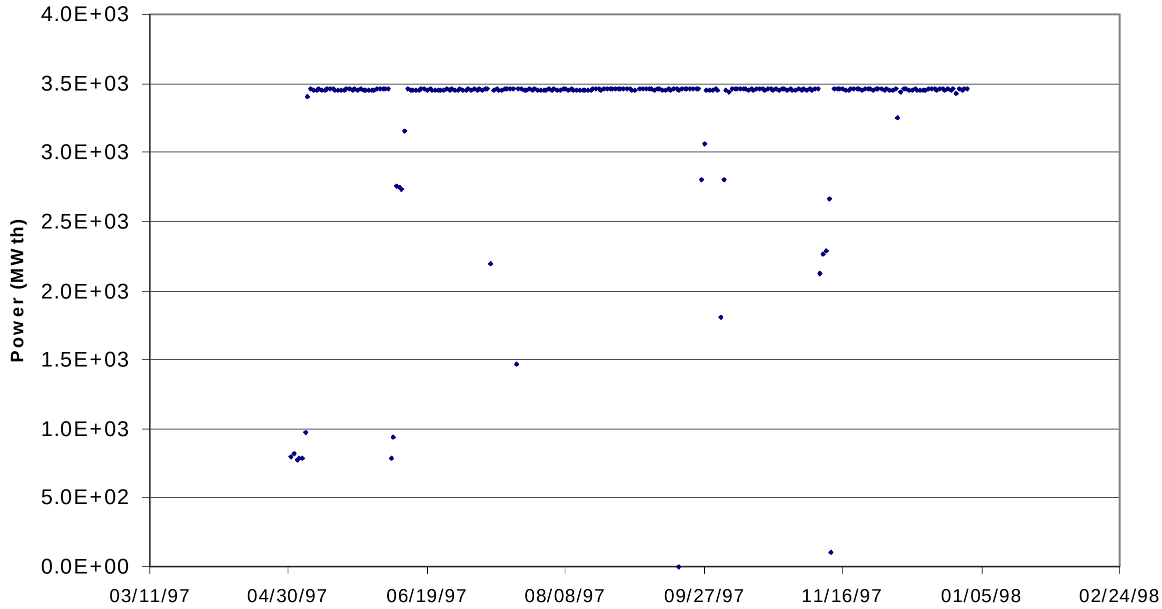

Figure 23-1
Power History, Limerick Unit 2

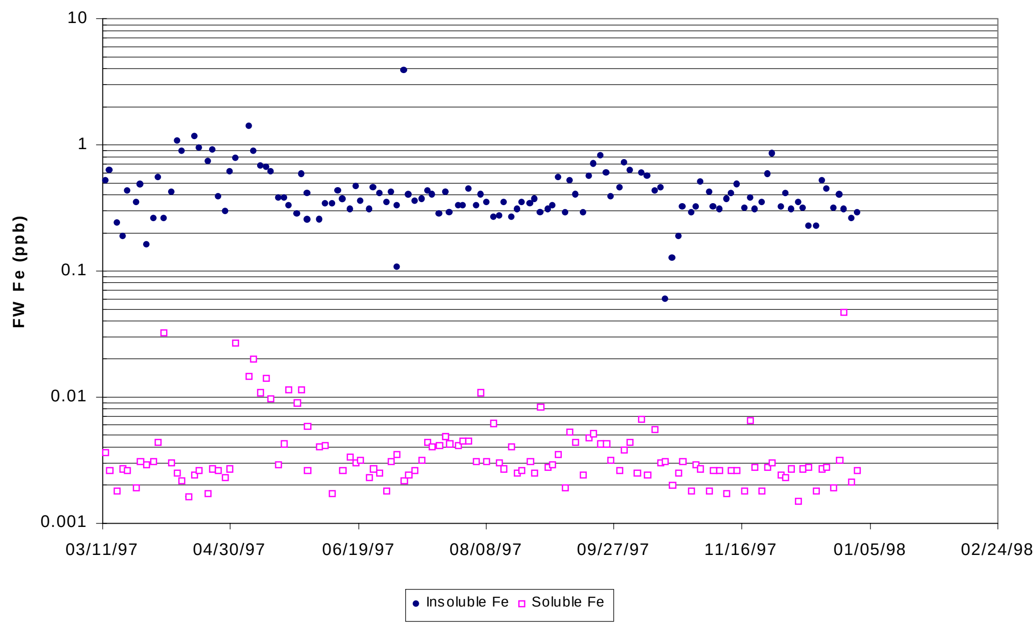

Figure 23-2
Feedwater Iron, Limerick Unit 2

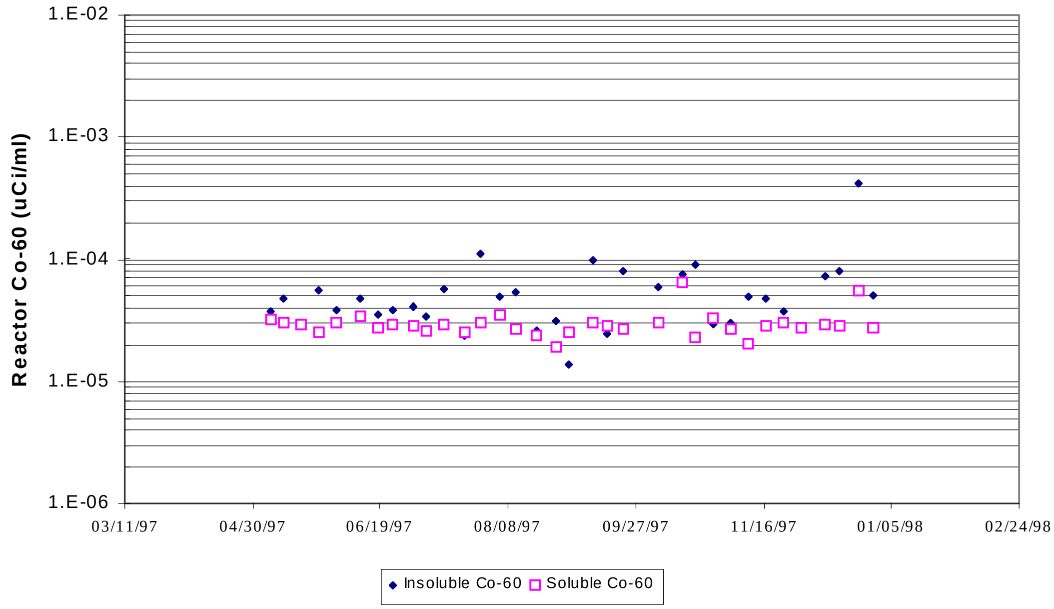

Figure 23-3
Reactor Water Cobalt 60, Limerick Unit 2

Feedwater Iron Control

In 1993 Limerick 2 added deep beds downstream of the original condensate filter/demineralizers to improve the removal of copper from the condenser tubes. In 1996, the plant began installing pleated filter septa in the filters and operated them in a non-precoat mode, eliminating burial volumes from condensate precoat materials and also providing greater removal of insoluble iron. The deep bed resins used for this application do not have to be cleaned, allowing the resin bed and the developed ion exchange zone to remain undisturbed throughout the bed's useful life. With non-precoat pleated pre-filter elements installed, feedwater iron concentrations decreased to about 0.2 ppb. In March, 1997, Limerick 2 started injecting iron oxide into the feedwater to maintain a minimum feedwater iron in the range of about 0.5 – 1 ppb to control insoluble Co-60 transport in the primary system. The insoluble feedwater iron concentration averaged 0.55 ppb and soluble iron averaged 0.005 ppb during 1997.

Recirculation Piping Dose Rates

Two BRAC data points were reported, with the dose rates decreasing significantly between 1995 and 1997 from 164 mR/hr to 107 mR/hr, respectively. Limerick 2 originally had a significant input of zinc to the primary system from the admiralty condenser tubes and due to incomplete zinc removal by the original filter/demineralizers. When the deep beds were started up in 1993, Limerick 2 began adding natural zinc oxide, and then switched to DZO in 1997. Reactor water zinc concentrations range from 3 to 5 ppb.

Piping Gamma Scan Data

Limerick 2 has performed several recirculation piping gamma scans. The results are summarized in Table 23-4.

Table 23-4
Limerick Unit 2 Recirculation Piping Gamma Scan Results

Date	4/91	2/93	2/95	1/97
Total Activity (uCi/cm^2)	1.9	8.9	12.9	11.3
% Co-60	16	38	38	40
% Co-58	50	14	5	5
% Mn-54	15	23	40	27
% Zn-65	13	22	14	22

The total specific activity showed an increasing trend from 4/91 – 2/95, and the 4/97 results suggest that the activity has either stabilized or that a decreasing trend has started.

Radiation Exposure

Radiation exposure three-year rolling averages for the two units, Limerick 1 and Limerick 2, are as follows:

1997 239 person-Rem

1996 256 person-Rem

1995 251 person-Rem

1994 274 person-Rem

1993 218 person-Rem

1992 204 person-Rem

1991 181 person-Rem

1990 164 person-Rem

Limerick Non-Precoated Pleated Septa Performance

Limerick experience with non-precoated pleated septa is presented in the Limerick Unit 1 section.

24

MONTICELLO

Table 24-1
Monticello Plant Design Parameters

Parameter	Value
Commercial Operation Date	6/71
Capacity (MWe)	545
BWR Type	3
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Monticello Milestones

Milestone events for Monticello are given in Table 24-2. The 1989 chemical decontamination was performed on the recirculation piping and on the RHR (Residual Heat Removal) System piping. This decon, which was performed prior to the start of zinc injection, resulted in the removal of 97.3 curies. The 1991 chemical decontamination was performed on the recirculation, RHR, and RWCU systems, and resulted in the removal of 115.1 curies which included 35.4 curies of Zn-65. The 1993 chemical decontamination was performed on the recirculation and RHR piping, and removed 220 curies including 123.1 curies Zn-65. Pleated septa were installed in one of five F/D's in 1996, and extended to three of five in 1997.

Table 24-2
Monticello Milestones

Monticello										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser	1984									
Recirc. Pipe Replacement	1984									
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.		9/89		3/91		2/93				
HWC (scfm)		2/89 15→30	→	40	→	→	→	→	→	→
Noble Metals Coating										
NZO		11/89	→	→	→					
DZO						4/93	→	→	→	→
Iron Injection										
Crud Resins										
Pleated Filters									2/96	→

Radiation Data

Recirculation System dose rates are summarized in Table 24-3.

Table 24-3
Monticello Recirculation System Dose Rates

Monticello – Recirculation System Dose Rates (mR/hr)									
	5/86	11/87	4/89	9/89	9/89	7/90	9/90	4/91	4/91
EFPY									
BRAC	200	350	613	760	21	258	300	613	21
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers				1050	157			840	50

Monticello – Recirculation System Dose Rates (mR/hr)									
	1/92	4/92	2/93	2/93	4/94	6/94	10/94	4/96	
EFPY									
BRAC	147	275	467	38	300	250	231	231	
A Suction								300	
B Suction								200	
A Discharge								200	
B Discharge								225	
Avg Risers	700	960	1400	475		555	475	330	

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots are presented in Figures 24-1, 24-2 and 24-3, respectively.

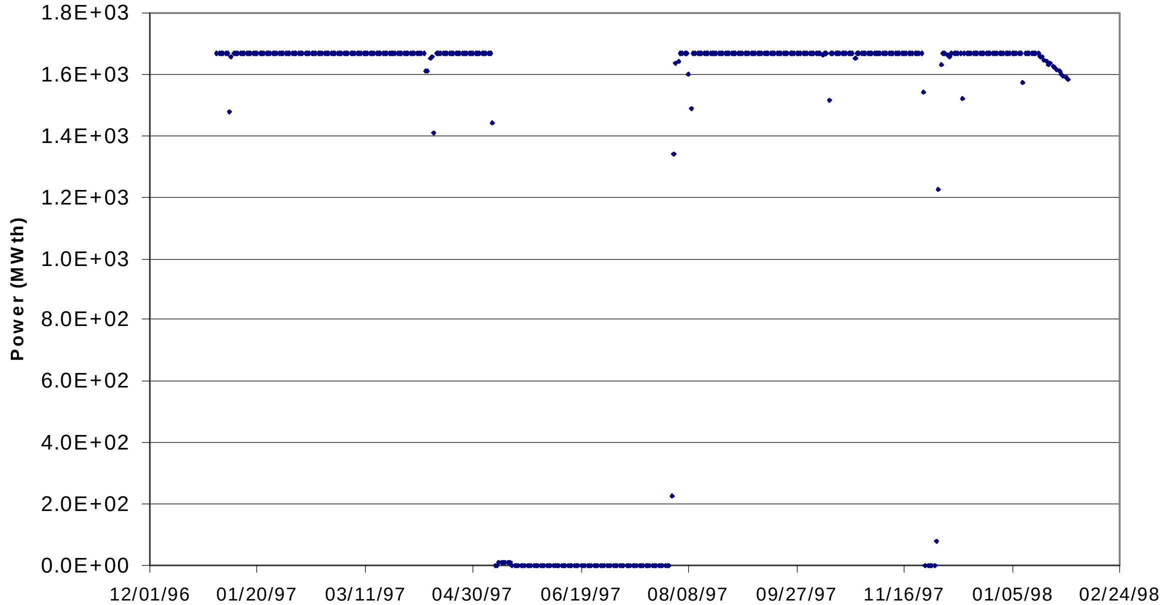

Figure 24-1
Power History, Monticello

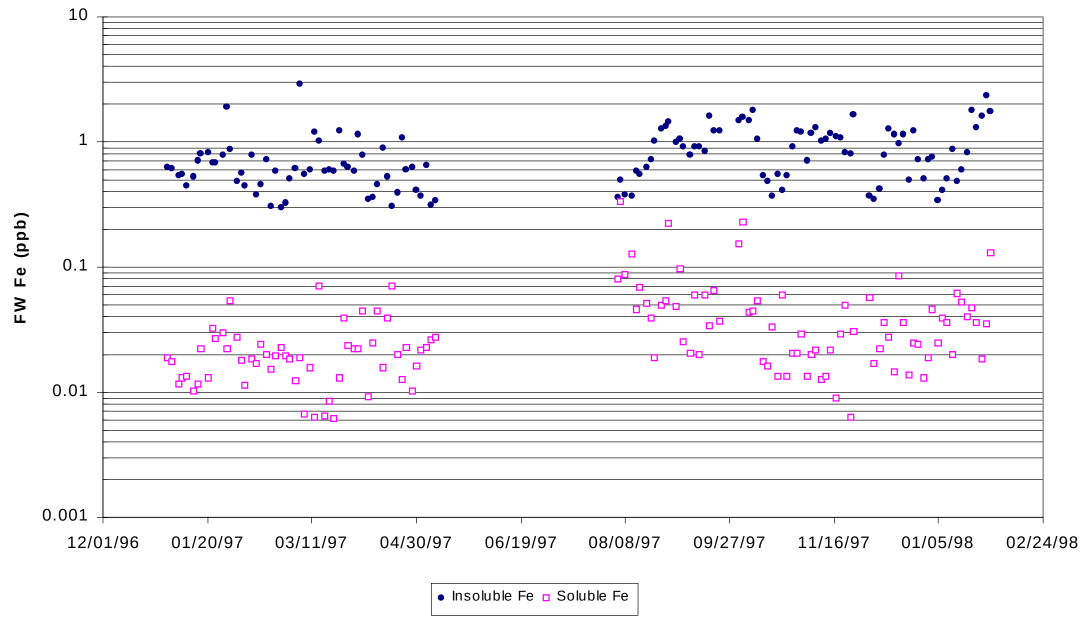

Figure 24-2
Feedwater Iron, Monticello

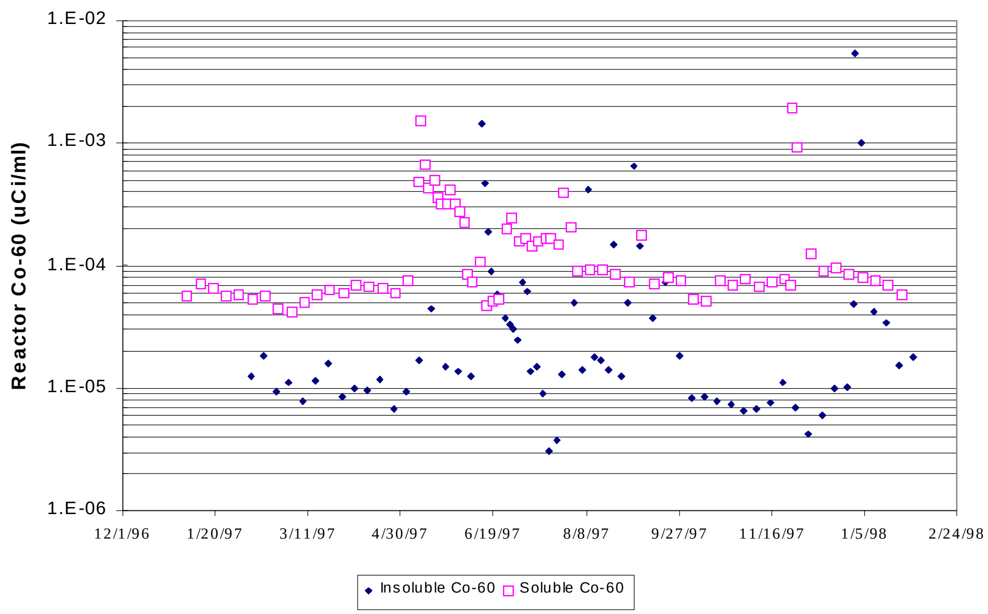

Figure 24-3
Reactor Water Cobalt 60, Monticello

Feedwater Iron Control

Insoluble feedwater iron concentrations in 1997 were are between 0.5 and 2.0 ppb with an average of 0.81 ppb. The 1997 average soluble feedwater iron concentration was 0.04 ppb.

Recirculation Piping Dose Rates

Monticello initiated both natural zinc injection and hydrogen water chemistry in 1989. The plant switched to DZO in April, 1993. Recirculation piping dose rates were high prior to the start of HWC and zinc injection, and then continued to increase, reaching 467 mR/hr prior to the chemical decontamination in 1993. After the 1993 decon and the start of DZO, dose rates peaked at 300 mR/hr in 4/94, after which they decreased and appear to have stabilized at approximately 230 mR/hr. Reactor water soluble Co-60 averages about 2.0E-4 uCi/ml at Monticello.

Piping Gamma Scan Data

Recirculation piping gamma scan data are summarized in Table 24-4. While activity reached almost 70 uCi/cm^2, the major contributions were from Zn-65 and Cr-51. Since switching to DZO addition, both the total activity and the contribution from Zn-65 have decreased. The Zn-65 contribution should continue to decrease as the inventory decays.

Table 24-4
Monticello Recirculation Piping Gamma Scan Results

Date	5/86	11/87	9/89	7/90	9/90	4/91	1/92	4/92
Total Activity (uCi/cm^2)	9.7	15.5	27.3	19.6	13.4	23.5	26.1	56.9
% Co-60	53	73	84	41	63	55	11	9
% Co-58	10	7	3	7	8	5	3	
% Mn-54	13	12	9	3	5	2	1	
% Zn-65	13	8	4	17	23	38	38	45
% Cr-51							48	43

Date	2/93	6/94	10/94					
Total Activity (uCi/cm^2)	67.4	30.2	25.1					
% Co-60	10	17	24					
% Co-58								
% Mn-54								
% Zn-65	81	66	73					
% Cr-51	7	14						

Stellite Reduction

Stellited feedwater regulating valves were replaced in 1987, an the station has been replacing control stellited rod blades. As of December, 1997, most of the blades have been replaced.

Radiation Exposure

Station dose exposure three year rolling averages are as follows:

1997 131 person-Rem

1996 226 person-Rem

1995 311 person-Rem

1994 335 person-Rem

1993 358 person-Rem

Monticello Precoated Pleated Filter Septa Performance

The severity of the application challenge to the pleated septa at Monticello is slightly higher than at Peach Bottom and significantly lower than at Browns Ferry. Three of the five CF/D vessels are using Memtec pleated filter septa, with the earliest installation date being February 1996. Filters A (10 μm septa) and E (4 μm septa) are being monitored.

Both filters used precoats plus body feed during their initial runs; the first three runs for Filter A, and the first six runs for Filter E. During the use of body feed, there was a decline in run lengths. The quantity of body feed used per run was gradually reduced until its use was abandoned. During the use of body feed, and thereafter, the precoat dose was 0.028 dry pounds/10 inches of septum length. This dose is about 1/3 the dose used on the non-pleated septa. Precoats are prepared by mixing powdered cation and anion resins together in the Precoat Tank. The cation/anion ratio on a dry weight basis is 2/1. A liquid polymeric polyelectrolyte is added to control slurry flocculation.

Because of a reactor water sulfate spike coincident with placing Filter E in service, the first set of septa have been replaced with new 10 μm septa. Prior to the spike there had been at least one effluent resin trap plugging incident.

In general the pleated septa have provided satisfactory service in terms of run lengths and effluent iron. During the period for which filter performance data has been provided, the average CDI iron concentration was 11.4 ppb. The average is based on 82 determinations during the approximately 600 days of operation during the period.

Figures 24-4 and 24-5 are plots of normalized ΔPs, and effluent iron and conductivities for the first and eighth runs of Filter A, respectively. In both runs, upward inflections in the conductivity curves roughly correspond to changes in the slopes of the ΔP curves. This suggests that changes in flow paths through the filter septa and non-uniform precoats may be partially responsible for the inflections in the conductivity curves.

During the first run with 10 μm septa in Filter A, effluent iron was only slightly below 2 ppb by the end of run, which lasted 53 days to an 8 psi endpoint. However, by the eighth run, the effluent iron was below 1.5 ppb about 26 days after the start of the run and below 1 ppb by the end of run, which lasted 39 days to a 6 psi endpoint.

Normalized ΔPs, and effluent irons and conductivities for the first and eighth runs of Filter E, respectively, are plotted in Figures 24-6 and 24-7. The possible relationship between effluent conductivity and the slopes of the ΔP curves can be seen in the curves for the first run; however, it is less evident than in the curves for Filter A. This may indicate better precoat uniformity was achieved on the 4 μm septa of Filter E than on the 10 μm septa of Filter A.

During the first run with 4 μm septa in Filter E, effluent iron fell below 1 ppb about 10 days after the start of the run which lasted 64 days to a 7 psi endpoint. By the eighth run, the effluent iron was below 0.5 ppb after about 3 days, and declined to 0.04 ppb by the end of the run which lasted 31 days to a 6 psi endpoint.

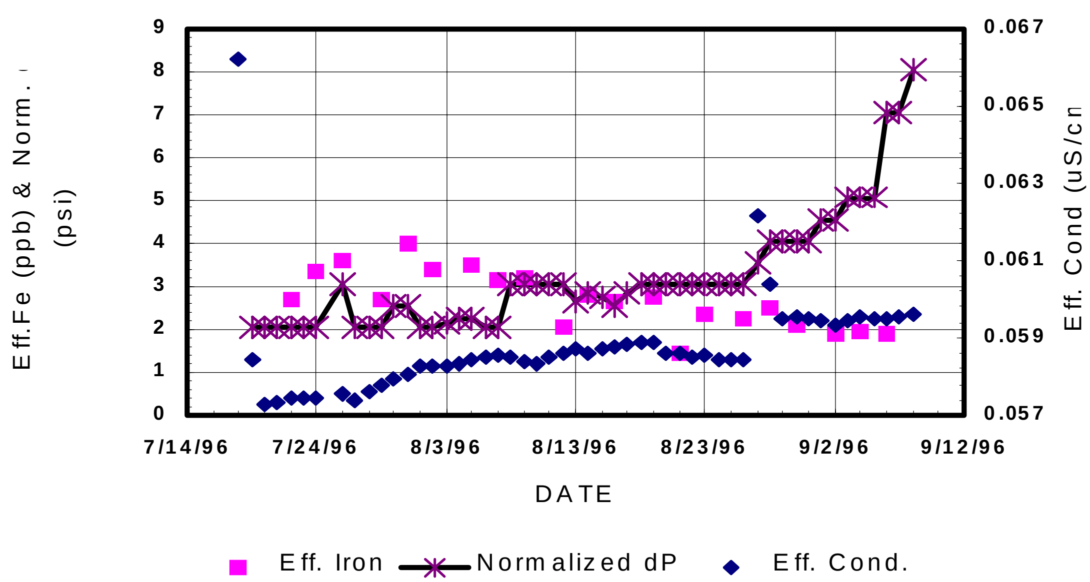

Figure 24-4
Filter A, First Run, Monticello

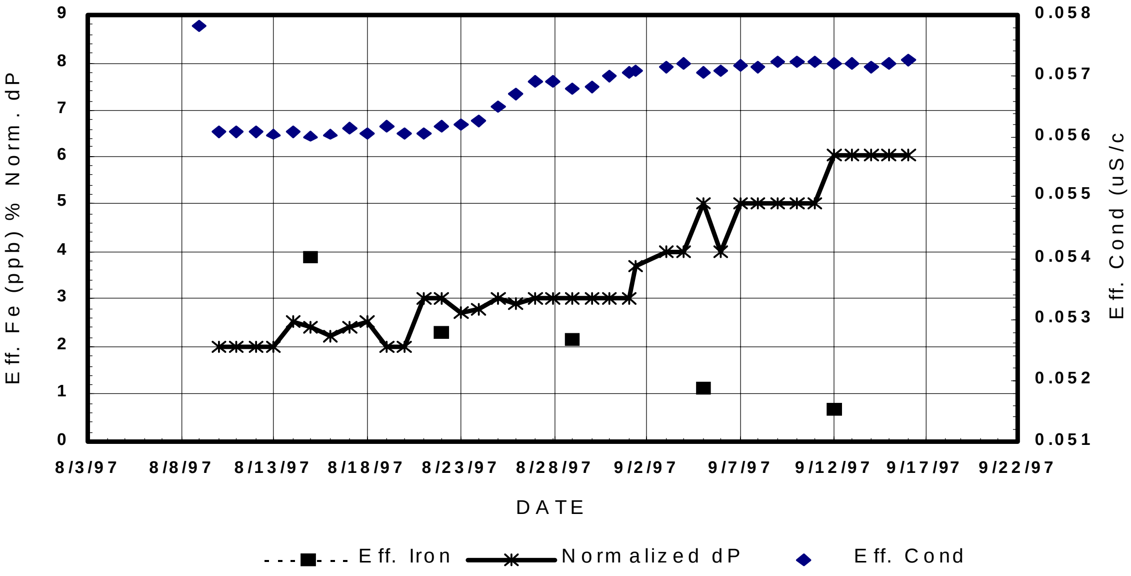

Figure 24-5
Filter A, Eighth Run, Monticello

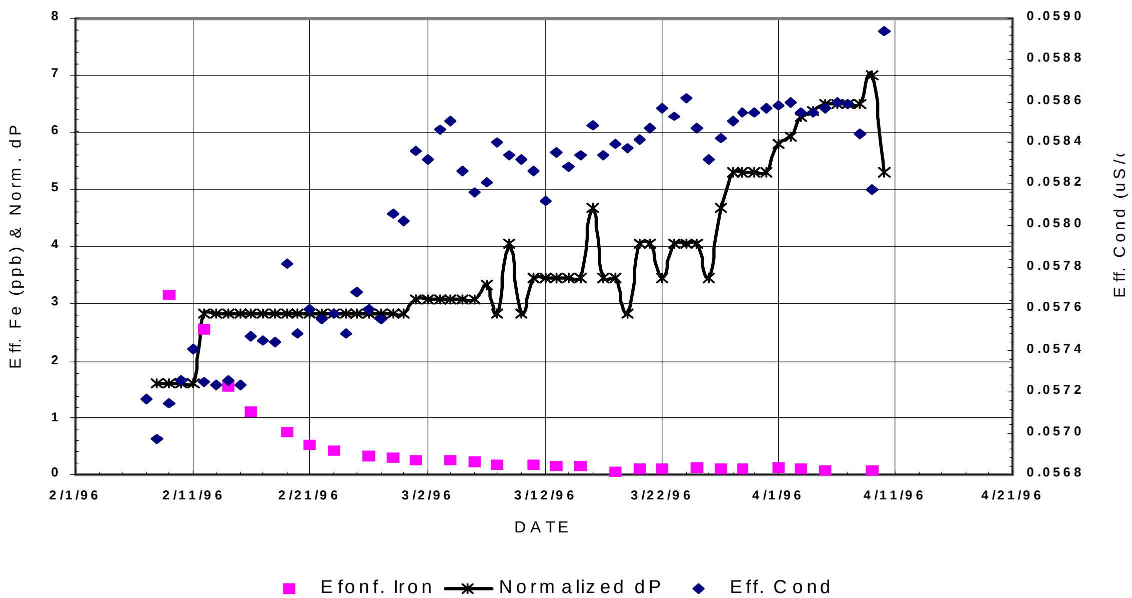

Figure 24-6
Filter E, First Run, Monticello

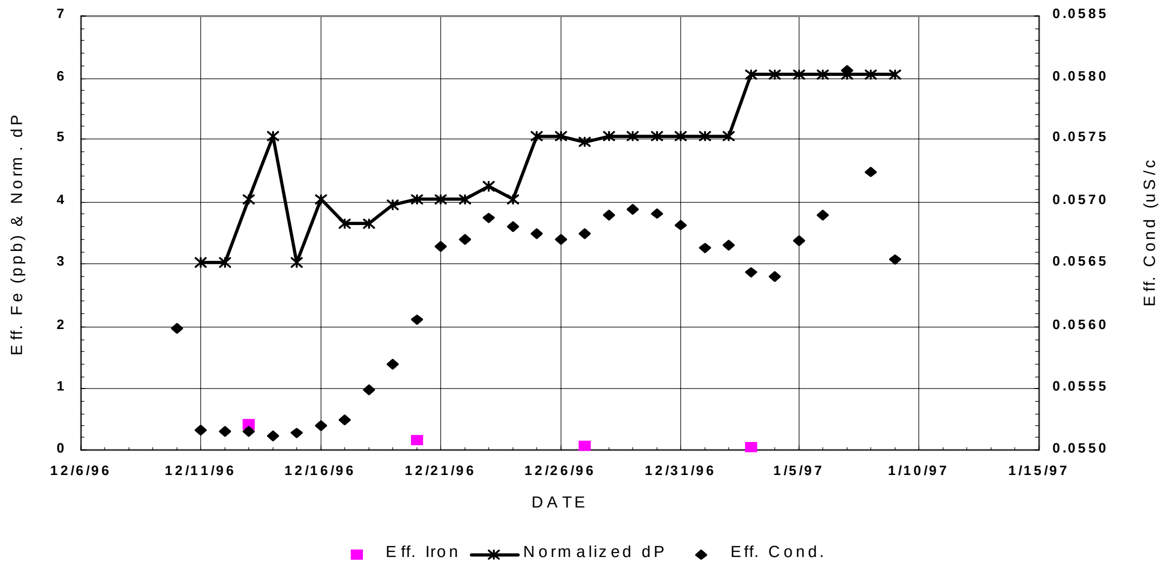

Figure 24-7
Filter E, Eighth Run, Monticello

Run length and longevity statistics for the monitored pleated septa at Monticello through December 31, 1997 are shown in Table 24-5.

Table 24-5
Monticello Pleated Septa Performance Statistics

Filter	**A**	**E**
Septa Particle Rating (μm)	10	4
Total Elapsed Days Since Initial Service	531.0	693.0
Total Operating Time (Actual Days)	449.0	558.0
Total Operating Time (Base Flow Days)	446.5	543.4
Avg. Run Length (Base Flow Days/Run)	40.6	32.0

25

NINE MILE POINT UNIT 2

Table 25-1
Nine Mile Point Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	4/88
Capacity (MWe)	1184
BWR Type	5 (Mark IV)
Drains Path	Forward Pumped
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	2%

Nine Mile Point Unit 2 Milestones

Milestone events for Nine Mile Point Unit 2 are given in Table 25-2. Nine Mile Point Unit 2 started natural zinc oxide injection in 1988, when the plant started up. A 5% power uprate to 3467 MWth was implemented in September, 1994. A failure of the moisture separator reheater in June, 1997 caused CDI iron concentrations to increase.

Table 25-2
Nine Mile Point Unit 2 Milestones

Nine Mile Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate							9/94			
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO	4/88	→	→	→	→	→	→	→	→	→
DZO										
Iron Injection										
Crud Resins						8/93	X			1/98
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 25-3.

Table 25-3
Nine Mile Point Unit 2 Recirculation Piping Dose Rates

Nine Mile Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Nov-88	Nov-90	Mar-92	Jan-93	Oct-93	Apr-95	Sep-96		
EFPY	0.45	1.4	2.25	3.4					
BRAC	37.8	118	164	184	182	188	230		
A Suction		136	182		204	275	250		
B Suction		140	152		174	200	200		
A Discharge		98	183		205	90	250		
B Discharge		99	138		157		220		
Avg Risers		199	283		334	379	353		

Trend Data

Power, Feedwater iron and reactor water cobalt 60 trend plots for Nine Mile 2 are presented in Figures 25-1, 25-2 and 25-3, respectively.

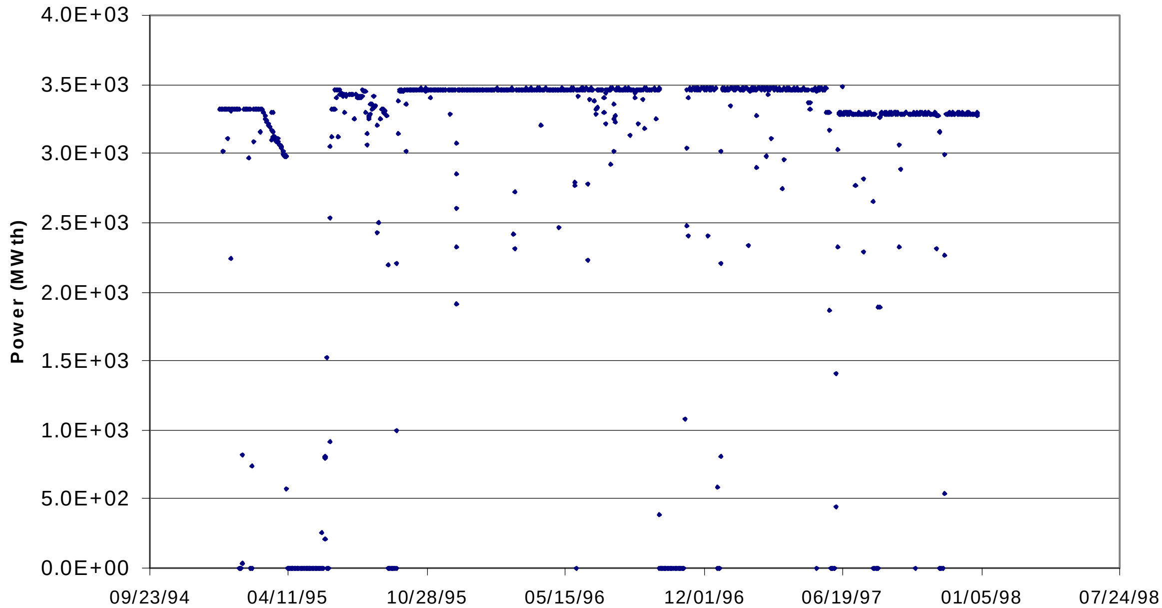

Figure 25-1
Power History, Nine Mile Point Unit 2

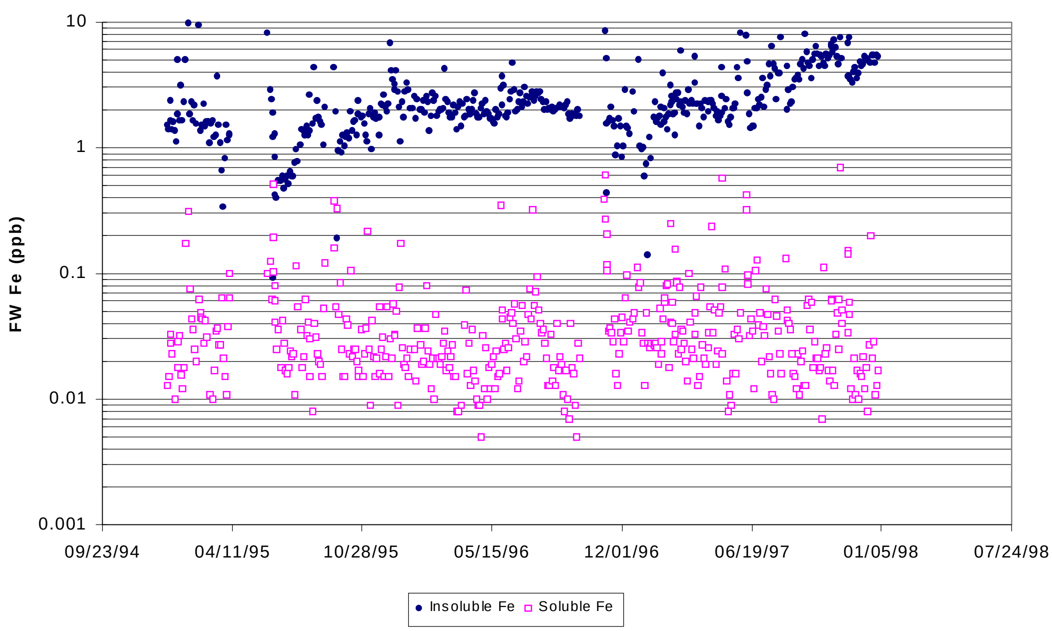

Figure 25-2
Feedwater Iron, Nine Mile Point Unit 2

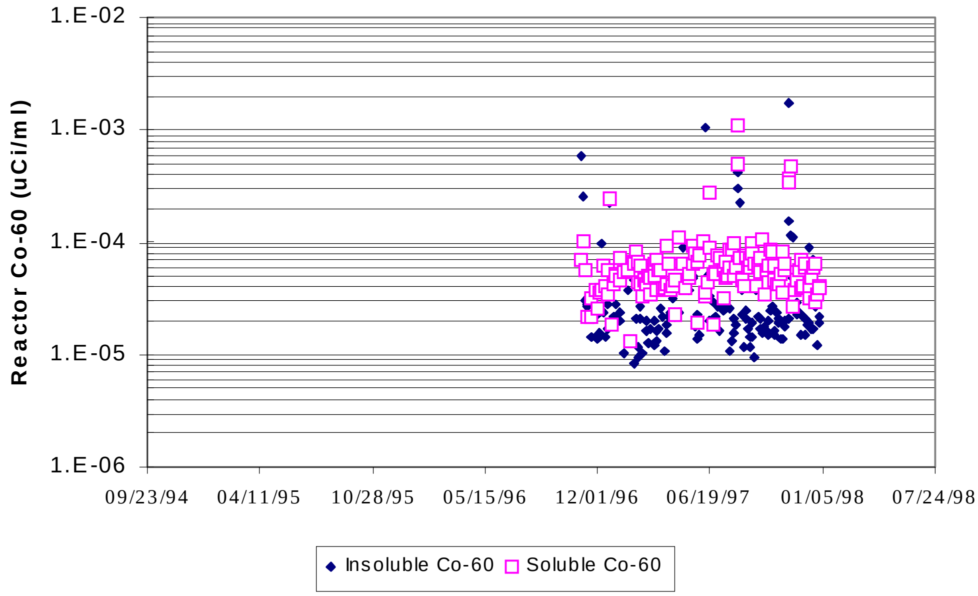

Figure 25-3
Reactor Water Cobalt 60, Nine Mile Point Unit 2

Feedwater Iron Control

During power operations in 1997, insoluble feedwater iron averaged of 3.96 ppb, while the average soluble iron concentration was 0.05 ppb. Increased feedwater iron and copper were coincident with loss of the MSR (moisture separator reheater) in June, 1997. Reactor water Co-58 and Co-60 trends do not indicate increasing trends as the feedwater iron increased. The increased feedwater metals are from condensate; FPD iron was < 1ppb. The increase in average CDI Fe from about 12 ppb before the MSR problem to about 19 ppb after the MSR problem indicates an increase in the iron source term by about 1.7 lb Fe/day. The MSR problem has led to a trial of low crosslinked resins at Nine Mile 2 under an EPRI Tailored Collaboration project.

Recirculating Pipe Dose Rates

Historical BRAC data show steadily increasing dose rates from the initial plant operation to 230 mR/hr in 1996. Nine Mile 2 has been adding natural zinc oxide since start up. Reactor water insoluble Co-60 was approximately 2E-5 uCi/ml while the soluble Co-60 was slightly higher at 7.7 E-5 uCi/ml. The BRAC dose rate data do not indicate that they have stabilized yet.

Piping Gamma Scan Data

Nine Mile 2 gamma scan results up to 1/93 are summarized in Table 25-4. There were no data reported after 1993.

Table 25-4
Nine Mile Point Unit 2 Recirculation Piping Gamma Scan Results

Date	11/88	11/90	3/92	1/93
Total Activity (uCi/cm^2)	3.1	11.9	13.7	16.8
% Co-60	19	34	40	38
% Co-58	29	11	8	4
% Mn-54	13	21	17	25
% Zn-65	32	30	32	29

The piping total activity was still on an increasing trend at the time of the 1/93 gamma scan; this trend is consistent with the BRAC dose rate trend. The gamma scan data also indicate that approximately one-third of the recirculation piping activity is from Zn-65. The Zn-65 percentage is relatively constant while the fraction of Co-60 in the piping corrosion film increased from 19% to 38%.

Stellite Reduction

Nine Mile 2 has replaced 24 control rod blades. Twelve blades were replaced in 1995 and an additional 12 were replaced in 1996.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997 233 person-Rem

1996 230 person-Rem

1995 281 person-Rem

1994 257 person-Rem

1993 262 person-Rem

26

OYSTER CREEK

Table 26-1
Oyster Creek Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/69
Capacity (MWe)	640
BWR Type	2 (Non-Jet Pump)
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	3% (6% max.)

Oyster Creek Milestones

Milestone events for Oyster Creek are given in Table 26-2. The original aluminum-bronze condenser tubes were replace in with titanium tubes in 1975. The 1986 chemical decontamination of the recirculation piping removed approximately 55.3 curies of activity. The 1991 decon of the recirculation piping removed 38.3 curies, and a concurrent decontamination of the RWCU piping removed 8.3 curies. New resin cleaning technology from Japan was implemented in January, 1993, to replace the original Air Bump & Rinse resin cleaning process.

Table 26-2
Oyster Creek Milestones

Oyster Creek										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser	1975									
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.	1986			4/91						
HWC (scfm)					2/92 @5	12	→	→	10.6	→
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins						12/93	→	12/95		
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in the following Table 26-3.

Table 26-3
Oyster Creek Recirculation System Dose Rates

Oyster Creek – Recirculation System Dose Rates (mR/hr)									
	Apr-90	Feb-91	May-91	Jun-92	Nov-92	Sep-94	Sep-96	Apr-97	
EFPY	10.9	11.6	11.6	12.5	12.9	14.4	16.1	16.6	
BRAC	282	256	40.7	188	188	294	389	370	
A Suction	300	300	10	200	200	300	400	340	
A Discharge	300	320	20	180	200	300	400	380	
B Suction	280	200	12	200	180	300	400	380	
B Discharge	320	200	8	160	180	200	400	300	
C Suction	300	280	240	220	180	320	380	400	
C Discharge	260	260	24	180	180	280	350	380	
D Suction	260	280	15	160	180	320	380	360	
D Discharge	240	260	18	180	200	300	400	380	
E Suction	300	240	20	220	200	300	400	380	
E Discharge	260	220	40	180	180	320	380	400	

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots are presented for Oyster Creek in Figures 26-1, 26-2 and 26-3, respectively.

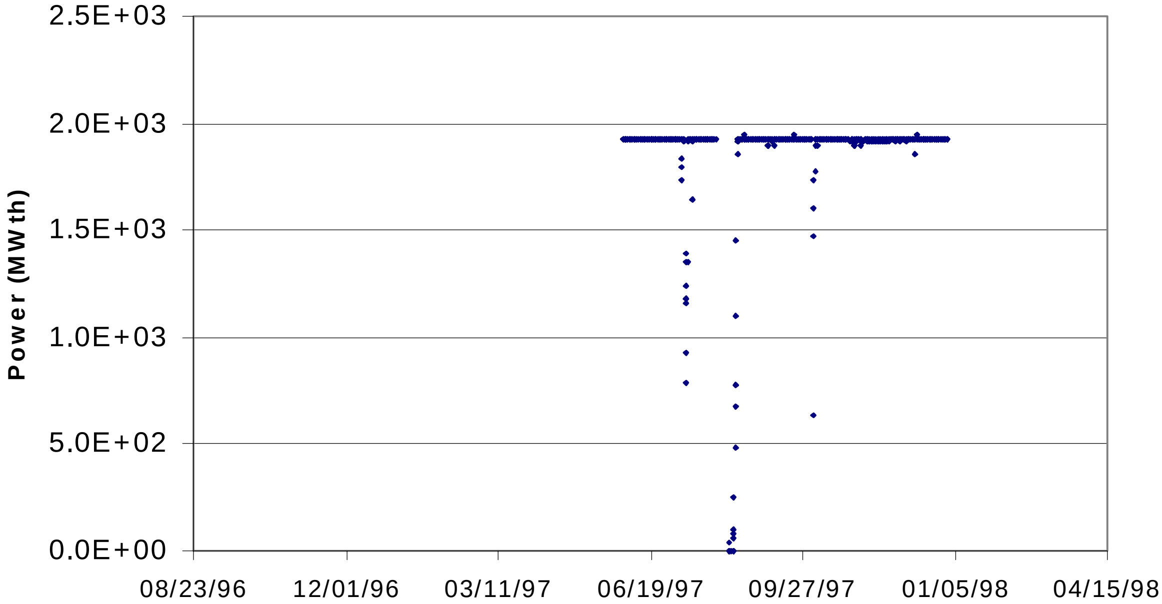

Figure 26-1
Power History, Oyster Creek

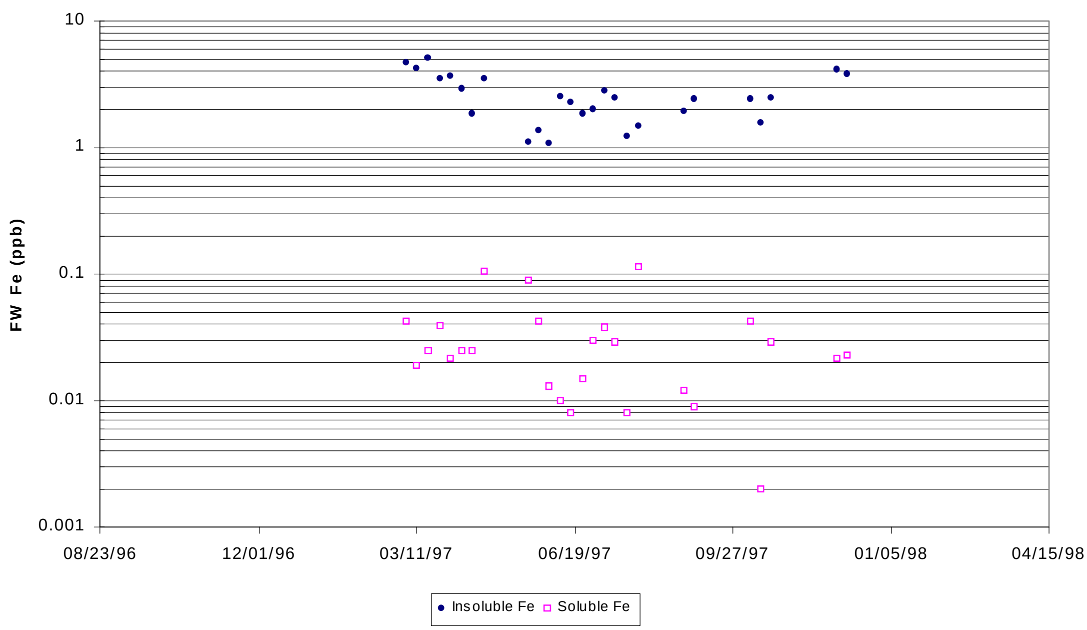

Figure 26-2
Feedwater Iron, Oyster Creek

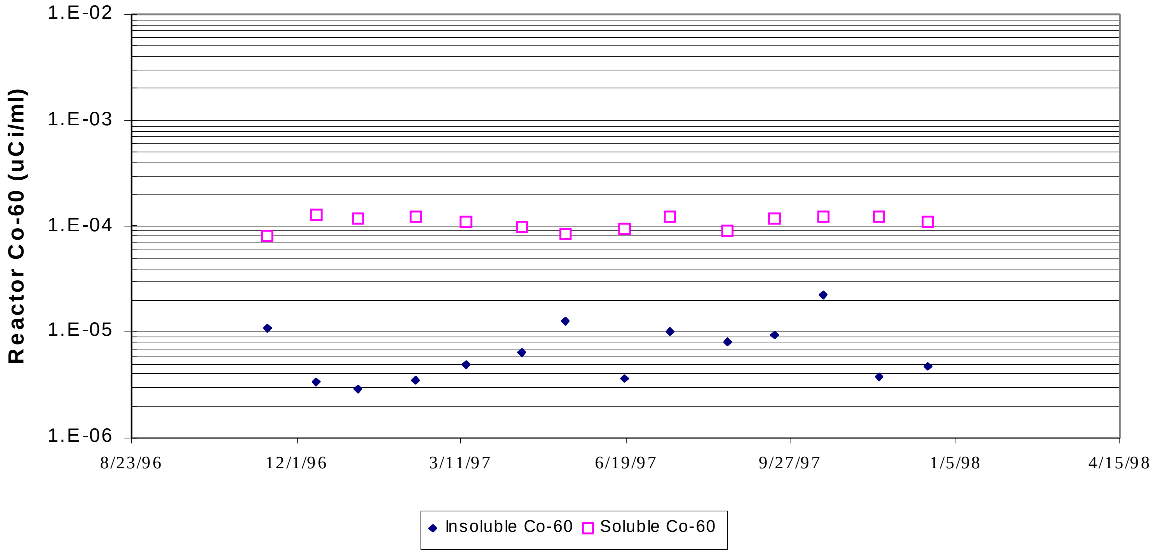

Figure 26-3
Reactor Water Cobalt 60, Oyster Creek

Feedwater Iron Control

In 1993, Oyster Creek has installed resin cleaning technology from Japan to improve removal crud and resin fines from the beds. In addition, the plant applied low crosslinked resins for enhanced crud removal in two of the seven condensate demineralizer service vessels for a 2-year period from December 1993 through December 1995, until the increase in reactor water sulfate concentration became unacceptable. The plant has returned to using conventional resins, with the exception of one bed of less separable resins (Dow C500ES / SBR-C), which also has a lower void fraction and greater cation resin surface area than the conventional resins. The 1997 average feedwater insoluble iron concentration was 2.64 ppb and soluble feedwater iron averaged 0.032 ppb. The feedwater iron trend plot shows that iron decreases as the fuel cycle progresses. Period of increased feedwater iron during the fuel cycle are usually due to plant conditions which prevent maintaining a 30-day cleaning frequency for each bed.

Recirculation Piping Dose Rates

Piping dose rates at Oyster Creek are typically greater than 250 mR/hr. The last chemical decontamination in 1991 reduced the dose rates to 40 mR/hr, but the piping recontaminated and dose rates had increased to 390 mR/hr by September, 1996. . Reactor water soluble Co-60 activity was steady in 1997, averaging 1.10E-4 uCi/ml. Oyster Creek does not perform gamma scans of the recirculation system piping.

Stellite Reduction

Stellite in steam, condensate, and feedwater systems of the Oyster Creek BWR 2 is approximately 40 % higher than a typical BWR 4. **(Ref. TDR 962, BOP Cobalt Input at OCNGS, 1989).** Between 1987 and 1997, stellite surface area in the reactor system at Oyster Creek has been reduced by approximately 50%, from 177 ft^2 to 91 ft^2 through replacement of control blade components.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997 196 person-Rem

1996 461 person-Rem

1995 450 person-Rem

1994 639 person-Rem

1993 752 person-Rem

1992 717 person-Rem

27

PEACH BOTTOM UNIT 2

Table 27-1
Peach Bottom Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	7/74
Capacity (MWe)	1159
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Peach Bottom Unit 2 Milestones

Milestone events for Peach Bottom Unit 2 are given in Table 27-2. The original admiralty brass condenser tubes were replaced in 1991 with titanium tubes. The original 304 stainless steel recirculation piping was replaced in 1985 with 316NG stainless steel. The plant performed a chemical decontamination of the original recirculation piping prior to the replacement. There have been no chemical decons performed on the new recirculation piping.

Table 27-2
Peach Bottom Unit 2 Milestones

Peach Bottom Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser				X						
Recirc. Pipe Replacement	1985									
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										5/97 @ 13
Noble Metals Coating										
NZO					6/92	→	→	→		
DZO									10/96	→
Iron Injection										
Crud Resins										
Pleated Filters									5/96	→

Radiation Data

Recirculation System dose rates are summarized in Table 27-3.

Table 27-3
Peach Bottom Unit 2 Recirculation System Dose Rates

Peach Bottom 2 – Recirculation System Dose Rates (mR/hr)									
	Mar-91	Nov-92	Oct-94	Sep-96					
EFPY									
BRAC	109	114	128	111					
A Suction	90	130	135	117					
B Suction	110	105	112	107					
A Discharge	115	90		117					
B Discharge	120	130	137	105					
Avg Risers	173	221	279	190					

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots for Peach Bottom 2 are presented in Figures 27-1, 27-2 and 27-3, respectively.

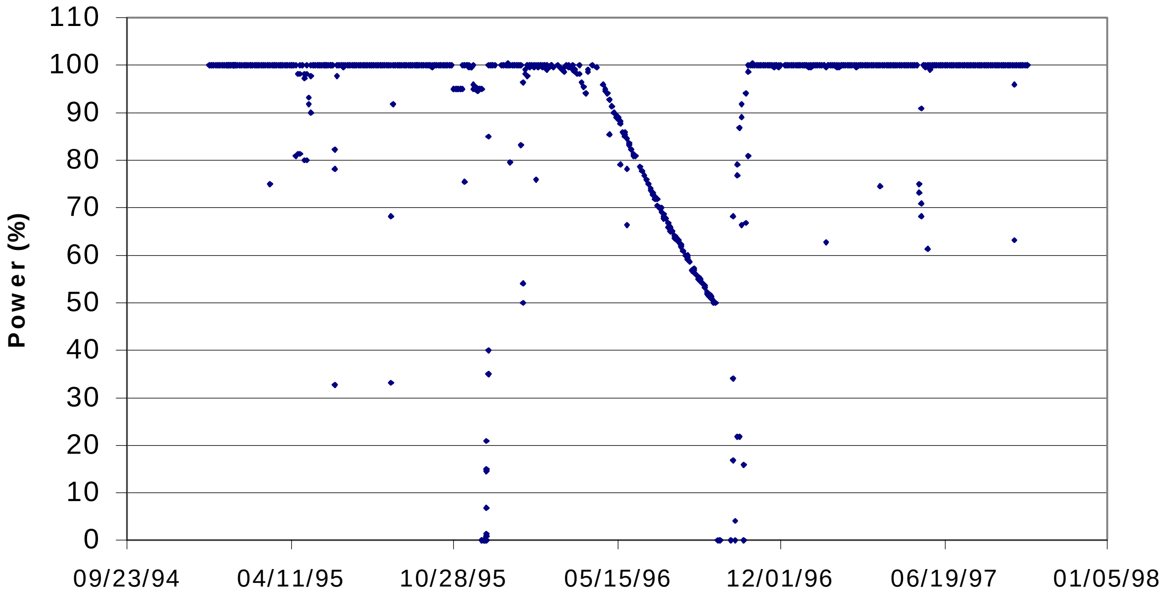

Figure 27-1
Power History, Peach Bottom Unit 2

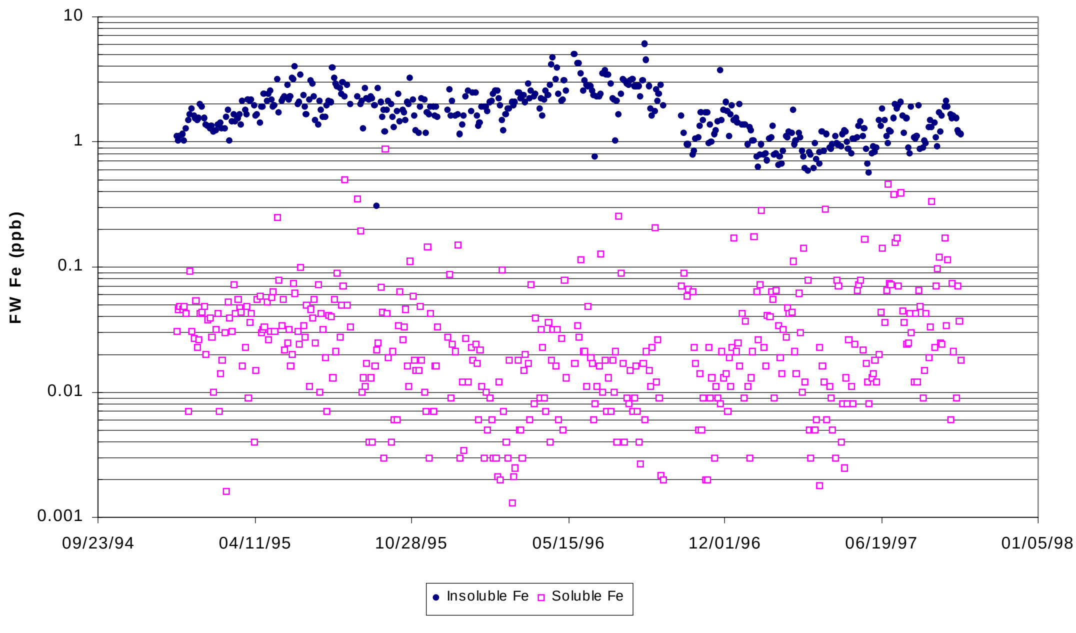

Figure 27-2
Feedwater Iron, Peach Bottom Unit 2

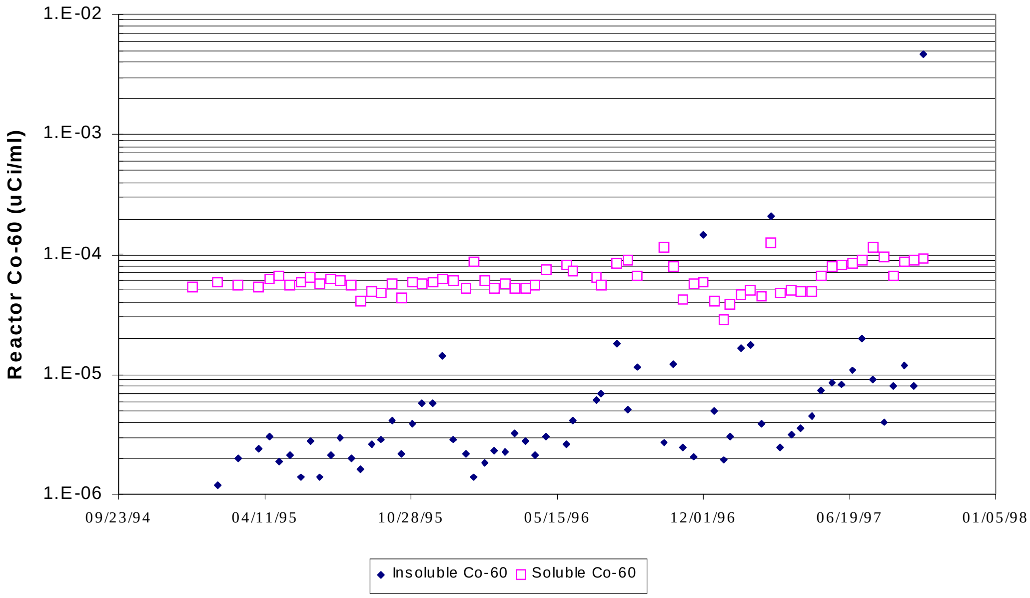

Figure 27-3
Reactor Water Cobalt 60, Peach Bottom Unit 2

Feedwater Iron Control

Precoatable pleated septa were installed in 3 of the 10 condensate filter/demineralizer vessels in May, 1996. The feedwater insoluble iron concentrations consequently decreased in the second half of 1996. In November, 1996, pleated septa were installed in 4 additional vessels, so 7 of the 10 vessels had the pleated septa. The 1997 average feedwater iron concentrations were 1.14 for the insoluble fraction and 0.057 ppb for the soluble fraction.

Recirculation Piping Dose Rates

Pipe dose rates have been relatively constant between 109 and 128 mR/hr from 1991 to 1996. The admiralty condenser tubes were replaced with titanium in 1991, and natural zinc oxide addition was started at that time to replace the zinc source from the original condenser tubes. In October, 1996, Unit 2 switched to DZO. Hydrogen injection was initiated in May, 1997. In 1997 reactor water soluble Co-60 activity averaged 7.3E-5 uCi/ml.

Piping Gamma Scan Data

Peach Bottom 2 recirculation piping gamma scan data are summarized in Table 27-4.

Table 27-4
Peach Bottom Unit 2 Recirculation Piping Gamma Scan Results

Date	3/91	10/94	9/96
Total Activity (uCi/cm^2)	9.37	11.42	9.2
% Co-60	64	48	43
% Co-58	19	5	3
% Mn-54	9	34	29
% Zn-65	9	10	17

The data indicate that the total activity may be staying about constant. However, the composition of the corrosion film has changed, showing an increased activity contribution from Mn-54 and Zn-65, and a decline in Co-60 and Co-58. The Zn-65 contribution is expected decrease over the next several years due to the switch to DZO addition.

Peach Bottom Precoated Filter Septa Performance

The flow per unit length of septum and the average influent iron concentrations at Peach Bottom define a moderate run length application challenge severity (RLI). The severity is fairly representative of the challenge at most stations using precoated pleated septa, except for Browns Ferry which has the highest application challenge severity among this class of plants. Run lengths and septa longevity have been good. The strategy of using yarn wound septa in three vessels and pleated septa in four has been successful in controlling feedwater iron at close to 0.5 ppb, thus avoiding the need for iron injection. The singular problem has been resin passage.

A total of four sets of Unit 2 pleated filter septa have been replaced because of resin passage concerns. The first set replaced, from Filter 2D, was fitted with Graver yarn wound septa because Memtec pleated septa with a newly designed attachment were not available at the time required. Thus the ratio of CF/D's using pleated septa to those using yarn wound septa has been changed from 7/3 to 6/4. The intention is to return the ratio to 7/3 pleated/wound, provided that the resin passage problem is eliminated or sufficiently reduced. The dates of first service for the replacement septa are shown in Table 27-5:

Table 27-5
Peach Bottom Unit 2 Condensate F/D Septa Replacements

Filter 2D (Graver yarn wound)	September 1, 1997
Filter 2E (Memtec 10 μm pleated)	December 27, 1997
Filter 2G (Memtec 10 μm pleated)	October 15, 1997
Filter 2J (Memtec 10 μm pleated)	January 13, 1998

Peach Bottom filter systems do not have effluent resin traps. Therefore, resin intrusion to the reactor results from any passage of resin from the CF/D's. For some time, perturbations in reactor water conductivity and sulfates have been seen when CF/D's using pleated septa are first placed in service with new precoats. Also, resin, in varying amounts, has been found in samples of the precoat tank return stream taken during and at the completion of the precoat cycle. These indications of resin passage have been non-existent or minimal for CF/D's using yarn wound septa, and for the CF/Ds using 2 or 4 μm pleated septa.

It is suspected that the resin passage is at least partially due to deficiencies in the attachment hardware originally supplied with the pleated septa. Graver hardware is used with all of the yarn wound septa and with the 2 μm or 4 μm pleated septa that do not pass resin. Three sets of new pleated septa have been installed with new design hardware from the septa supplier. In addition, three sets of the used pleated septa have been removed, refitted with new hardware and re-installed. Two CF/Ds using the new hardware went into service in the last quarter of 1997, and the remaining four in January and February of 1998. Although the new hardware appears to have decreased the resin passage, station personnel are awaiting further results before concluding that the resin passage has been sufficiently reduced.

Run length and longevity statistics for the pleated septa monitored at Peach Bottom are summarized in Table 27-6.

Table 27-6
Peach Bottom Units 2 & 3 Run Length and Longevity Statistics For Pleated Septa

Filter	2D	3A	3B	3D
Septa Particle Rating (μm)	10	2	4	10
Total Elapsed Days Since Initial Service	476.0	940.0	935.0	604.0
Total Operating Time (Actual Days)	440.0	797.0	820.0	511.0
Total Operating Time (Base Flow Days)	428.7	775.6	805.0	498.5
Avg. Run Length (Base Flow Days/Run)	53.6	36.9	35.0	38.3

28

PEACH BOTTOM UNIT 3

Table 28-1
Peach Bottom Unit 3 Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/74
Capacity (MWe)	1159
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Peach Bottom Unit 3 Milestones

Milestone events for Peach Bottom Unit 3 are given in Table 28-2. The original condenser tube admiralty brass condenser tubes were replaced in 1991 with titanium tubes. The original 304 stainless steel recirculation piping was replaced in 1988 with 316NG stainless steel. The plant performed a chemical decontamination on the original recirculation piping prior to replacement. There have been no chemical decons performed on the new recirculation piping.

Table 28-2
Peach Bottom Unit 3 Milestones

Peach Bottom Unit 3										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser				12/91						
Recirc. Pipe Replacement	12/88									
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										3/97 @ 13
Noble Metals Coating										
NZO					6/92	→	→	→		
DZO									10/96	→
Iron Injection										
Crud Resins										
Pleated Filters								5/95	→	→

Radiation Data

Recirculation System dose rates are summarized in Table 28-3.

Table 28-3
Peach Bottom Unit 3 Recirculation System Dose Rates

Peach Bottom 3 – Recirculation System Dose Rates (mR/hr)									
	Nov-91	Nov-93	Oct-95	Sep-96					
EFPY									
BRAC	203		188	111					
A Suction	60	nm	170	117					
B Suction	nm	nm	178	107					
A Discharge	250	nm	225	117					
B Discharge	300	nm	180	105					
Avg Risers	110	276	286	190					

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots for Peach Bottom 3 are presented in Figures 28-1, 28-2 and 28-3, respectively.

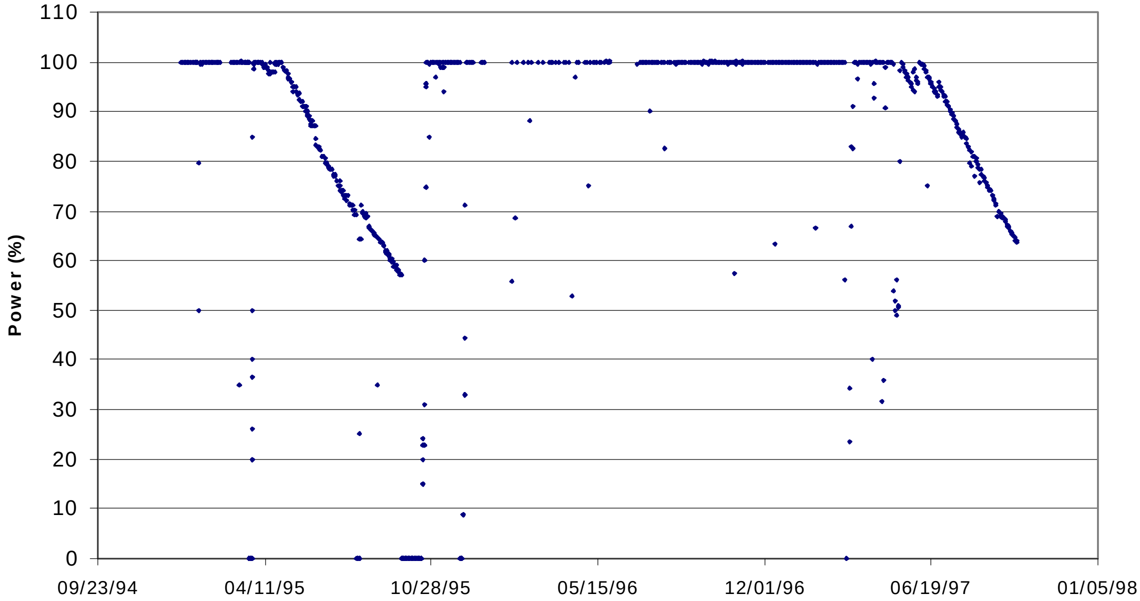

Figure 28-1
Power History, Peach Bottom Unit 3

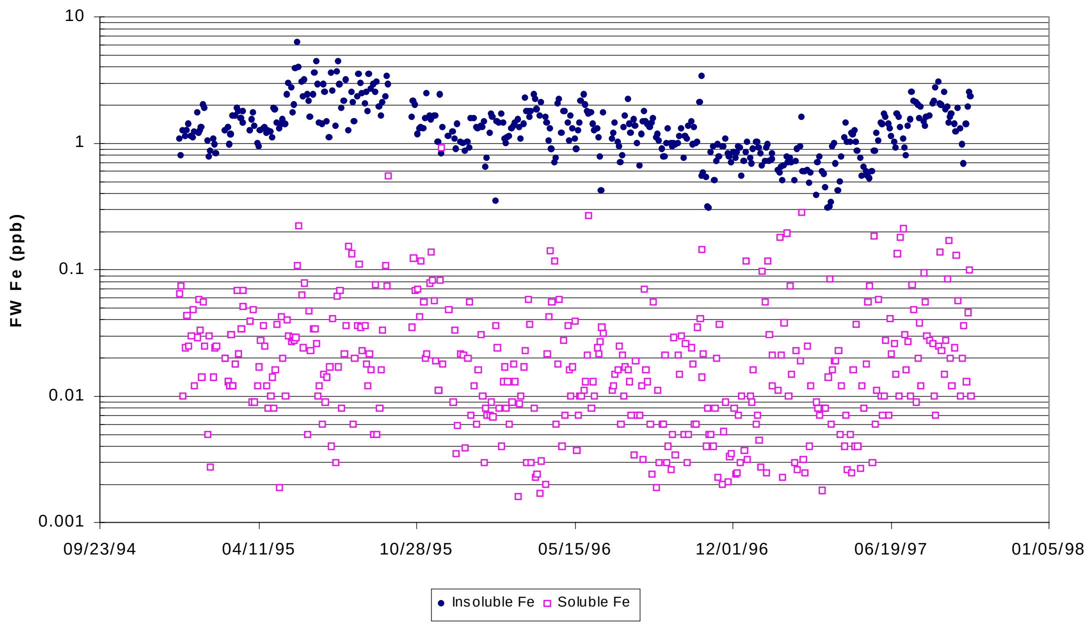

Figure 28-2
Feedwater Iron, Peach Bottom Unit 3

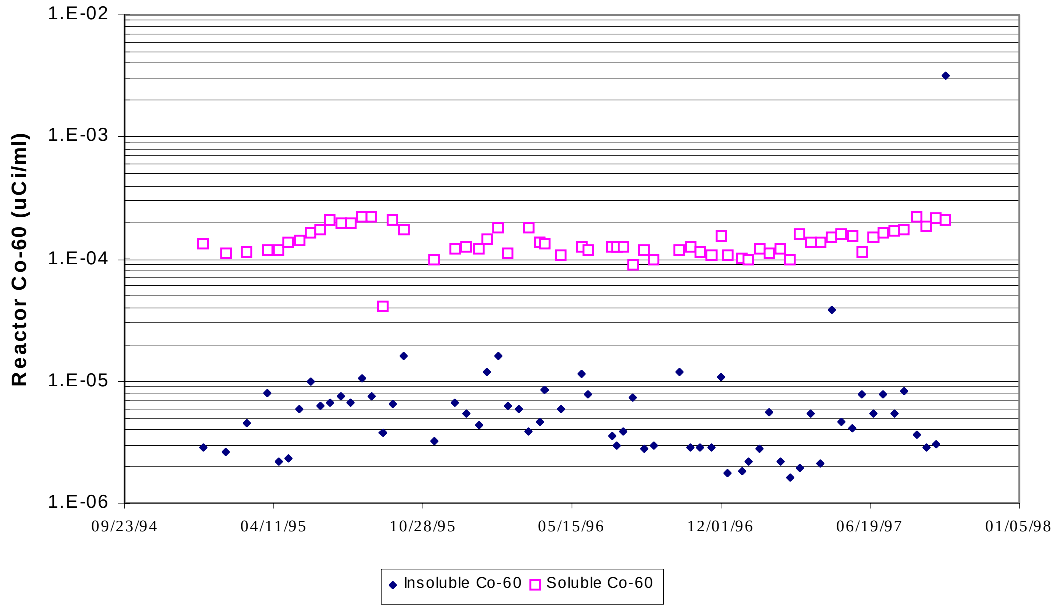

Figure 28-3
Reactor Water Cobalt 60, Peach Bottom Unit 3

Feedwater Iron Control

Peach Bottom 3 installed precoatable pleated septa starting in 1995, extending them to 7 of 10 condensate filter/demineralizer vessels by April, 1996. During steady state operation in January through May of 1997 the feedwater insoluble iron concentration was consistently less than 1 ppb. As the plant coasted down in power to the 10/97 refueling outage, feedwater iron gradually increased to approximately 2 ppb. The 1997 average concentrations for feedwater insoluble and soluble iron were 1.16 ppb and 0.038 ppb, respectively.

Recirculation Piping Dose Rates

Although Peach Bottom 3 piping dose rates have been relatively constant at approximately 200 mR/hr from 1991 to 1995, they are higher by about a factor of 2 than the Unit 2 recirculation piping dose rates. Reactor water soluble Co-60 was relatively constant during 1996 and 1997, with the 1997 average of 1.53E-4 uCi/ml. Insoluble Co-60 varied a factor of about 10, from 2E-6 to 2E-5 uCi/ml. The admiralty condenser tubes were replaced in 1991 with titanium, removing a source of zinc to the primary system, but addition of natural zinc oxide was started at that time to replace the zinc source. In October, 1996 Unit 3 switched to DZO, and hydrogen injection was initiated in March, 1997. The impact of these changes on piping dose rates has not yet been reported.

Piping Gamma Scan Data

Peach Bottom 3 recirculation piping gamma scan results are summarized in Table 28-4.

Table 28-4
Peach Bottom Unit 3 Recirculation Piping Gamma Scan Results

Date	**11/91**	**11/93**	**10/95**
Total Activity (uCi/cm^2)	5.2	11.1	17.1
% Co-60	54	54	56
% Co-58	15	8	4
% Mn-54	12	19	20
% Zn-65	17	17	18

The Zn-65 activity contribution is expected to decrease as the Zn-65 inventory decays.

Stellite Reduction

Peach Bottom has a program to replace stellited valve seats with alternative materials as opportunities arise during regular maintenance activities.

Radiation Exposure

Station radiation exposure three-year rolling averages for the Peach Bottom 2 and Peach Bottom 3 plant are as follows:

1997 384 person-Rem

1996 419 person-Rem

1995 509 person-Rem

1994 545 person-Rem

1993 663 person-Rem

1992 605 person-Rem

1991 680 person-Rem

Peach Bottom Precoated Filter Septa Performance

Filter performance data for Unit 2 and Unit 3 are discussed under Peach Bottom 2.

29

PERRY

Table 29-1
Perry Plant Design Parameters

Parameter	Value
Commercial Operation Date	11/87
Capacity (MWe)	1250
BWR Type	6
Drains Path	Forward Pumped
Condensate Polishing	Filters + Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

Perry Milestones

Milestone events for Perry are given in Table 29-2.

Table 29-2
Perry Milestones

Perry										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO			X	→	→	→	→	→	→	→
Iron Injection										
Crud Resins										
Pleated Filters				8/91	→	→	→	→	→	→

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plotted for Perry are presented in Figures 29-1, 29-2 and 29-3, respectively.

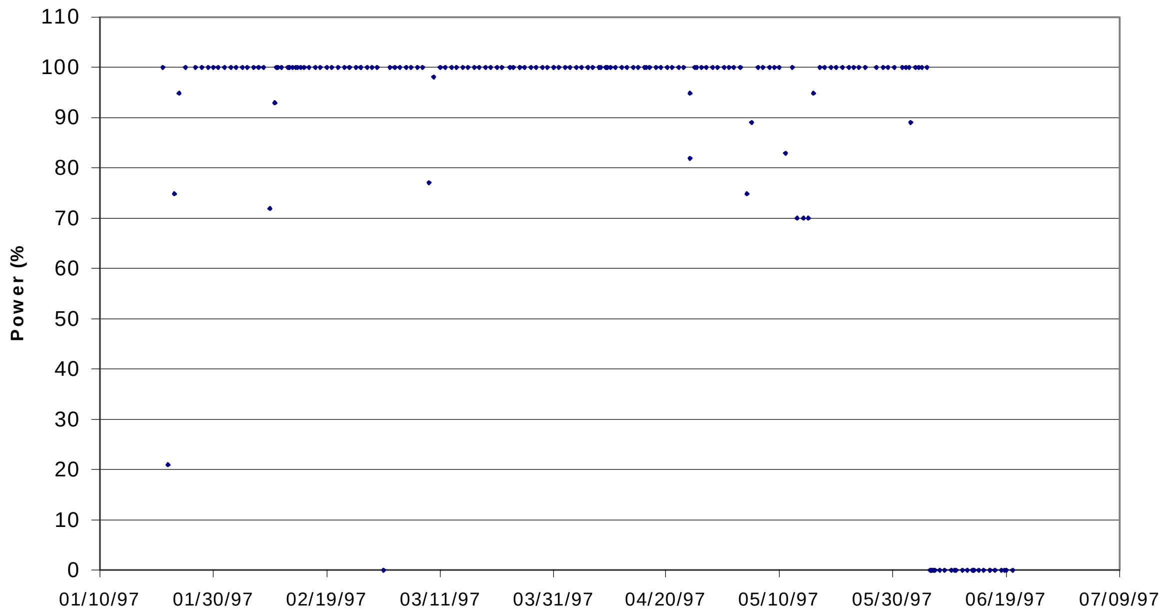

Figure 29-1
Power History, Perry

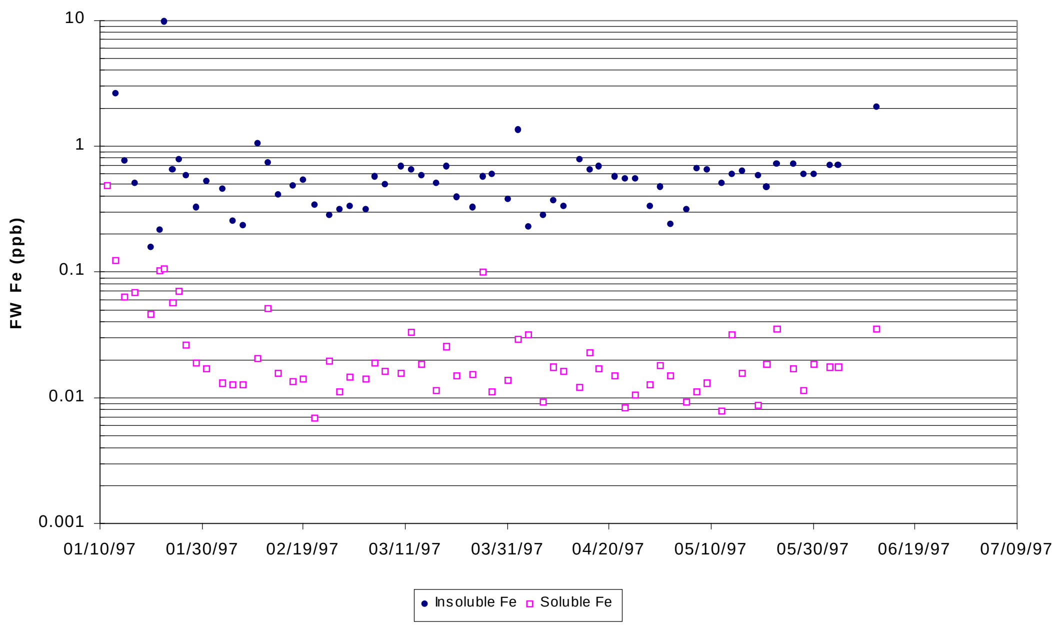

Figure 29-2
Feedwater Iron, Perry

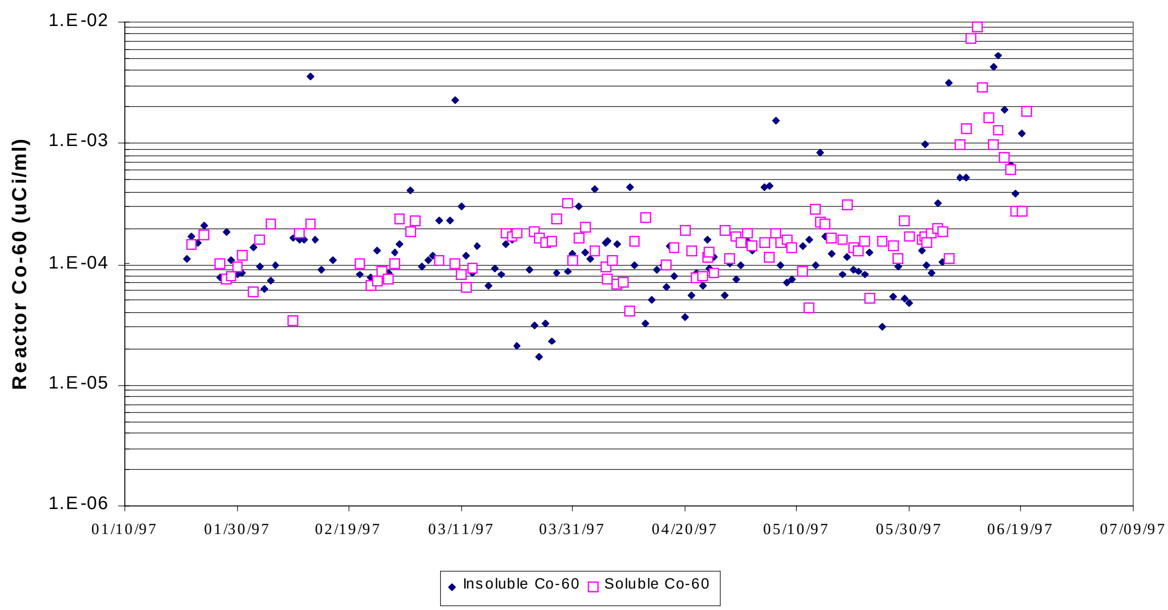

Figure 29-3
Reactor Water Cobalt 60, Perry

Feedwater Iron Control

Feedwater iron averages about 0.5 ppb when the plant is operating at steady state. The 1997 averages for insoluble and soluble feedwater iron concentrations for the data reported were 0.92 ppb and 0.034 ppb, respectively. Perry uses non-precoat pleated septa upstream of the deep bed condensate polishers.

Recirculation Piping Dose Rates

Dose rate data were not provided. Natural zinc oxide has been injected since 1990, with approximately 6 ppb Zn maintained in reactor water. Reactor water soluble Co-60 activity is in the high range among BWR's, with an average of 4.0 E-4 uCi/ml.

Radiation Exposure

Station radiation dose for 1997 was 279 person-Rem.

Perry Non-Precoated Pleated Septa Performance

There are eight Condensate Filters at Perry. Seven contain Memtec pleated septa, four with 2 μm and three with 4 μm rated septa. The eighth filter contains Graver pleated septa, which is used as little as possible since it provides the shortest run lengths. That is, only six of the seven filters are normally on-line.

The performance of Memtec septa in Filters C, D and G are being monitored. Filter C contains the oldest 2 μm septa, initial service on May 31, 1995. Filter G contains the oldest 4 μm septa, initial service on May 12, 1995. The youngest filter septa (4 μm) are in Filter D, initial service on December 23, 1996.

The Memtec septa at Perry have one of the lowest application challenge severities, based on seven filters on-line and an average CDI iron concentration of 10 ppb. For much of their lives, the Memtec septa have achieved long run lengths with flow normalized final ΔPs less than 5 psi, and ΔP rise rates less than 0.01 psi/day on the 4 μm septa and less than 0.02 psi/day on the 2 μm septa. However, during 1997 the ΔP rise rates of the oldest 2 and 4 μm septa more than doubled, while the rise rate of the youngest 4 μm septa were affected to a much lesser extent, if at all. That is, an aging effect on the Memtec septa at Perry became apparent. The step in rise rates is likely associated with temporary CDI iron concentration increases and the change in the heater drain flow path that occurred during 1997.

Piping and Moisture Separator Reheater (MSR) problems during early 1997 effected CDI iron concentrations. The average CDI iron concentration for January through April 1997 was 23 ppb; by May 1997 the concentration had declined to 11.8 ppb.

During a June shutdown the MSR was taken out of service, and heater drains were temporarily cascaded to the condenser rather than pumped forward. During a refueling outage (September 13 to October 22, 1997) the MSR was repaired; drains are again pumped forward. CDI iron concentrations have been said to be in the “low teens” (ppb) since the restart following the outage.

Run length and longevity statistics for the pleated septa monitored at Perry are shown in Table 29-3.

Table 29-3
Perry Non-Precoat Condensate Filter Performance Statistics

Filter	**C**	**D**	**G**
Septa Particle Rating (µm)	2	4	4
Total Elapsed Days Since Initial Service	959.2	387.2	978.2
Total Operating Time (Actual Days)	722.1	327.0	851.9
Total Operating Time (Base Flow Days)	685.9	322.7	782.5
Avg. Run Length (Base Flow Days/Run)	68.6	107.6	97.8

30

PILGRIM

Table 30-1
Pilgrim Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/72
Capacity (MWe)	687
BWR Type	4G-Mark I
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

Pilgrim Milestones

Milestone events for Pilgrim are given in Table 30-2. The original condenser tubes have been replaced with titanium tubes. The extraction steam piping with was replaced with chrome-moly.

Table 30-2
Pilgrim Milestones

Pilgrim										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)				32 (1991)	→	→	→	→	→	→
Noble Metals Coating										
NZO										
DZO										1997
Iron Injection										
Crud Resins										
Pleated Filters										

31

QUAD CITIES UNIT 1

Table 31-1
Quad Cities Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	2/73
Capacity (MWe)	833
BWR Type	3
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1.2% (2% max.)

Quad Cities Unit 1 Milestones

Milestone events for Quad Cities Unit 1 are given in Table 31-2.

Table 31-2
Quad Cities Unit 1 Milestones

Quad Cities Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)				47	→	→	→	→	→	→
Noble Metals Coating										
NZO										
DZO										1/98
Iron Injection										
Crud Resins										
Pleated Filters								6/95	→	→

Trend Data

Power and feedwater iron trend plots for Quad Cities 1 are presented in Figures 31-1 and 31-2, respectively. Cobalt 60 data were not provided.

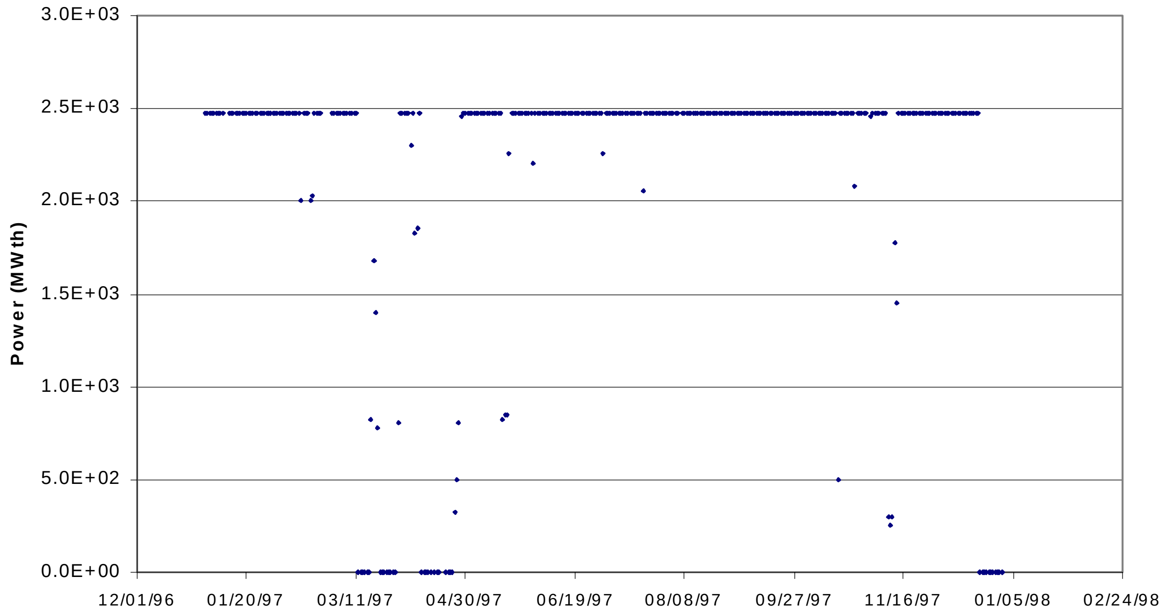

Figure 31-1
Power History, Quad Cities Unit 1

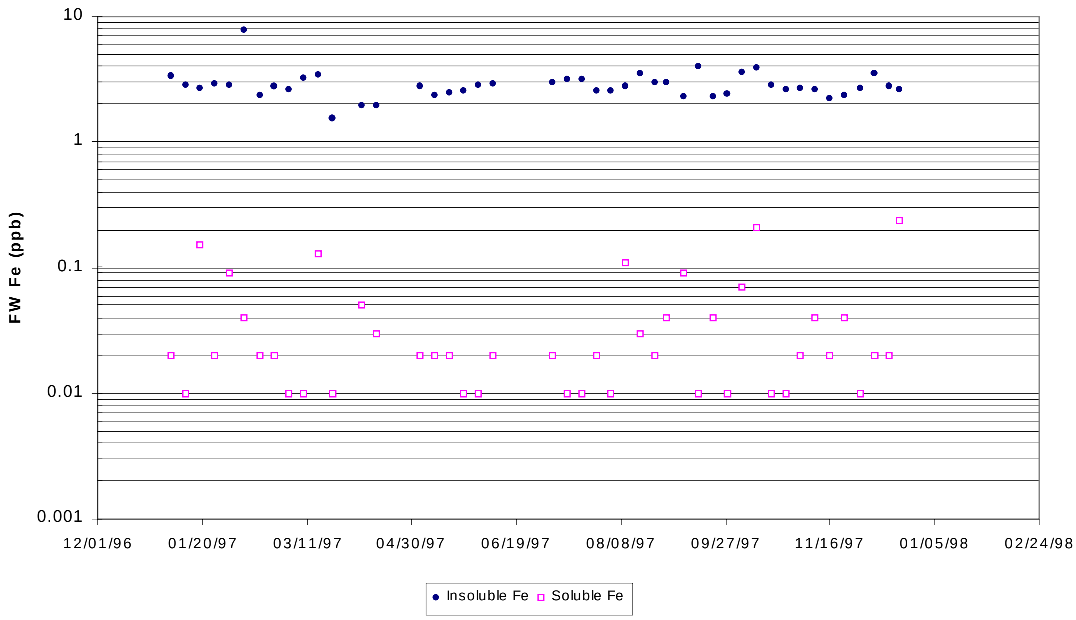

Figure 31-2
Feedwater Iron, Quad Cities Unit 1

Feedwater Iron Control

The 1997 averages for reported values of insoluble and soluble feedwater iron were 2.91 ppb and 0.041 ppb, respectively.

Quad Cities Precoated Pleated Filter Septa Performance

In Quad Cities Unit 1, three of the seven CF/D vessels contain Memtec pleated septa; one vessel with 4 µm septa, and two vessels with 10 µm rated septa. The earliest installation is June 1997, and the most recent is November 1997. Effluent iron from pleated septa is about 0.2 to 0.3 ppb. Run lengths have been reported to be consistently 45 days or better; about 3 times longer than runs with the Graver non-pleated yarn wound septa. The runs with pleated septa have been terminated at 8 psid or less.

Based on Na-24 removal, the ion exchange efficiency is lower for precoats on the pleated septa as opposed to precoats on the Graver non-pleated yarn wound septa. On the same basis, Quad Cities uses 0.28 dry pounds of PD-11 per septum rather than the 0.24 dry pounds used at Browns Ferry and Peach Bottom. At 0.24 dry pounds, removal of Na-24 decreased from 70% to 0% in 40 days. With 0.28 dry pounds, Na-24 removal starts at > 80% and decreases to 30% in 40 days.

Several deficiencies in the septa attachment hardware supplied with the Memtec septa were detected prior to installation, and the hook and guide rod assemblies with the deficiencies were rejected. There have been no resin leakage incidents at Quad Cities. Memtec has taken steps that have significantly reduced the hardware rejection rate. Quad Cities has a replacement schedule that will have all CF/Ds in Unit 1 using pleated septa by January 1999 and in Unit 2 by May 1999.

Unit 2 has been shutdown for several months due to fire protection concerns. Unit 2 has been in a maintenance outage since September, 1997. Four of the seven CF/Ds in Unit 2 now have Memtec pleated septa; two with 10 μm septa, and 4 m and 20 μm septa are each used in single vessel trials.

The RLI for both Quad Cities units is 33.4.

32

QUAD CITIES UNIT 2

Table 32-1
Quad Cities Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	3/73
Capacity (MWe)	833
BWR Type	3
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1.2% (2% max.)

Quad Cities 2 Milestones

Milestone events for Quad Cities Unit 2 are given in Table 32-2.

Table 32-2
Quad Cities Unit 2 Milestones

Quad Cities Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)				47	→	→	→	→	→	→
Noble Metals Coating										
NZO										
DZO										1/98
Iron Injection										
Crud Resins										
Pleated Filters									10/96	→

Trend Data

Power and feedwater iron trend plots for Quad Cities 2 are presented in Figures 32-1 and 32-2, respectively. Cobalt 60 data were not provided.

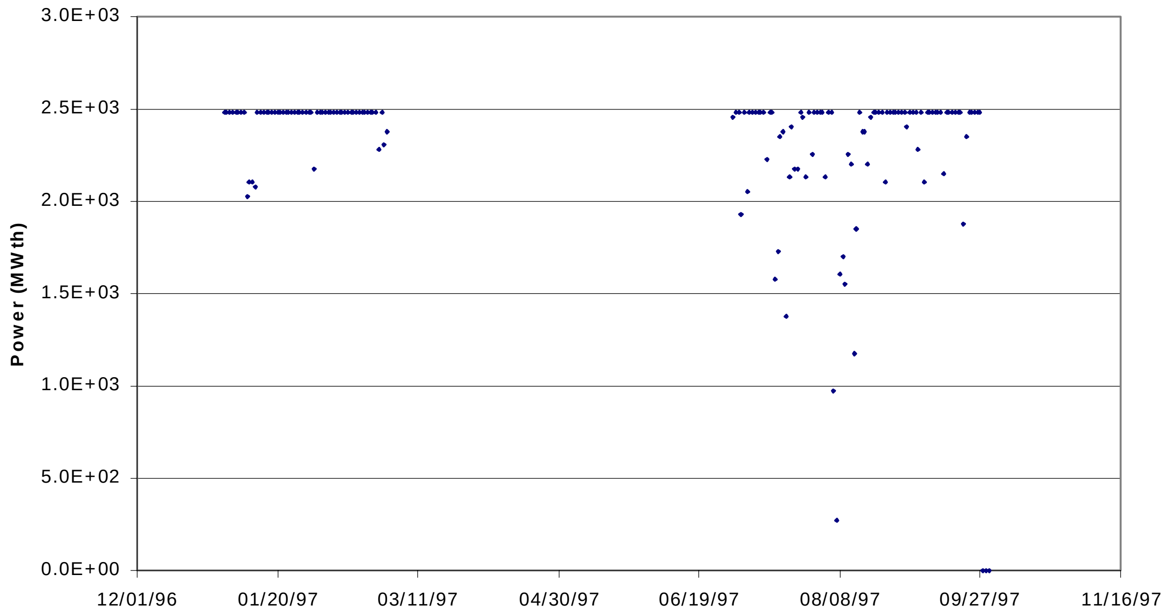

Figure 32-1
Power History, Quad Cities Unit 2

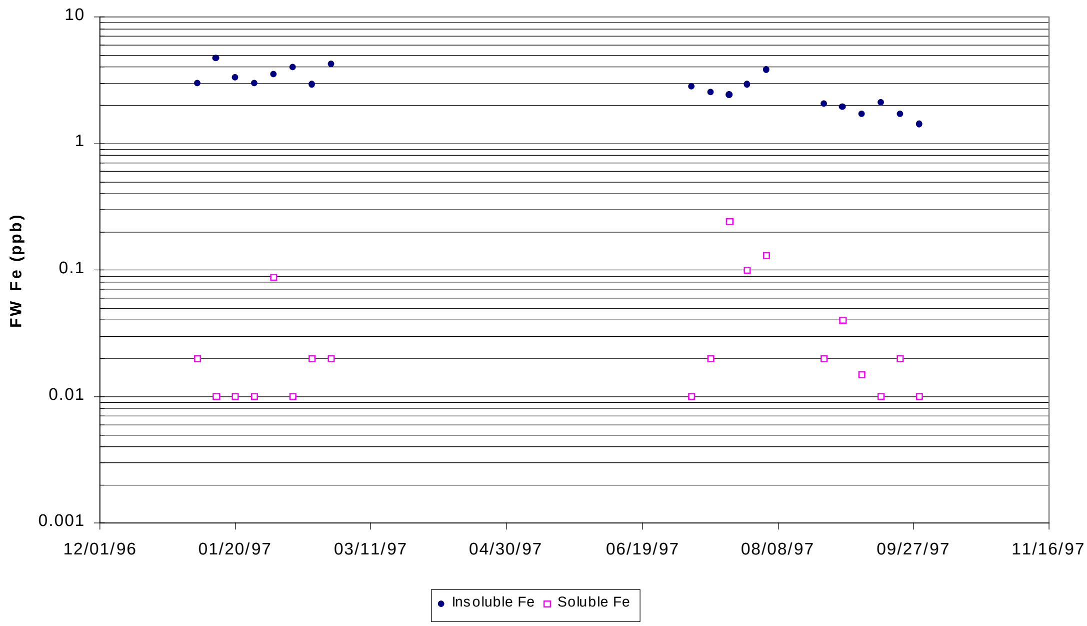

Figure 32-2
Feedwater Iron, Quad Cities Unit 2

Feedwater Iron Control

Quad Cities 2 has installed pleated septa in 2 of the 6 condensate filter/demineralizer vessels. Feedwater iron showed a decreasing trend starting in 9/97. Average feedwater insoluble and soluble iron concentrations based on reported 1997 data were 2.86 ppb and 0.041 ppb, respectively.

Radiation Exposure

Station radiation exposure for Quad Cities 1 and Quad Cities 2 for 1997 was 650 person-Rem.

Quad Cities Precoated Pleated Filter Septa Performance

The pleated septa experience at Quad Cities 1 and 2 is summarized under Quad Cities 1.

33

RIVER BEND

Table 33-1
River Bend Plant Design Parameters

Parameter	Value
Commercial Operation Date	6/86
Capacity (MWe)	986
BWR Type	6
Drains Path	Forward Pumped
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1%

River Bend Milestones

Milestone events for River Bend are given in Table 33-1. The recirculation and RWCU piping was decontaminated in 1992. The activity removed included 48.9 Ci from the recirculation piping and 18.9 Ci from RWCU. The low crosslinked crud removal resin bed was removed from service in 3/97.

Table 33-2
River Bend Milestones

River Bend										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.					X					
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										6/97
Iron Injection										
Crud Resins							2/94	→	→	3/97
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 33-3.

Table 33-3
River Bend Recirculation System Dose Rates

River Bend – Recirculation System Dose Rates (mR/hr)									
	1987	1989	1990	1992		1993	1994	1996	
EFPY					post decon				
BRAC	215	355	322	315	37	231	300	312	
A Suction	280	350	160	310	15	200	nm	320	
B Suction	200	320	460	400	50	300	300	400	
A Discharge	180	350	350	280	45	225	400	260	
B Discharge	200	400	320	270	40	200	200	270	
Avg Risers	310		650		67		490	764	

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots are presented in Figures 33-1, 33-2 and 33-3, respectively. Only total Co-60 values were provided.

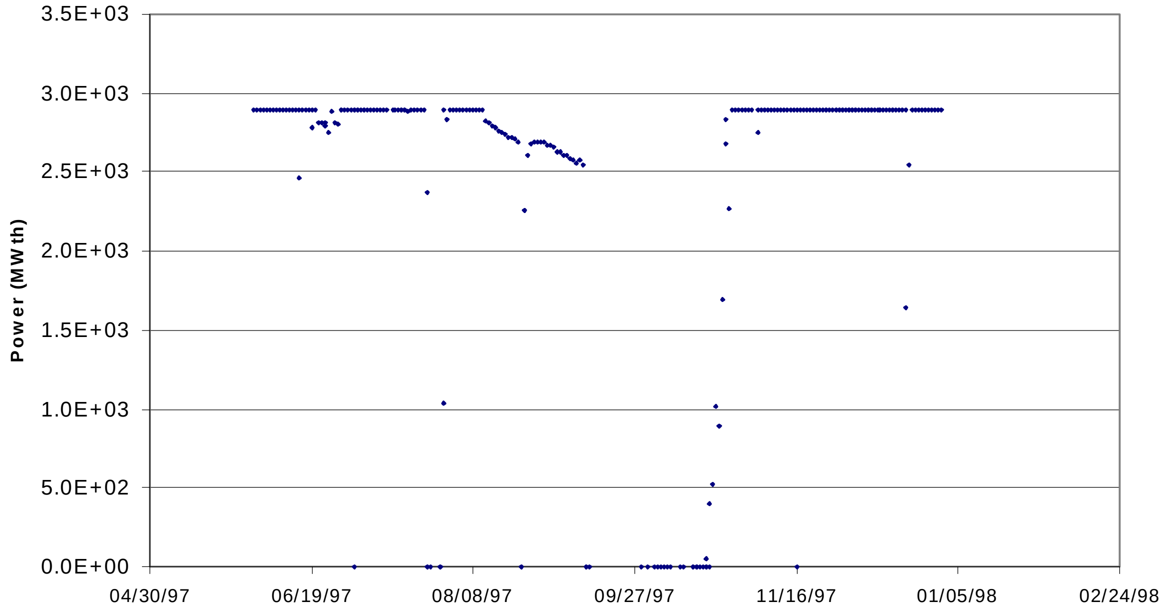

Figure 33-1
Power History, River Bend

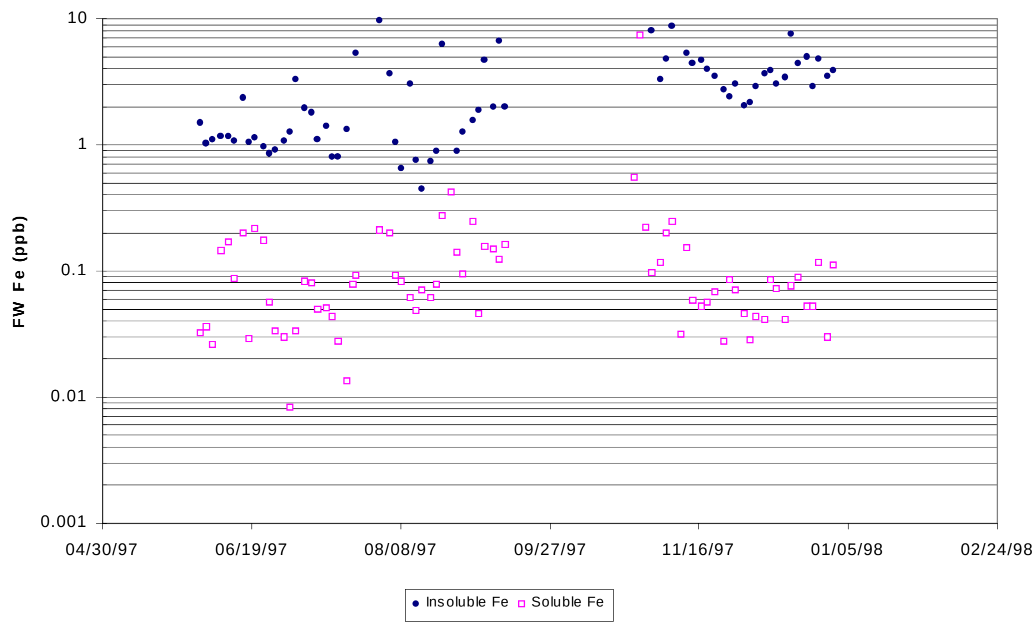

Figure 33-2
Feedwater Iron, River Bend

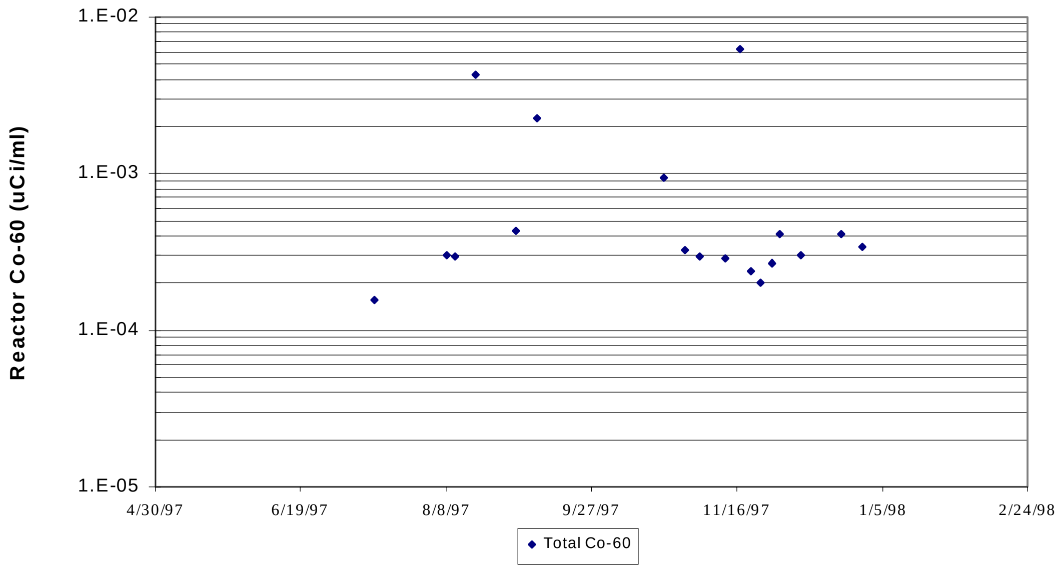

Figure 33-3
Reactor Water Cobalt 60, River Bend

Feedwater Iron Control

Feedwater insoluble and soluble iron concentrations averaged 3.67 ppb and 0.2 ppb, respectively, in 1997. The data show that reactor water sulfate and nitrate concentrations were high for the three month period of June, July and August, 1997, with sulfate averaging 6.3 ppb and nitrate averaging 5.8 ppb. During a non-refueling shutdown in April, 1998, it was found that two of the three ultrasonic transducer banks on the URC system were not operating, which could be a reason for the increased feedwater iron starting in the latter part of 1997. River Bend also removed a bed of low crosslinked resins from service during 1997.

Recirculation Piping Dose Rates

In June, 1997 River Bend initiated DZO. Reactor water zinc concentrations ranged from 3 ppb the first month of zinc injection to 9 ppb by the third month. . The average reactor water soluble zinc concentration in 1997 was 6.1 ppb. Dose rates at River Bend have trended high, reaching 300 mR/hr in 1992 when the recirculating pipe was chemically decontaminated.. The dose rates increased to 300 mR/hr in 1996. With the start of depleted zinc injection, dose rates are expected to stabilize and then decrease.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997	258 person-Rem
1996	327 person-Rem
1995	258 person-Rem
1994	468 person-Rem
1993	339 person-Rem
1992	430 person-Rem

34

SUSQUEHANNA UNIT 1

Table 34-1
Susquehanna Unit 1 Plant Design Parameters

Parameter	Value
Commercial Operation Date	6/83
Capacity (MWe)	1131
BWR Type	4 Mark II
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1

Susquehanna Unit 1 Milestones

Milestone events for Susquehanna Unit 1 are given in Table 34-2.

Table 34-2
Susquehanna Unit 1 Milestones

Susquehanna Unit 1										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins						2/93	→	4/95		
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 34-3.

Table 34-3
Susquehanna Unit 1 Recirculation System Dose Rates

Susquehanna Unit 1 – Recirculation System Dose Rates (mR/hr)									
Outage	1R1O	2R1O	3R1O	4R1O	5R1O	6R1O	7R1O	8R1O	9R1O
Date					1990	1992	1993	1995	1996
EFPY	1.36	2.06	3.21	4.37	5.53	6.73	7.82	8.97	10.14
BRAC	153	145	130	175	143	135	140	112	140
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers	217	203	160	300	135	135	107	120	130

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots are presented in Figures 34-1, 34-2 and 34-3, respectively.

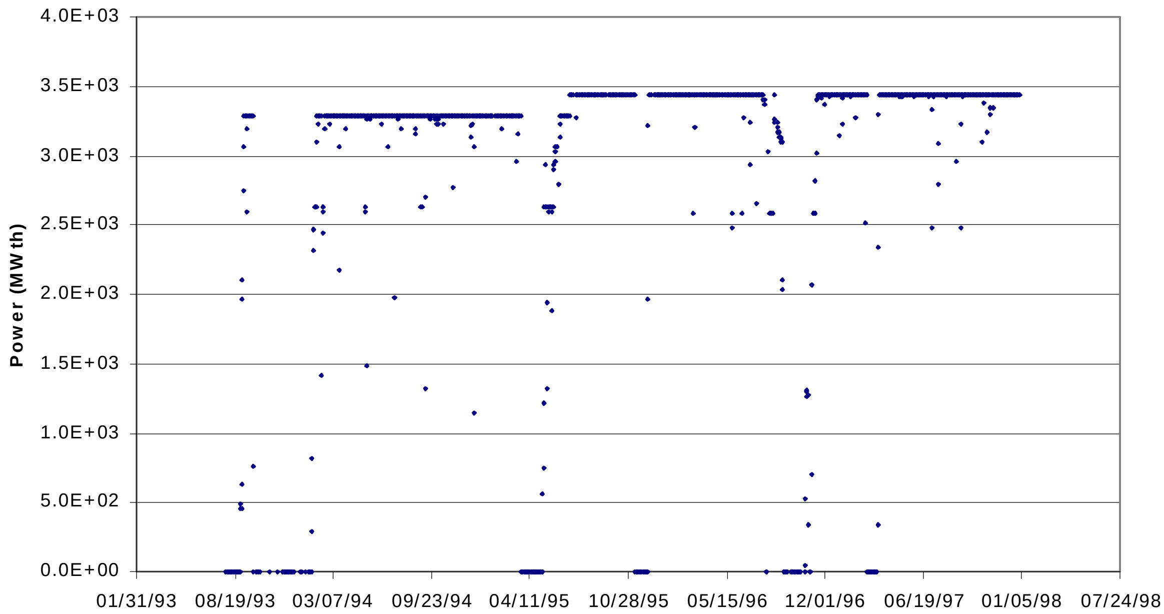

Figure 34-1
Power History, Susquehanna Unit 1

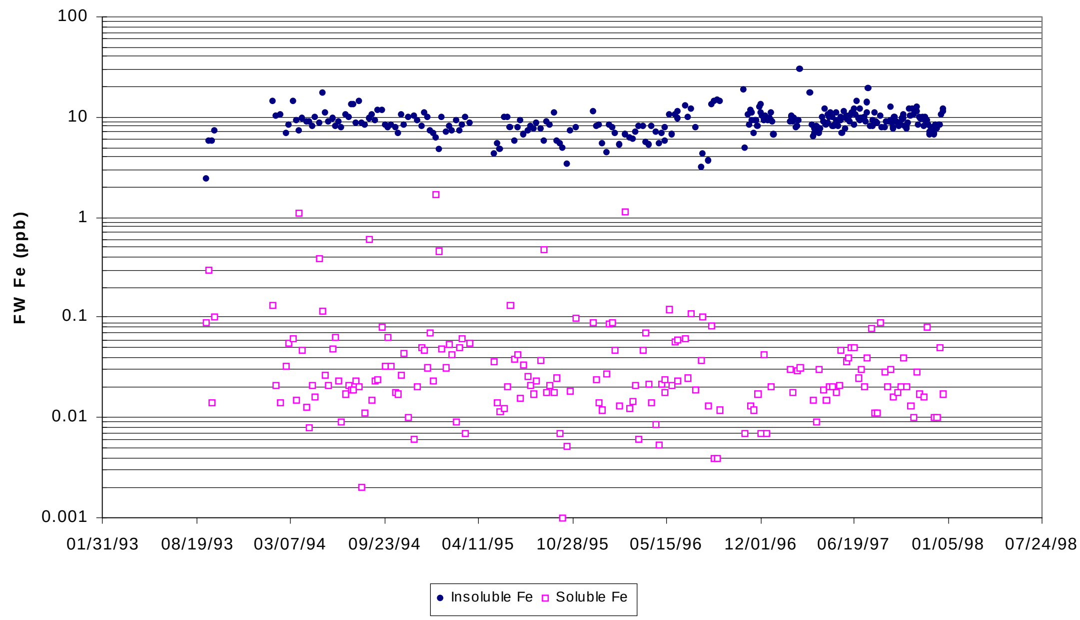

Figure 34-2
Feedwater Iron, Susquehanna Unit 1

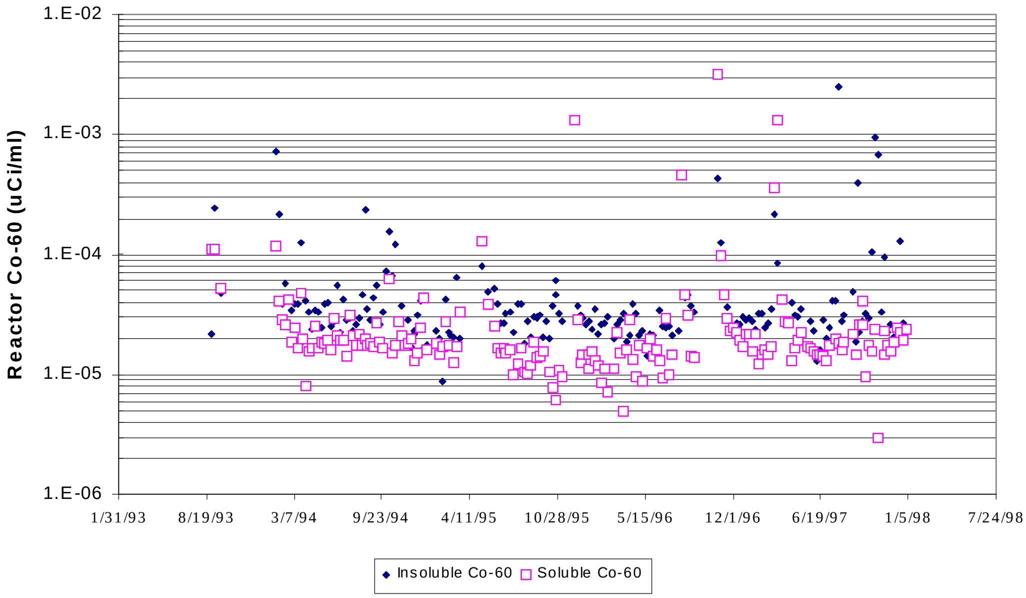

Figure 34-3
Reactor Water Cobalt 60, Susquehanna Unit 1

Feedwater Iron Control

Feedwater iron concentrations at Susquehanna 1 have been historically high compared to other U.S. BWR's. The plant is in the process of installing full flow condensate pre-filters upstream of the deep bed demineralizers to lower feedwater iron. The 1997 the average feedwater insoluble and soluble iron concentrations were 9.61 ppb and 0.028 ppb, respectively.

Recirculating Pipe Dose Rates

Recirculation piping dose rates for Susquehanna 1 have been relatively stable, ranging from 112 mR/hr to 175 mR/hr. The dose rates reached a minimum in 1995 at 112 mR/hr, which is during the use of low crosslinked resins for enhanced crud removal, and during the time the feedwater iron concentrations were also reduced. The 1997 average reactor water soluble Co-60 activity was 5.30E-5 uCi/ml, which is among the lower values achieved in the industry.

Piping Gamma Scan Data

Gamma scan data for the recirculation piping are summarized in Table 34-4.

Table 34-4
Susquehanna Unit 1 Recirculation Piping Gamma Scan Results

Date	**1R1O**	**2R1O**	**3R1O**	**4R1O**
Total Activity (uCi/cm^2)	13.8	12.1	12.3	10.4
% Co-60	39	45	48	49
% Co-58	23	15	8	3
% Mn-54	29	28	27	30
% Zn-65			11	13

Date	**1990**	**1992**	**1993**	**1995**	**1996**
Total Activity (uCi/cm^2)	10.8	12.5	11	16.2	10
% Co-60	46	39	50	44	32
% Co-58	4	2		4	3
% Mn-54	31	35	36	40	51
% Zn-65	14	14	11	5	6
% Fe-59		9	3	7	8

The gamma scan data indicate that in 1995, when the BRAC dose rates reached a minimum of 112 mR/hr, the piping gamma scan total activity and Co-60 activity peaked at 16.2 uCi/cm^2 and 7.1 uCi/cm^2, respectively. The reason for this apparent discrepancy has not been requested from station personnel.

Stellite Reduction

Susquehanna 1 has reduced the stellite surface area by 15 % since 1990. The initial stellite surface area was 52 ft^2 and it was reduced to 44 ft^2.

Susquehanna Non-Precoat Pleated Filter Septa Performance

The initial use of Unit 1 CFs with Memtec pleated filter septa has been pushed forward from late 1997 to the first quarter of 1998. Initial use of Unit 2 CFs remains tentatively scheduled for late 1998.

35

SUSQUEHANNA UNIT 2

Table 35-1
Susquehanna Unit 2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	2/85
Capacity (MWe)	1131
BWR Type	4 Mark II
Drains Path	Cascaded
Condensate Polishing	Deep Beds
RWCU Capacity (% Feedwater Flow)	1

Susquehanna Unit 2 Milestones

Milestone events for Susquehanna Unit 2 are given in Table 35-2. In the sixth refueling outage, modifications for a 5% power uprate were installed. Replacement of the extraction steam piping from carbon steel to Cr-Mo was started in 1993, and by 1994 40% of the surface area had been upgraded. The project encompassed upgrades to the turbine shell to feedwater heater shell, and the No. 2, No. 3 and No. 4 extraction piping. Low crosslinked resins for enhanced crud removal were in use from 2/93 – 6/96.

Table 35-2
Susquehanna Unit 2 Milestones

Susquehanna Unit 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate							6/94			
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement						Start	→ (40%)	→	→	End
Chem. Decon.										
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins						2/93	→	→	6/96	
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 35-3.

Table 35-3
Susquehanna Unit 2 Recirculation System Dose Rates

Susquehanna Unit 2 – Recirculation System Dose Rates (mR/hr)									
	Jul-86	Jan-88	Jul-89	Feb-91	Jun-92	Jan-94	Sep-95	1997	
EFPY	1.41	2.66	3.79	4.96	6.21	7.41	8.63	9.79	
BRAC	124	111	180	195	120	140	140	133	
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers	188	300	320	375	155	190	190	163	

Trend Data

Power, feedwater iron and cobalt 60 trend plots of Susquehanna 2 are presented in Figures 35-1, 35-2 and 35-3, respectively.

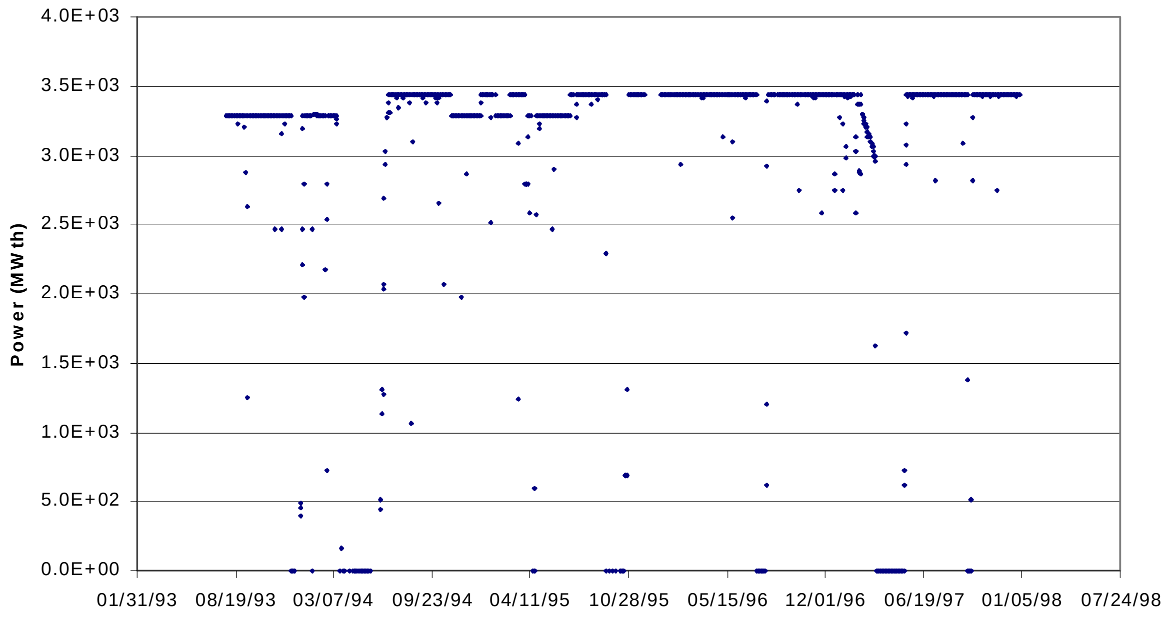

Figure 35-1
Power History, Susquehanna Unit 2

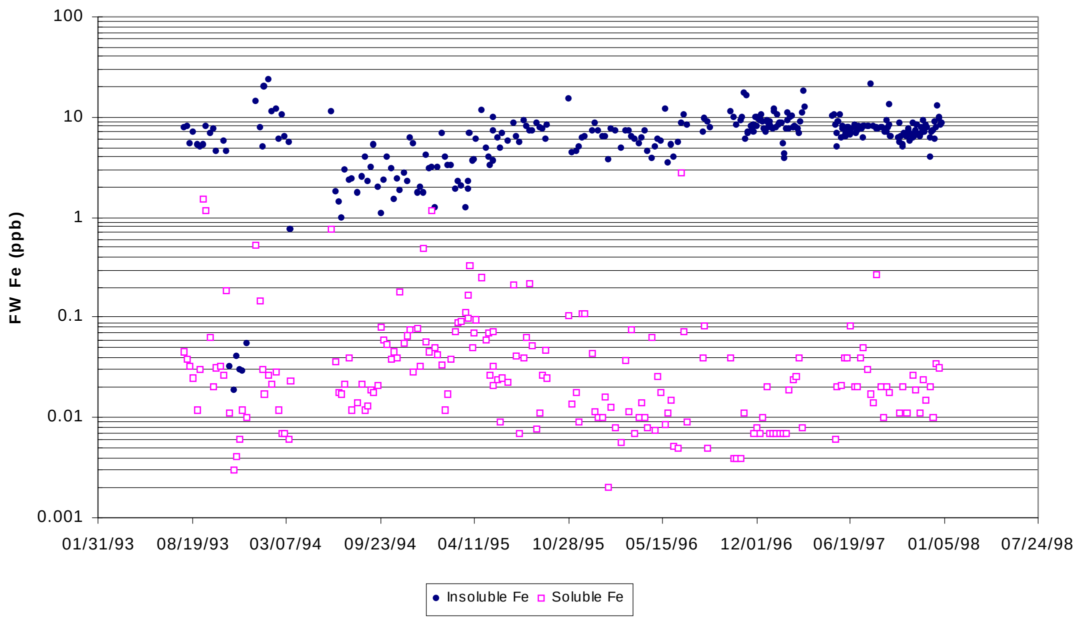

Figure 35-2
Feedwater Iron, Susquehanna Unit 2

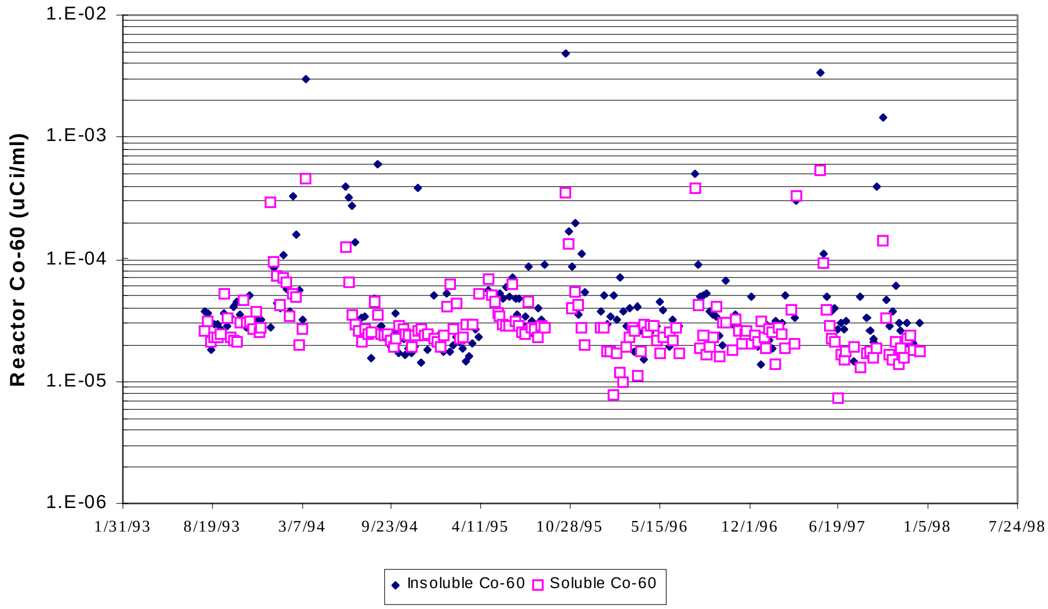

Figure 35-3
Reactor Water Cobalt 60, Susquehanna Unit 2

Feedwater Iron Control

Feedwater iron concentrations at Susquehanna 2 have been historically high among U.S. BWR's. The extraction steam piping has been replaced with Cr-Mo steel, crud resins have been used and the plant is in the process of installing full flow condensate filters upstream of their deep beds to lower feedwater iron. Steady state feedwater iron concentrations were approximately 5.5 ppb in 1993, 3 ppb in 1994, 6 ppb in 1995, 7.5 ppb in 1996, and 8 ppb in 1997. The lower feedwater iron averages corresponds roughly to the period of crud resin use between February, 1993 and June, 1996.

Recirculation Piping Dose Rates

Piping dose rates at Susquehanna 2 are relatively stable but slightly higher than at Unit 1. The dose rates range from 111 mR/hr to 195 mR/hr. The 195 mR/hr value was from 1991 and the dose rates have trended down since that time. In 1997, the average reactor water soluble Co-60 activity was 4.69E-5 uCi/ml, which is in the low range among U.S. BWR's.

Piping Gamma Scan Data

Recirculation piping gamma scan results are summarized in Table 35-4. The piping gamma scan results show a small variation in the total activity.

Table 35-4
Susquehanna Unit 2 Recirculation Piping Gamma Scan Results

Date	7/89	7/89	2/91	6/92	1/94	9/95	1997
Total Activity (uCi/cm^2)	12.1	13.9	13.6	7.9	8.6	12.5	11.4
% Co-60	34	38	48	49	48	47	38
% Co-58	23	9	7			3	4
% Mn-54	33	44	34	38	47	38	47

Stellite Reduction

The Susquehanna 2 stellite surface area has been reduced by 14 % since 1990. The initial stellite surface area of 52 ft^2 was reduced to 44.8 ft^2.

Radiation Exposure

Station radiation exposure three-year rolling averages for both units, Susquehanna 1 and Susquehanna 2, were reported as follows:

1997 390 person-Rem

1996 402 person-Rem

1995 417 person-Rem

1994 500 person-Rem

1993 522 person-Rem

1992 557 person-Rem

Susquehanna Non-Precoat Pleated Filter Septa Performance

Susquehanna Condensate Filter System experience is presented in the Unit 1 section.

36

VERMONT YANKEE

Table 36-1
Vermont Yankee Plant Design Parameters

Parameter	Value
Commercial Operation Date	11/72
Capacity (MWe)	550
BWR Type	4
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1%

Vermont Yankee Milestones

Milestone events for Vermont Yankee are given in Table 36-2. The recirculation piping was replaced in 1986; the original material was 316 Hatachi stainless steel.

Table 36-2
Vermont Yankee Milestones

Vermont Yankee										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement	1986									
RWCU Pipe Replacement	1986									
Extraction Steam Pipe Replacement										
Chem. Decon.	1985									
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO										
Iron Injection										
Crud Resins										
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 36-3.

Table 36-3
Vermont Yankee Recirculation System Dose Rates

Vermont Yankee – Recirculation System Dose Rates (mR/hr)									
	8/87	7/88	2/89	3/90	9/90	3/91	5/91	9/91	3/92
EFPY	10.5	11.2	11.7	12.6	13	13.5	13.7	13.9	14.4
BRAC	80	75	75	85	85	85	100	100	100
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Vermont Yankee – Recirculation System Dose Rates (mR/hr)									
	4/12/93	8/28/93	3/17/95	10/21/96					
EFPY	15.3	15.6	16.8	18.2					
BRAC	95	100	80	65					
A Suction			55						
B Suction			55						
A Discharge			55						
B Discharge			50						
Avg Risers									

Trend Data

Power, feedwater iron and reactor water cobalt 60 trend plots are presented in Figures 36-1, 36-2 and 36-3, respectively.

Feedwater Iron Control

In 1997, Vermont Yankee feedwater iron concentrations ranged between 0.5 to 2.0 ppb. The 1997 insoluble and soluble feedwater iron averages for the data reported were 1.58 ppb and 0.035 ppb, respectively. The plant has not applied pleated septa. A station representative noted that the feedwater iron trend shown in Figure 36-2 shows typical seasonal variations, with feedwater iron typically in the 0.6 – 0.8 ppb range during the winter and increasing to the 1-2 ppb range in summer.

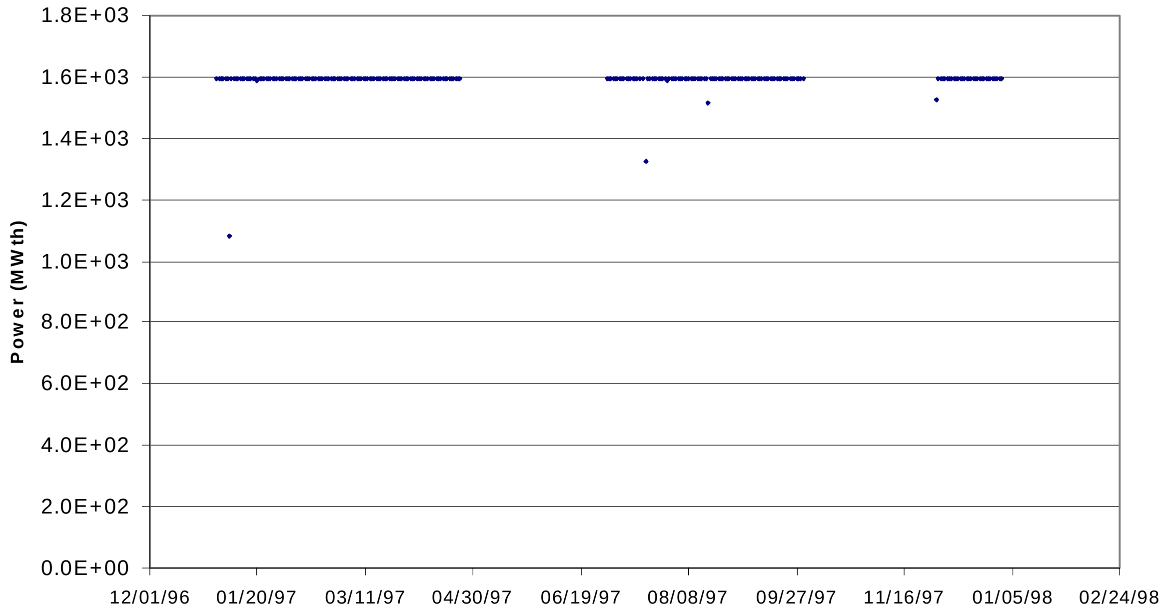

Figure 36-1
Power History, Vermont Yankee

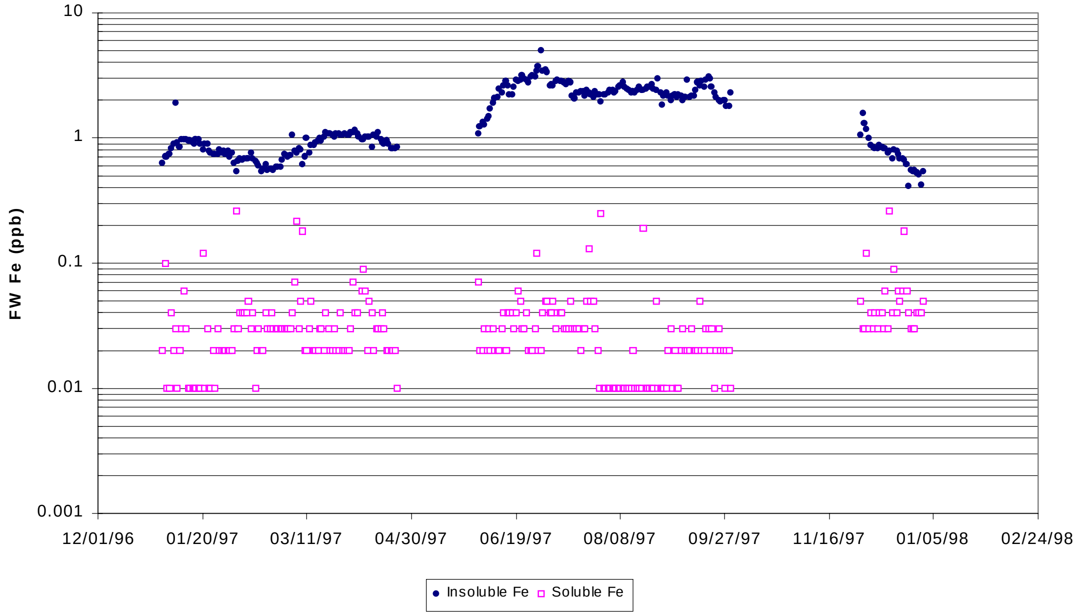

Figure 36-2
Feedwater Iron, Vermont Yankee

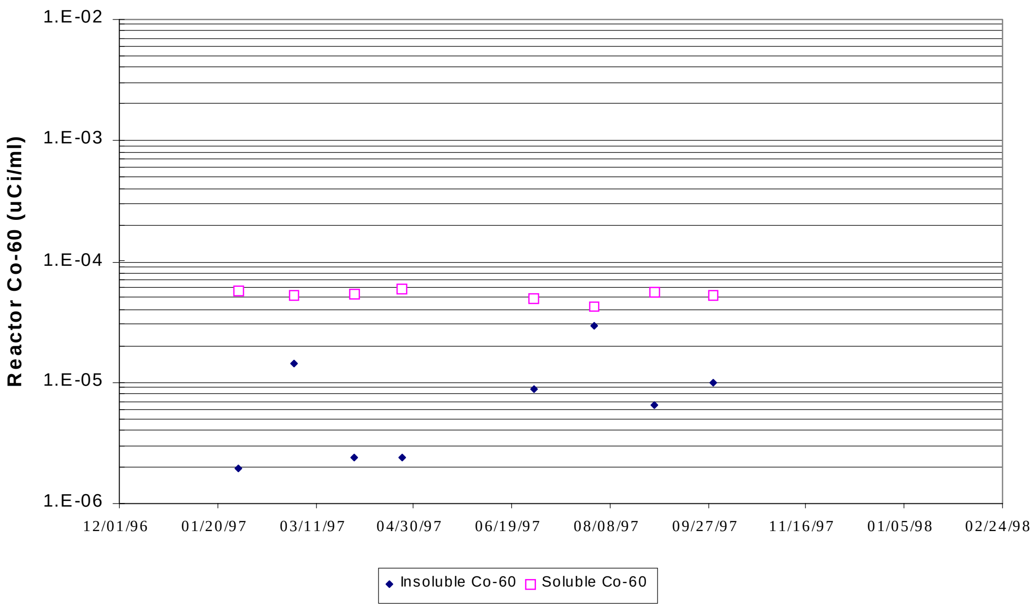

Figure 36-3
Reactor Water Cobalt 60, Vermont Yankee

Recirculating Pipe Dose Rates

Reactor water soluble Co-60 activity is low at Vermont Yankee, with an average of 5.3 E-5 uCi/ml. The plant has had consistently low BRAC dose rates since replacing their recirculation piping in 1985. This is shown in Figure 36-4. The BRAC dose rates have been 100 mR/hr or less since 1986. Vermont Yankee has a natural zinc source in the admiralty brass condenser tubes, which contribute between 0.15 to 0.30 ppb zinc to the feedwater.

It is important to note that Vermont Yankee was not always a low dose rate plant although the zinc source from the condenser has been present since the initial plant startup. Prior to replacing their recirculation piping, the contact dose rates approached 1200 mR/hr, suggesting that the pipe replacement material, cobalt source reduction through stellite removal, or a combination of these actions may account for the low dose rates. The replacement recirculation pipe is Hitachi 316L stainless steel and is electropolished. A plant representative suggested that the combination of piping replacement and choice of material (electropolished stainless steel), the cobalt materials replacement program, zinc from the condenser and the fact that the plant has been successful in avoiding preventable transients (scrams) all contribute to maintaining low dose rates.

The plant has also replaced the LP turbine, which was reported to have resulted in a 25 % decrease in the feedwater iron. At the same time, zinc and copper in the CDI stream also decreased and changed from insoluble (filterable) species to soluble species. In depth chemistry data from previous cycles were not available for review.

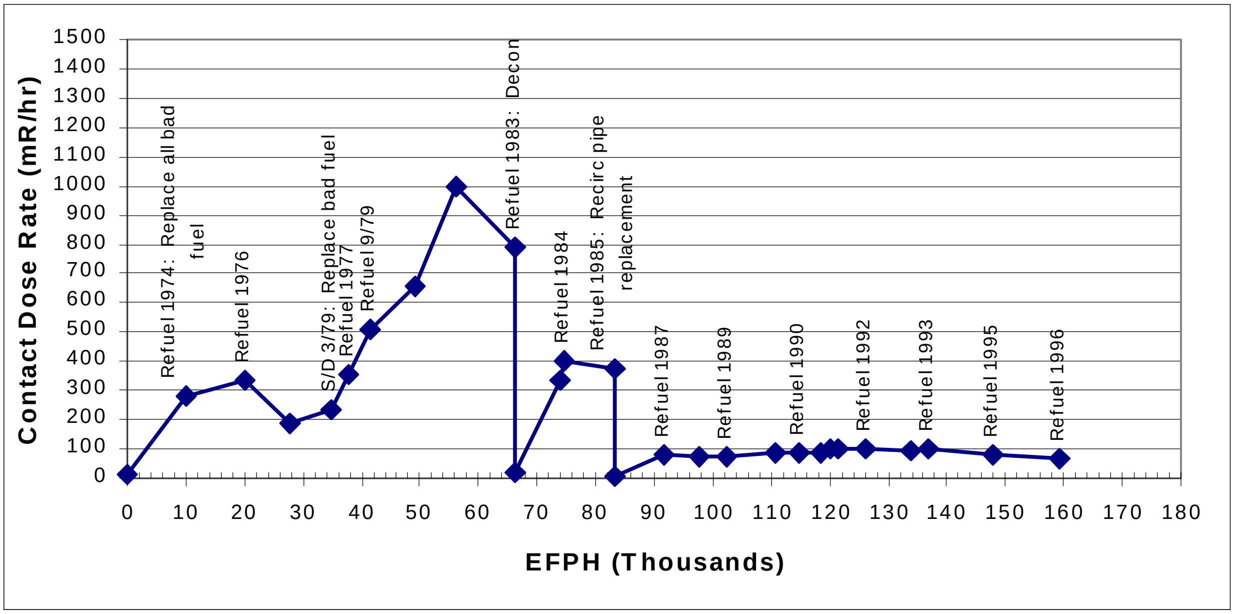

Figure 36-4
BRAC History, Vermont Yankee

Pipe Gamma Scan Data

One set of pipe gamma scan data from 1993 was provided. Total activity was approximately 4 uCi/cm^2 with about 60% attributable to Co-60. The fraction of Zn-65 in the recirculation pipe deposit is low at approximately 5% of the total curies reported.

Stellite Reduction

Vermont Yankee has replaced the stellite in the control rod pins and rollers and in the feedwater regulating valves. The feedwater regulating valves were changed prior to replacing the recirculation piping, thus eliminating a major source of cobalt.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997 157 person-Rem

1996 150 person-Rem

1995 141 person-Rem

37

WNP-2

Table 37-1
WNP-2 Plant Design Parameters

Parameter	Value
Commercial Operation Date	12/84
Capacity (MWe)	1180
BWR Type	5/6
Drains Path	Cascaded
Condensate Polishing	F/D
RWCU Capacity (% Feedwater Flow)	1

WNP-2 Milestones

Milestone events for WNP 2 are given in Table 37-2. The recirculation pipe chemical decontamination performed in 1992 removed 44.5 curies using a LOMI-AP-LOMI process. Iron injection was initiated in 1996 using iron oxalate.

Table 37-2
WNP-2 Milestones

WNP 2										
Milestone	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Power Uprate										
Retube Condenser										
Recirc. Pipe Replacement										
RWCU Pipe Replacement										
Extraction Steam Pipe Replacement										
Chem. Decon.					4/92					
HWC (scfm)										
Noble Metals Coating										
NZO										
DZO									9/96	→
Iron Injection									7/96	→
Crud Resins										
Pleated Filters										

Radiation Data

Recirculation System dose rates are summarized in Table 37-3.

Table 37-3
WNP-2 Recirculation System Dose Rates

WNP-2 – Recirculation System Dose Rates (mR/hr)									
	Apr-94	Apr-95	Apr-96	Apr-97					
EFPY									
BRAC	760	580	600	420					
A Suction									
B Suction									
A Discharge									
B Discharge									
Avg Risers									

Trend Data

Power and feedwater iron trend plots are presented for WNP-2 in Figures 37-1 and 37-2, respectively. Cobalt 60 data were not provided.

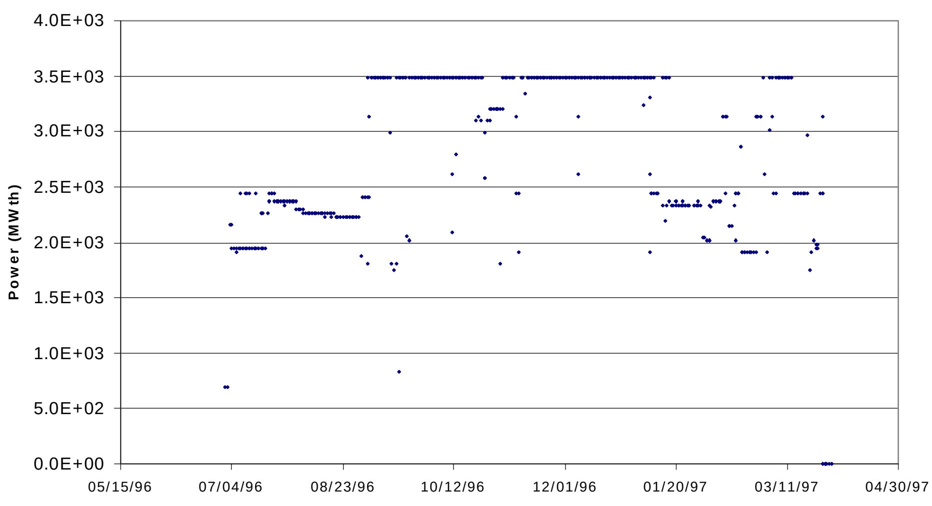

Figure 37-1
Power History, WNP-2

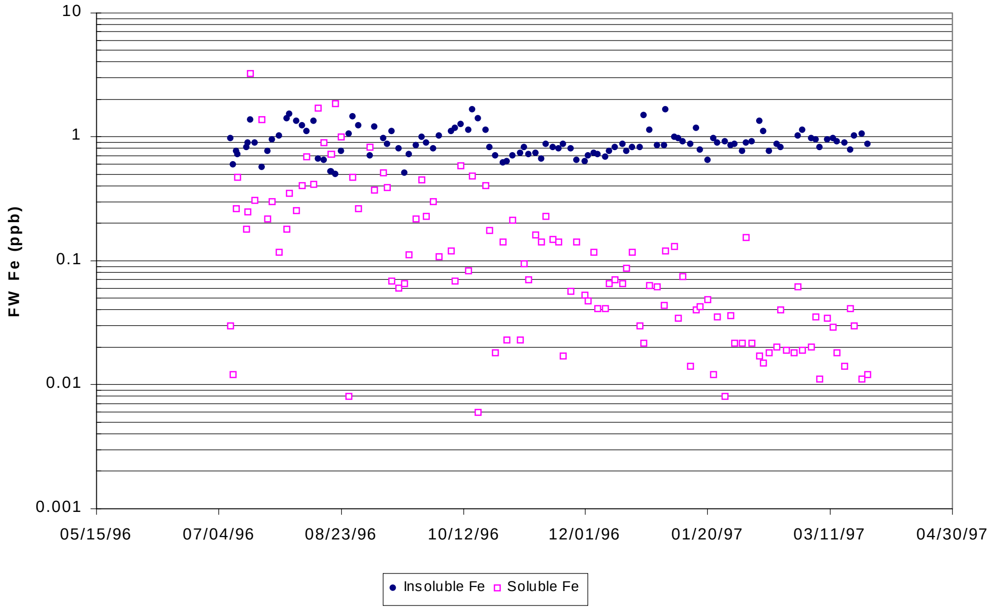

Figure 37-2
Feedwater Iron, WNP-2

Feedwater Iron Control

WNP-2 has initiated injection of iron into the feedwater to maintain iron concentrations at or above 0.5 ppb to control the transport of activated corrosion products. The iron is fed as iron oxalate, which has caused an increase in feedwater conductivity. The average feedwater conductivity for the cycle stating in June, 1996 when iron injection began, was 0.067 uS/cm. The average insoluble and soluble iron in the feedwater for reported 1997 data was 0.96 ppb and 0.036 ppb, respectively. The soluble feedwater iron showed a decreasing trend over the cycle, from about 0.3 ppb to <0.02 ppb.

Recirculation Piping Dose Rates

Recirculation piping dose rates were reduced in 1992 by a LOMI-AP-LOMI chemical decontamination of the discharge piping. Pipe dose rates, however, continue to be in the high range at approximately 400 mR/hr. Injection of DZO was started in September, 1996 after the start of iron injection. Reactor water isotopic data were not reported.

Pipe Gamma Scan Data

The gamma scan results indicate a decreasing concentration of Co-60 in the recirculation piping corrosion film. The average Co-60 concentration in 1995 and 1996 was 17 uCi/cm^2 while the average concentration in 1997 was 14 uCi/cm^2. Additional data were not available to determine if the total activity in the corrosion film also decreased.

Radiation Exposure

Station radiation exposure three-year rolling averages are as follows:

1997 405 person-Rem

1996 564 person-Rem

1995 597 person-Rem

1994 649 person-Rem

1993 489 person-Rem

1992 511 person-Rem

1991 471 person-Rem

38

OVERVIEW OF RECENT INDUSTRY DATA ON IRON AND DOSE CONTROL

Iron Data Summary

A plot of 1997 average feedwater iron for plants from which 1997 data have been provided is given in Figure 38-1. In addition, the averages along with other pertinent information such as the soluble and insoluble fractions, condensate polishing type and drains path, are given in Table 38-1.

As shown, 9 plants are within the current feedwater iron target range of 0.5 – 1.5 ppb, and all of these plants have either “filter + deep bed” or “filter demineralizer” condensate polishing. Data reported by two “deep bed” plants, Grand Gulf and FitzPatrick, indicate average total feedwater iron close to but slightly exceeding 1.5 ppb. Three plants have feedwater iron below the 0.5 ppb target minimum, including Brunswick 1, Brunswick 2 and Fermi 2.

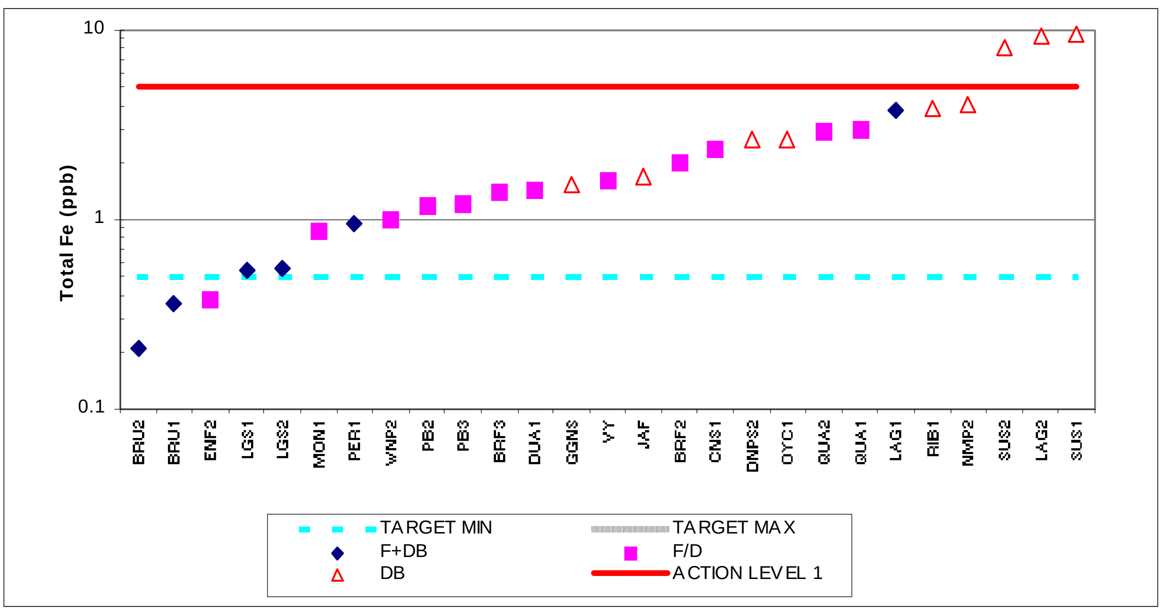

Figure 38-1
1997 Average Total Feedwater Iron For BWR's

Fifteen (15) plants, or about 55.5% of those providing 1997 feedwater iron data, have total iron averages above the 1.5 ppb target maximum. The majority of these plants (9) have only deep beds for condensate polishing.

The 1997 average for Laguna Verde 1 includes operations with deep beds alone until about mid-March, a period through the end of June when pre-filters were being phased in, and about 6 months with full "filter + deep bed" operation. While feedwater total iron averaged about 3.75 ppb for the year, the average was about 1.7 ppb with full filter + deep bed operation. The reason for Laguna Verde 1 exceeding 1.5 ppb is the significant contribution from the forward pumped drains (>5 ppb).

Filter demineralizer plants exceeding 1.5 ppb feedwater iron include Vermont Yankee, Browns Ferry 2, Cooper Nuclear, Quad Cities 1 and Quad Cities 2. These plants can potentially reduce iron to the current target range through partial use of precoatable pleated filters, and several of these plants have begun initial use of pleated filters.

Table 38-1
1997 Average Feedwater Iron Results

Plant Name	**Feedwater Iron (ppb)**			**Condensate Polishing (1)**	**Drains Path**
	Insoluble	**Soluble**	**Total**		
Brunswick 2	0.076	0.135	0.211	F+DB	Forward
Brunswick 1	0.223	0.136	0.359	F+DB	Forward
Fermi 2	0.313	0.065	0.377	F/D	Forward
Limerick 1	0.530	0.005	0.535	F+DB (2)	Cascaded
Limerick 2	0.546	0.005	0.550	F+DB (2)	Cascaded
Monticello	0.831	0.038	0.869	F/D	Cascaded
Perry	0.922	0.034	0.956	F+DB	Forward
WNP-2	0.955	0.036	0.991	F/D (2)	Cascaded
Peach Bottom 2	1.137	0.057	1.194	F/D	Cascaded
Peach Bottom 3	1.161	0.038	1.199	F/D	Cascaded
Browns Ferry 3	1.316	0.094	1.410	F/D	Cascaded
Duane Arnold	1.399	0.041	1.440	F/D	Cascaded
Grand Gulf	1.523	0.005	1.528	DB	Forward
Vermont Yankee	1.576	0.035	1.611	F/D	Cascaded
FitzPatrick	1.665	0.013	1.678	DB	Cascaded
Browns Ferry 2	1.962	0.007	1.969	F/D	Cascaded
Cooper Nuclear	2.360	0.011	2.370	F/D	Cascaded
Dresden 2	2.515	0.017	2.621	DB	Cascaded
Oyster Creek	2.643	0.032	2.675	DB	Cascaded
Quad Cities 2	2.861	0.042	2.903	F/D	Cascaded
Quad Cities 1	2.914	0.041	2.954	F/D	Cascaded
Laguna Verde 1	3.734	0.014	3.749	F+DB	Forward
River Bend	3.668	0.205	3.872	DB	Forward
Nine Mile Point 2	3.962	0.053	4.015	DB	Forward
Susquehanna 2	8.091	0.028	8.119	DB	Cascaded
Laguna Verde 2	9.330	0.012	9.342	DB	Forward
Susquehanna 1	9.611	0.028	9.639	DB	Cascaded

(1) Condensate Polishing Type DB = Deep Bed, F+DB = Filter + Deep Bed, F/D = Filter Demineralizer

(2) Plant is injecting iron into the feedwater

There are also three plants reporting 1997 feedwater iron data with averages exceeding the EPRI feedwater iron Action Level 1 limit of 5 ppb. These are Susquehanna 1, Susquehanna 2 and Laguna Verde 2. All three plants were originally designed with "deep bed only" condensate polishing and are in the process of installing condensate pre-filters.

It is noted that, from Table 38-1, the three lowest feedwater iron plants also have the highest percentages of soluble iron in the feedwater. Soluble iron as a percentage of total feedwater iron ranges for 64.0% for Brunswick 2, 37.9% for Brunswick 1 and 17.2% for Fermi 2. These three plants all have forward pumped drains. Also, only plants with forward pumped drains had soluble feedwater iron average values exceeding 0.1 ppb.

The CDI (Condensate Demineralizer Inlet) iron concentration is an important parameter to consider in assessing the challenge to a given plant's condensate purification process for effectively and efficiently controlling effluent iron. A plot of 1997 the average CDI total iron concentrations for 20 plants from which these data were received is shown in Figure 38-2. These results are also given in Table 38-2, along with the insoluble and soluble iron fractions (where available).

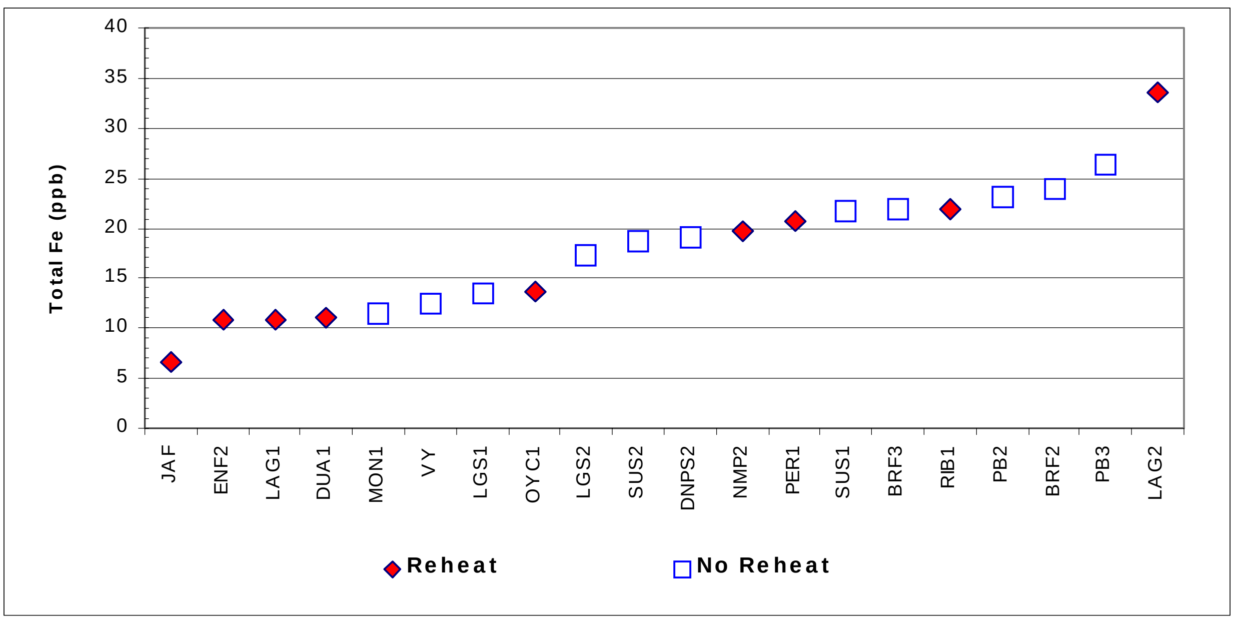

Figure 38-2
1997 Average CDI Total Iron Concentration

FitzPatrick had the lowest CDI iron (6.53 ppb), while Laguna Verde 2 had the highest (33.49 ppb). Some differences in CDI iron between units at the same site are of interest to note. The greatest disparity is between Laguna Verde 1 (10.91 ppb) and Laguna

Verde 2 (33.49 ppb). Another example, although less accentuated than Laguna Verde, is that Susquehanna 2 had lower average CDI iron than Susquehanna 1; although CDI iron fluctuates significantly, perhaps the replacement of carbon steel extraction steam piping with stainless steel is beginning to have a measurable benefit in terms of crud source term reduction at Susquehanna.

The magnitude of the CDI iron concentration is also an indictor of the type of action that must be taken by a specific plant to provide sufficient removal of iron from condensate. FitzPatrick, having low CDI iron, can control feedwater iron within or near the current target range using only deep beds and standard resins. Oyster Creek, with about 14 ppb CDI iron, has reached the target range with standard resins, but only after a resin aging period of about 6 months. Dresden, and now Nine Mile 2 with the MSR problem, have CDI iron concentrations in the 20 ppb range and find deep beds with standard resins alone are not sufficient for iron control. Consequently, Dresden has continued the use of some low crosslinked resins and Nine Mile 2 has installed one bed with low crosslinked resins (an EPRI Tailored Collaboration Project). Susquehanna has not been successful in controlling feedwater iron in the target range with deep beds and standard resins, and is in the process of installing pre-filters.

Table 38-2
1997 Average Condensate Inlet Iron

Plant Name	CDI Iron (ppb)			Reheat (Yes/No)	Drains Path
	Insoluble	Soluble	Total		
FitzPatrick	6.526	0.054	6.581	Yes	Cascaded
Fermi 2	8.393	2.386	10.779	Yes	Forward
Laguna Verde 1	10.828	0.086	10.914	Yes	Forward
Duane Arnold			11.044	Yes	Cascaded
Monticello	10.329	1.077	11.406	No	Cascaded
Vermont Yankee	12.318	0.174	12.492	No	Cascaded
Limerick 1	13.118	0.394	13.512	No	Cascaded
Oyster Creek	13.409	0.257	13.666	Yes	Cascaded
Limerick 2	16.884	0.370	17.254	No	Cascaded
Susquehanna 2	18.567	0.104	18.670	No	Cascaded
Dresden 2			19.156	No	Cascaded
Nine Mile Point 2	18.976	0.679	19.655	Yes(1)	Forward
Perry			20.800	Yes	Forward
Susquehanna 1	21.755	0.054	21.808	No	Cascaded
Browns Ferry 3			21.814	No	Cascaded
River Bend	21.238	0.764	22.002	Yes	Forward
Peach Bottom 2	20.489	2.600	23.088	No	Cascaded
Browns Ferry 2			23.848	No	Cascaded
Peach Bottom 3	24.370	1.999	26.369	No	Cascaded
Laguna Verde 2	33.490	0.034	33.524	Yes	Forward

(1) Nine Mile 2 reheat not available due to damage to MSR in June, 1997.

Dose Data Summary

Dose rate data for BRAC points are being collected as part of the iron control monitoring effort. The monitoring of BRAC point dose rates was begun with an EPRI-sponsored GE survey in the 1970's. The term BRAC stands for "BWR Radiation Level Assessment and Control" (9). To generate the BRAC data, each BWR performs radiation surveys at similar points. Initially, various locations were surveyed, including recirculation piping, steam lines, reactor water cleanup system and heat exchangers. The points which plants typically report as their BRAC value is the average of the contact dose rates on suction and discharge piping of the reactor recirculation pumps. The measurements are made on vertical sections of the piping to be representative of the adsorbed radioactive corrosion products in the fixed film on the piping.

BRAC average data are provided in Figure 38-3, ranked in order of lowest to highest. These are the latest survey data obtained from each plant. The BRAC dose rates are also given in Table 38-3 along with the survey date, the date of the last recirculation piping chemical decontamination, and whether hydrogen is being injected or a form of zinc added. The BRAC data vary over a wide range, by a factor of about 8.5, from a low of 65 mR/hr to 550 mR/hr.

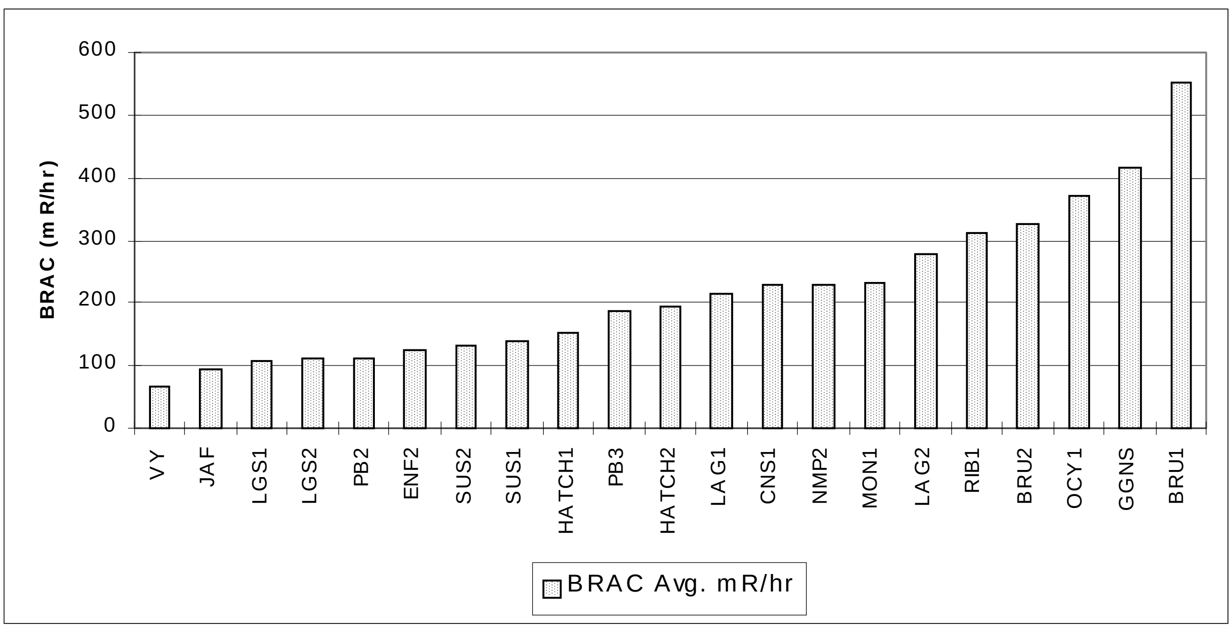

Figure 38-3
Industry BRAC Data (Most Recent Reported)

The BRAC data do not appear to correlate directly with feedwater iron, as shown in Figure 38-4, based on the 1997 average feedwater total iron concentrations. There are low iron plants with both high BRAC and low BRAC, and high iron plants with both relatively low BRAC (<150 mR/hr) and with high BRAC dose rates.

Table 38-3
Industry BRAC Data (Most Recent Reported)

Plant	BRAC (mR/hr)	BRAC Survey Date	Last Chem Decon Date	HWC	Zinc Addition
Vermont Yankee	65	Oct-96	1985	No	Natural[1]
FitzPatrick	92	Oct-96	Feb-94	Yes	DZO
Limerick 1	109	Feb-96	None	No	DZO
Limerick 2	110	Jan-97	None	No	DZO
Peach Bottom 2	111	Sep-96	None	Yes	DZO
Fermi 2	125	Oct-97	None	Yes	DZO
Susquehanna 2	133	May-97	None	No	None
Susquehanna 1	140	Oct-96	None	No	None
Hatch 1	153	Apr-96	Mar-96	Yes	DZO
Peach Bottom 3	188	Oct-95	None	Yes	DZO
Hatch 2	193	Mar-97	None	Yes	DZO
Laguna Verde 1	215	EOS 6	1994	No	None
Cooper	230	Mar-97	None	No	None
Nine Mile 2	230	Sep-96	None	No	NZO
Monticello	231	Apr-96	Feb-93	Yes	DZO
Laguna Verde 2	276	EOS 3	None	No	None
River Bend	312	1996	1992	No	None
Brunswick 2	325	Mar-96	Feb-96	Yes	DZO
Oyster Creek	370	Apr-97	Apr-91	Yes	None
Grand Gulf	417	Nov-96	Apr-95	No	None
Brunswick 1	550	Oct-96	Apr-95	Yes	DZO

(1) The source of feedwater zinc at Vermont Yankee is the main condenser tube material.

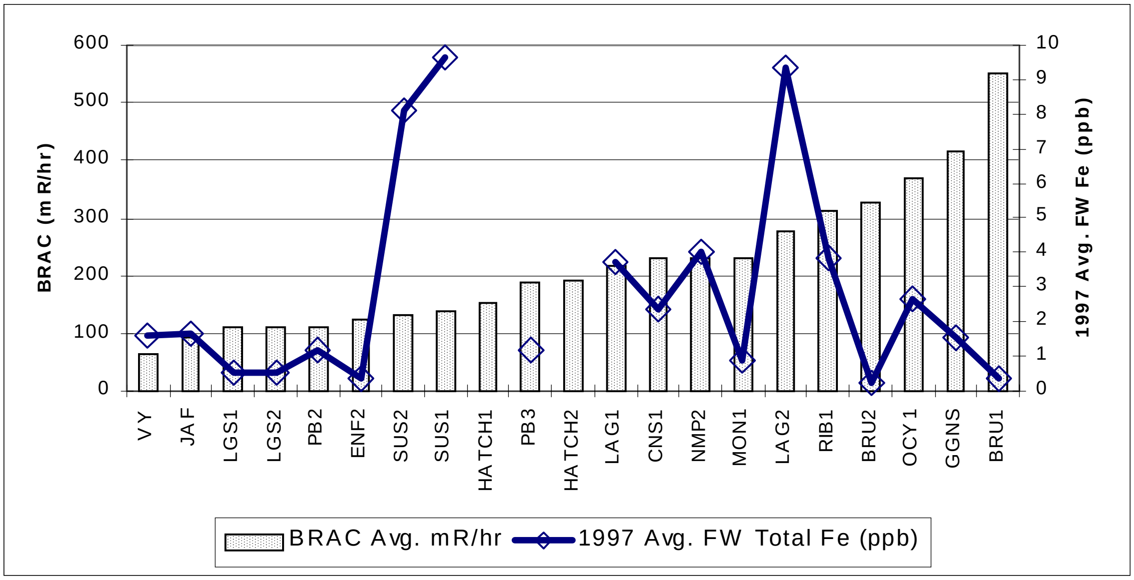

Figure 38-4
No Correlation: BRAC and Feedwater Iron

There does appear to be some correlation between BRAC and total Co-60, as can be seen in Figure 38-5 based on the 1997 average values. At least a general trend of increasing BRAC with increasing Co-60 is suggested by the data. The trend, however, is not smooth and there are a number of contrary data points.

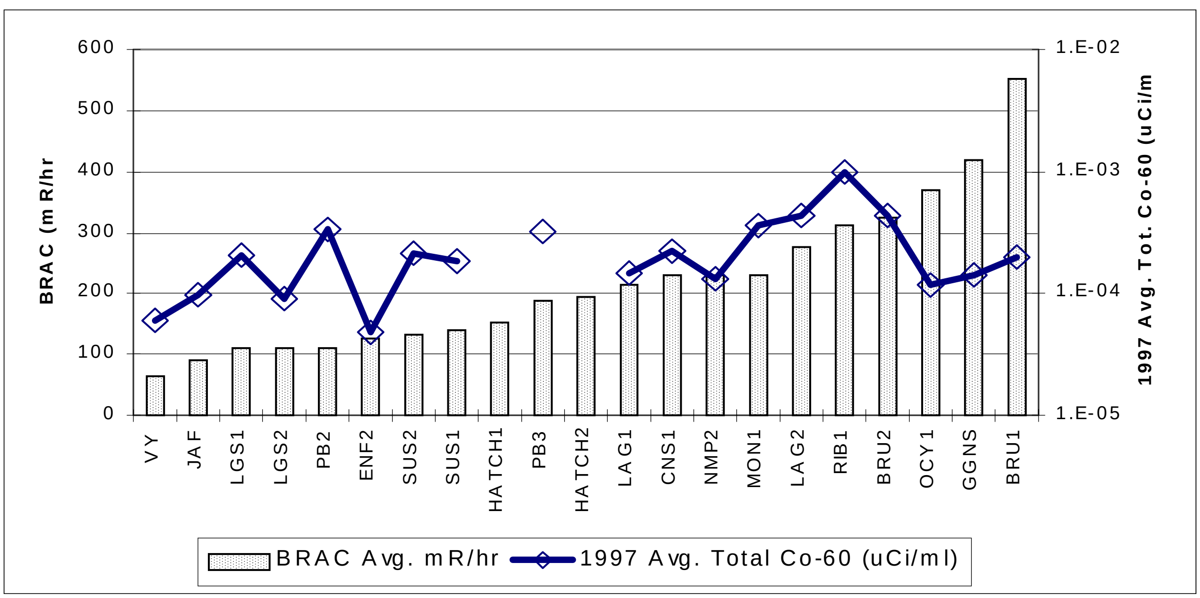

Figure 38-5
Weak Correlation: BRAC and Total Co-60

The clearest relationship is between BRAC and soluble Co-60. This is evident in the plot shown in Figure 38-6, where the deviations from the general trend of increasing BRAC with increasing Co-60 are smaller than the deviations with total Co-60. The correlation of BRAC with soluble Co-60 is expected because the BRAC surveys are taken on vertical piping sections where crud traps and consequent hot spots should be minimized and have negligible influence on the measurements.

A parametric plot of BRAC vs. soluble Co-60 is presented in Figure 38-7. The trend indicates that at reactor water soluble Co-60 concentrations up to about 7.5E-5 uCi/ml, there is a gradual increase in BRAC dose rates with increasing soluble Co-60. At soluble Co-60 concentrations above about 7.5E-5 uCi/ml, and certainly at concentrations above-4 uCi/ml, the BRAC dose rates increase exponentially as soluble Co-60 increases.

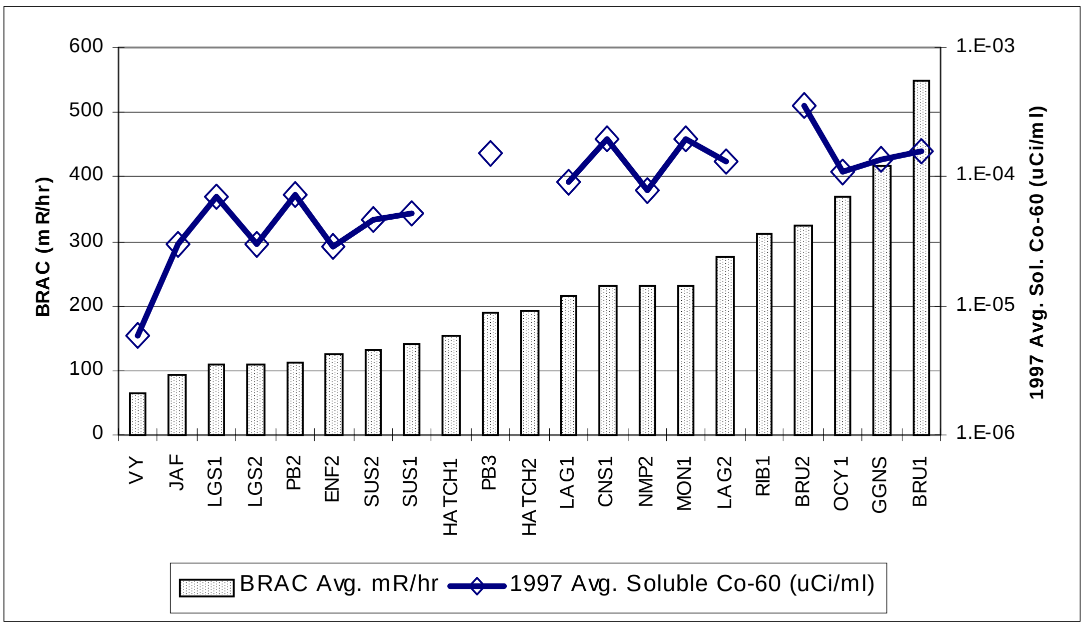

Figure 38-6
Strong Correlation: BRAC and Soluble Co-60

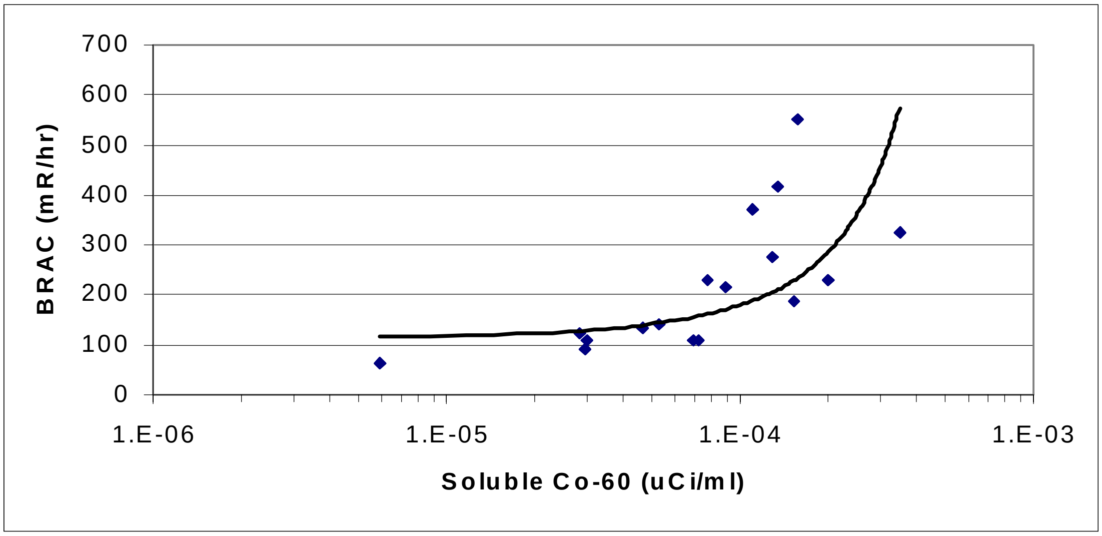

Figure 38-7
BRAC vs. Soluble Co-60

The data plotted in Figure 38-7 are plotted again in Figure 38-8, but with the zinc addition and hydrogen injection status of each plant indicated. These data suggest the following:

- At reactor water soluble Co-60 <7.5E-5 uCi/ml, BRAC dose rates are comparable for plants with no hydrogen or zinc, with zinc but no hydrogen, and with zinc and hydrogen. It is noted that the lowest BRAC value plotted is for Vermont Yankee, which is indicated as a zinc plant but the zinc source is the main condenser tubes.

- At soluble Co-60 >7.5E-5 uCi/ml for plants injecting hydrogen, BRAC dose rates at a given Co-60 concentration are lower when zinc is added than when no zinc is added. It is noted that this statement is based on the data of only one plant, Oyster Creek, with hydrogen but no zinc, and several plants with hydrogen plus zinc. Also, the BRAC value for Brunswick 1, which has been injecting DZO since 5/95, is higher than expected based on the results of other plants applying HWC and zinc.

- At Co-60 >7.5E-5 uCi/ml, plants with no hydrogen injection or zinc addition have higher BRAC dose rates at a given Co-60 concentration than plants with hydrogen injection and zinc addition.

- Above about 5 -7E-5 uCi/ml Co-60, for each chemistry regime shown in Figure 38-8, the BRAC dose rate increases about linearly with ln[Co-60].

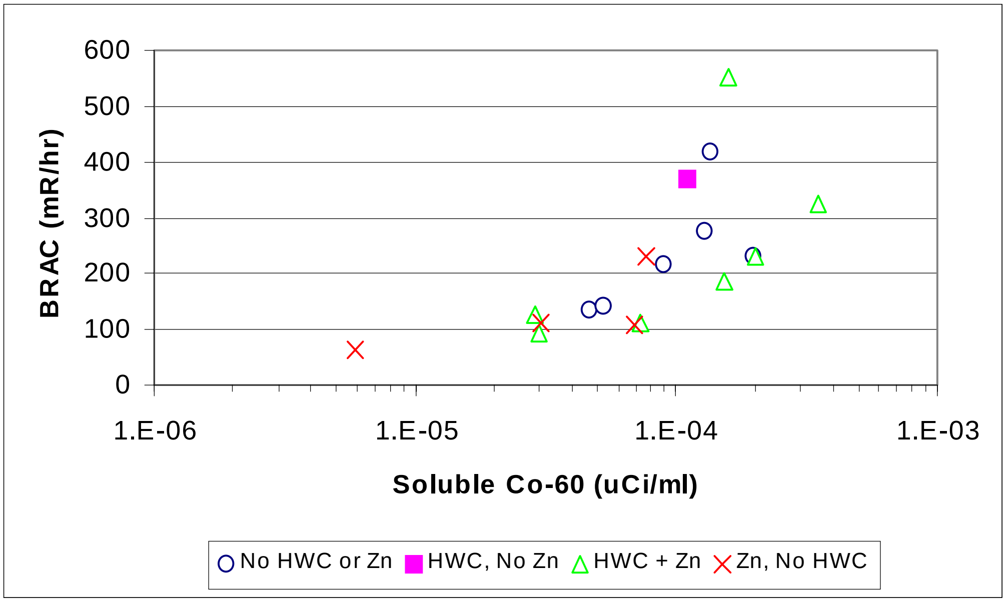

Figure 38-8
BRAC vs. Soluble Co-60 With Zinc Addition and Hydrogen Injection Status

Co-60 Data Summary

Co-60 data, along with data for other activated corrosion products, are being collected. The preliminary focus is on Co-60, which accounts for the majority of the dose at BWR's. The 1997 averages for Co-60 are plotted in Figure 38-9 and are also presented in Table 38-4. It is interesting to note that 9 plants, exactly half of the 18 plants for which 1997 fractionation data were available, had higher soluble than insoluble Co-60, while insoluble was higher for the other half.

As a convenient way of evaluating the large amount of data collected and to provide some smoothing, monthly averages were calculated for each parameter. These average Co-60 values, and the monthly averages for other parameters such as feedwater Fe, Zn and Ni, were used to test for correlations.

Soluble Co-60 is plotted against feedwater iron for reporting plants in Figure 38-10. In the high end of the feedwater iron range, above about 5 ppb, the plant data show an apparent suppression of reactor water soluble Co-60. These high iron range data are mainly from Susquehanna 1 and Susquehanna 2.

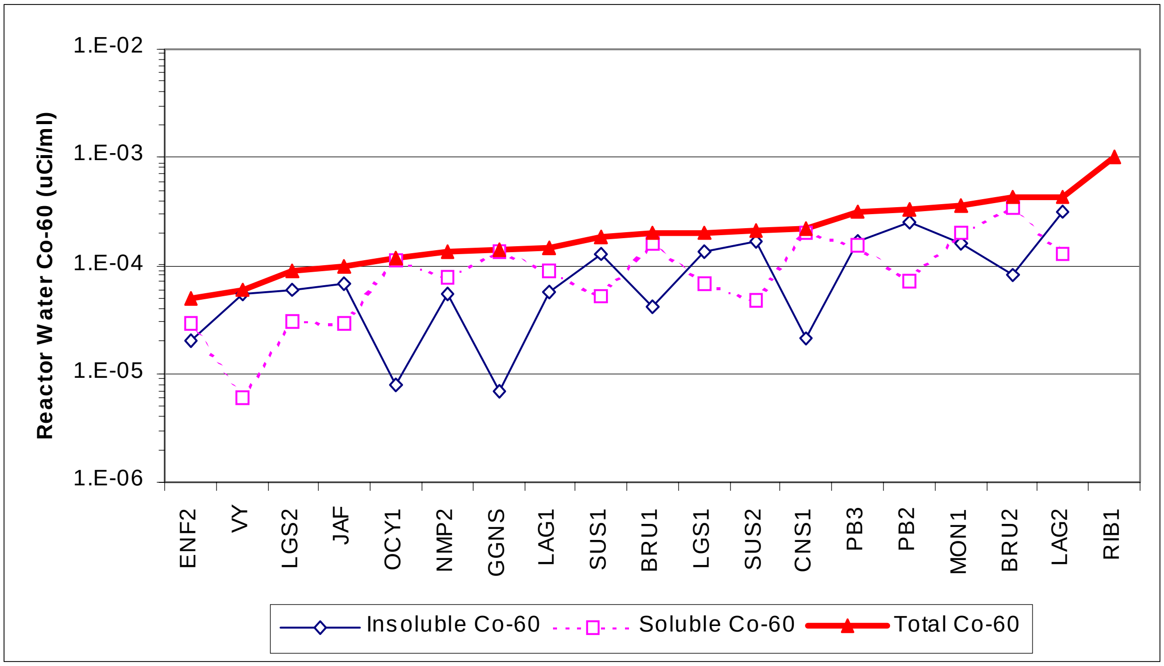

Figure 38-9
1997 Average Cobalt-60

Table 38-4
1997 Average Reactor Water Cobalt-60
(In Order of Increasing Total Co-60)

Plant	Insol. Co-60 (uCi/ml)	Sol. Co-60 (uCi/ml)	Tot. Co-60 (uCi/ml)	Last Chem Decon Date	HWC	Zinc Injection
Fermi 2	2.03E-05	2.85E-05	4.88E-05	None	Yes	DZO
Vermont	5.42E-05	5.94E-06	6.01E-05	1985	No	Natural(1)
Limerick 2	6.02E-05	3.01E-05	9.02E-05	None	No	DZO
FitzPatrick	6.95E-05	2.95E-05	9.90E-05	Feb-94	Yes	DZO
Oyster Creek	7.74E-06	1.10E-04	1.17E-04	Apr-91	Yes	No
Nine Mile 2	5.45E-05	7.71E-05	1.32E-04	None	No	NZO
Grand Gulf	6.98E-06	1.35E-04	1.42E-04	Apr-95	No	No
Laguna Verde 1	5.79E-05	8.93E-05	1.47E-04	1994	No	No
Susquehanna 1	1.29E-04	5.30E-05	1.82E-04	None	No	No
Brunswick 1	4.19E-05	1.57E-04	1.99E-04	Apr-95	Yes	DZO
Limerick 1	1.36E-04	6.90E-05	2.05E-04	None	No	DZO
Susquehanna 2	1.68E-04	4.68E-05	2.14E-04	None	No	No
Cooper	2.14E-05	1.99E-04	2.20E-04	None	No	No
Peach Bottom 3	1.67E-04	1.53E-04	3.20E-04	None	Yes	DZO
Peach Bottom 2	2.57E-04	7.26E-05	3.29E-04	None	Yes	DZO
Monticello	1.61E-04	2.00E-04	3.62E-04	Feb-93	Yes	DZO
Brunswick 2	8.02E-05	3.49E-04	4.30E-04	Feb-96	Yes	DZO
Laguna Verde 2	3.08E-04	1.30E-04	4.38E-04	None	No	No
River Bend			1.00E-03	1992	No	No

(1) The source of feedwater zinc at Vermont Yankee is the main condenser tube material.

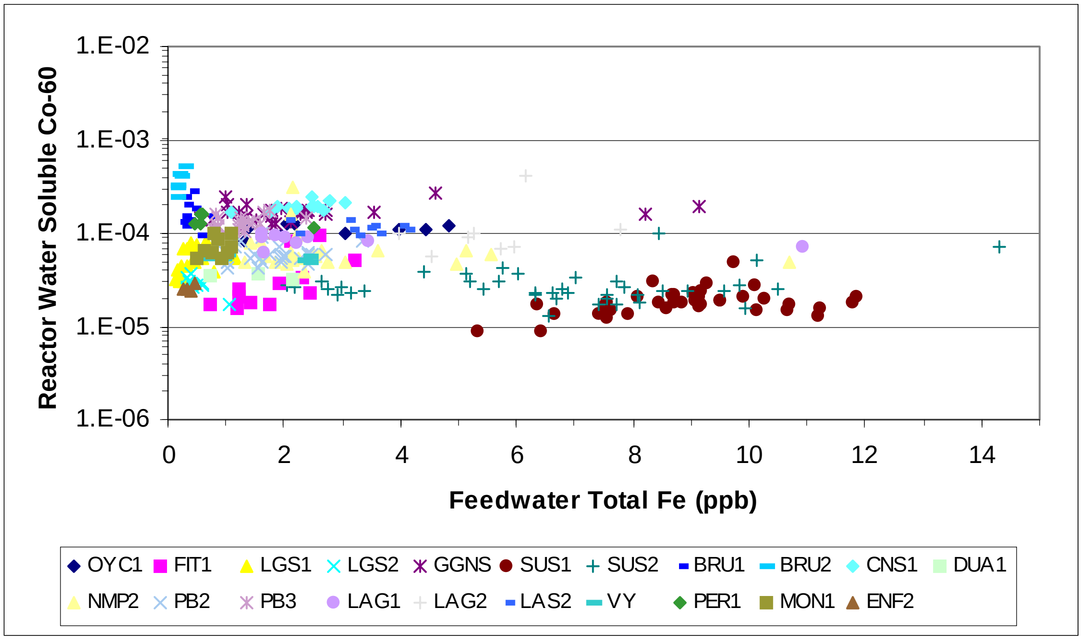

Figure 38-10
Soluble Co-60 vs. Feedwater Iron

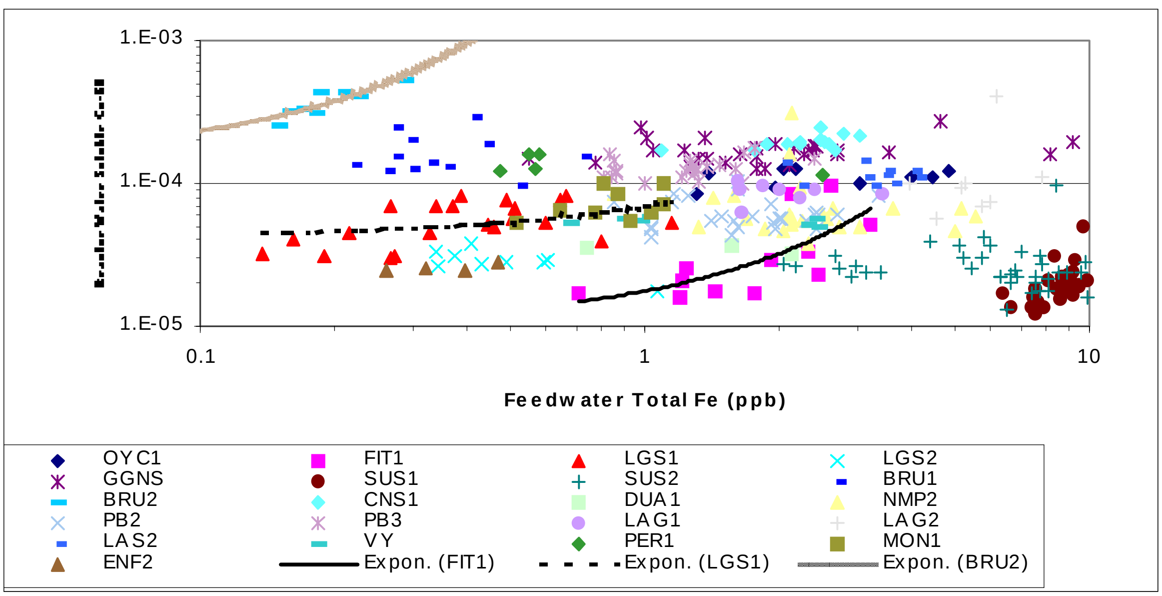

Figure 38-11
Soluble Co-60 vs. Feedwater Iron (with trend lines)

To examine the lower end of the feedwater iron range in more detail, the iron axis was expanded using a logarithmic scale. This plot is presented Figure 38-11. The data show a decreasing trend in soluble Co-60 with decreasing feedwater iron for each individual plant. To illustrate these individual plant trends, trend lines were added to the plots in Figure 38-11 for three plants; FitzPatrick, Limerick 1 and Brunswick 2. Similar trend lines were not added for other plants in order to maintain some degree of clarity in an already busy figure. In addition, these three plants were selected because they show the soluble Co-60 trend over a range of feedwater iron concentrations from 0.14 ppb to 3.2 ppb.

Since zinc and nickel compete with cobalt for sites in the corrosion film, the Fe/(Ni+Zn) molar ratio was determined for plants providing these data and that ratio was applied to test for a correlation. For clarity, a plot of the results for selected plants is shown in Figure 38-12. Trend lines were again added for FitzPatrick, Limerick 1 and Brunswick 2, three plants with Fe/(Ni+Zn) molar ratios spanning the range from <0.5 to >10. The data of all three plants show a declining trend in soluble Co-60 as the Fe/(Ni+Zn) ratio decreases. This trend is also evident for other plants.

The relative effects of Fe and (Ni+Zn) in the Fe/(Ni+Zn) molar ratio is shown in Figure 38-13 for FitzPatrick, Limerick 1 and Brunswick 2. The data show that both the iron value and the (Ni+Zn) term change significantly. For FitzPatrick, for example, the maximum/minimum Fe concentration is about 4.5 while the maximum/minimum (Ni+Zn) is 2.9.

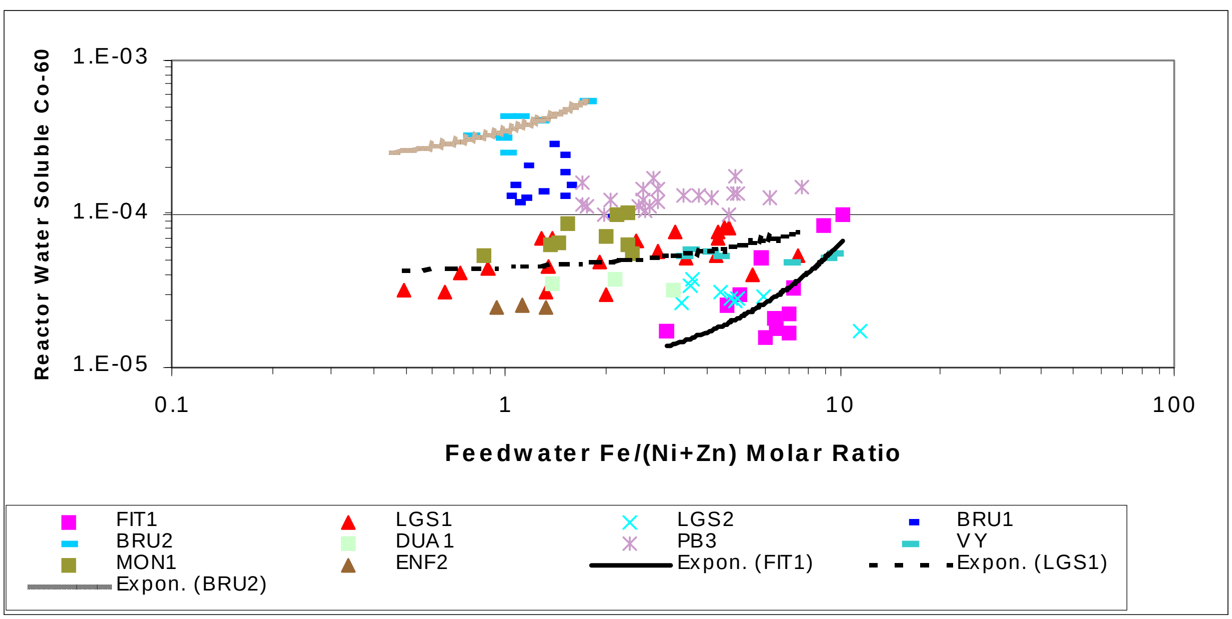

Figure 38-12
Soluble Co-60 vs. Fe/(Ni+Zn) Molar Ratio

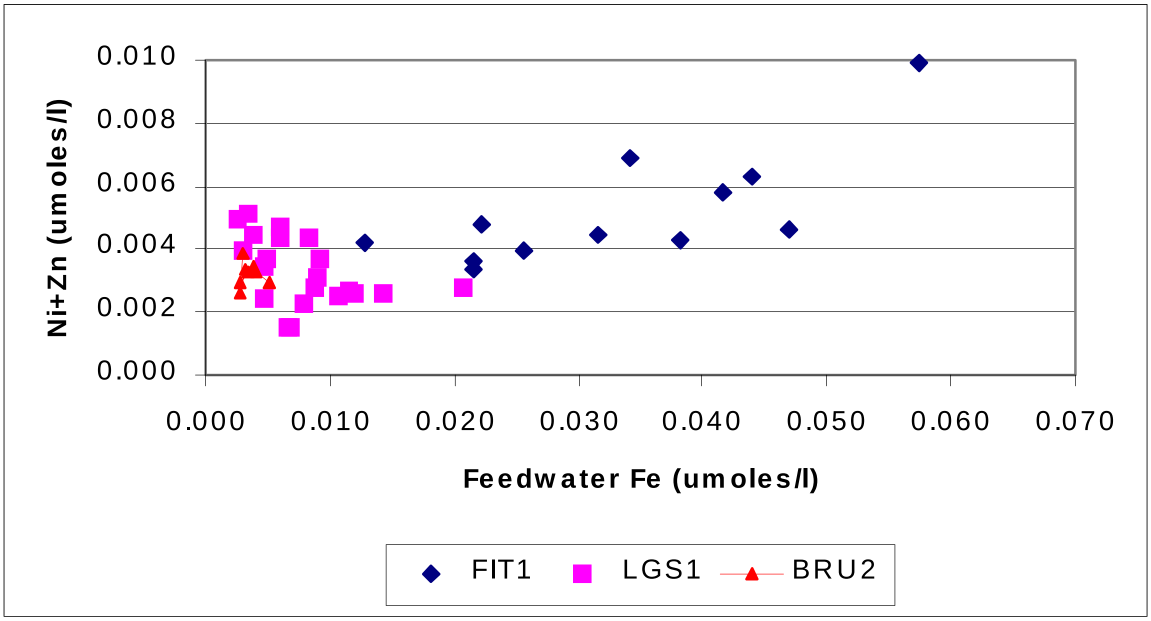

Figure 38-13
(Ni+Zn) vs. Feedwater Iron

The question remains as to why, at a specific Fe/(Ni+Zn) ratio, one plant's soluble Co-60 concentration is much higher than that of another plant. This may be primarily due differences in the cobalt source term, on which additional data are needed from various plants. This is an area identified for further investigation. Initial input from Brunswick indicates that about 4.2% of the original stellite surface area has been replaced with low cobalt materials.

The effects of the feedwater iron concentration and the feedwater Fe/(Ni+Zn) ratio on reactor water insoluble Co-60 appear to be more complex than on the soluble Co-60 component. A plot of the monthly average insoluble Co-60 vs. feedwater iron data available at the time this report was prepared is shown in Figure 38-14. Below 1 ppb feedwater iron, the data appear to indicate a trend of increasing insoluble Co-60 with decreasing feedwater iron. There also appears to be a minimum for insoluble Co-60 in the range of 1 – 2 ppb feedwater iron. Insoluble Co-60 also appears to show a weak but increasing trend with feedwater iron over the range of about 2 – 3.5 ppb.

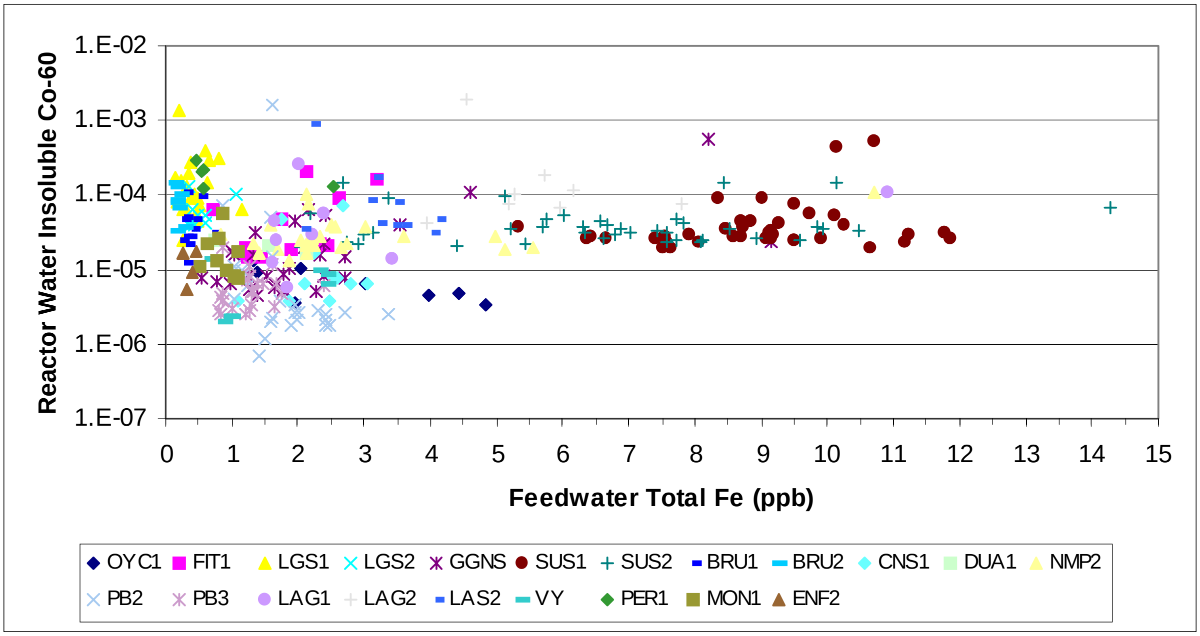

Figure 38-14
Insoluble Co-60 vs. Feedwater Iron

To focus in on the insoluble Co-60 trends in the lower end of the feedwater iron range, the iron axis was expanded using a logarithmic scale. This plot is presented Figure 38-15. The data in the low iron range, less than about 1 ppb, show a decreasing trend in insoluble Co-60 with increasing feedwater iron for an individual plant. This is illustrated by the data for Limerick 1 and Brunswick 2, for which trend lines are shown. As feedwater iron increases, insoluble Co-60 appears to go through a minimum in the 1 – 2 ppb iron range. For emphasis, the existence of this minimum is illustrated by the FitzPatrick trend line. As noted in the soluble Co-60 discussion, these three plants were selected for trend lines because as a group they show the insoluble Co-60 trend over a range of feedwater iron concentrations from 0.14 ppb to 3.2 ppb.

The insoluble Co-60 was also plotted as a function of the Fe/(Ni+Zn) molar ratio, as shown in Figure 38-16. These data appear to indicate a minimum insoluble Co-60 for a given plant in approximately the 2 – 7 Fe/(Ni+Zn) molar ratio range. This trend is more clearly apparent in the plot of Figure 38-17, where the data of selected plants spanning in range of the minimum are shown.

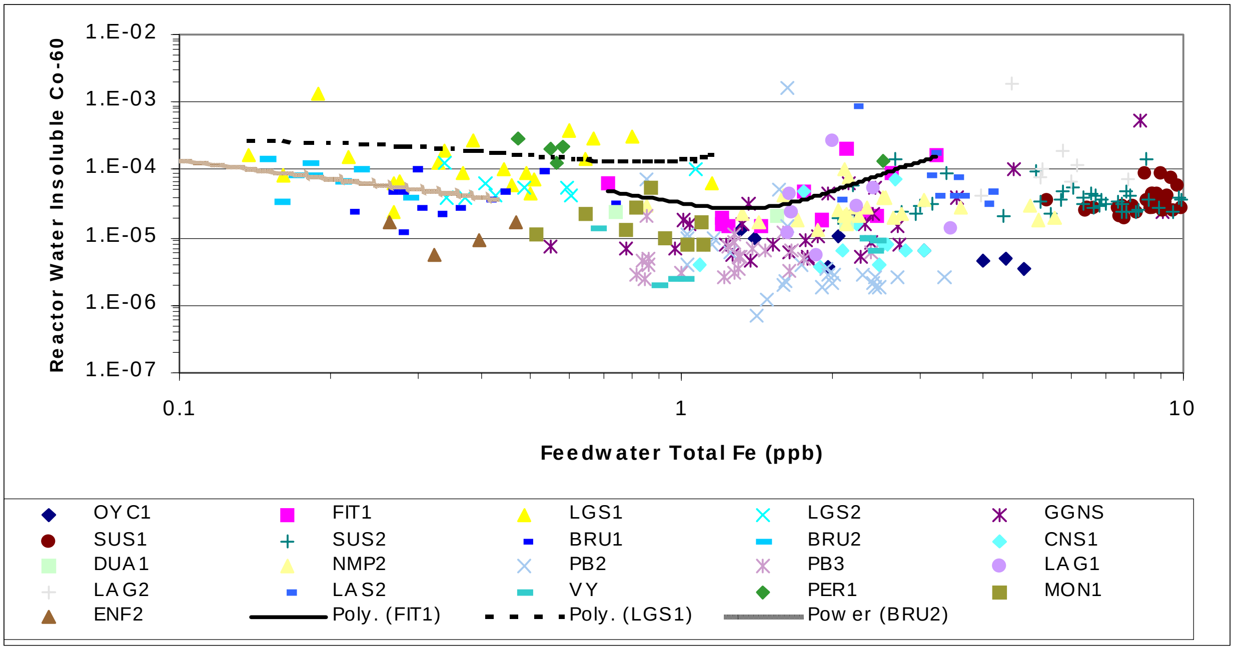

Figure 38-15
Insoluble Co-60 vs. Feedwater Iron (with trend lines)

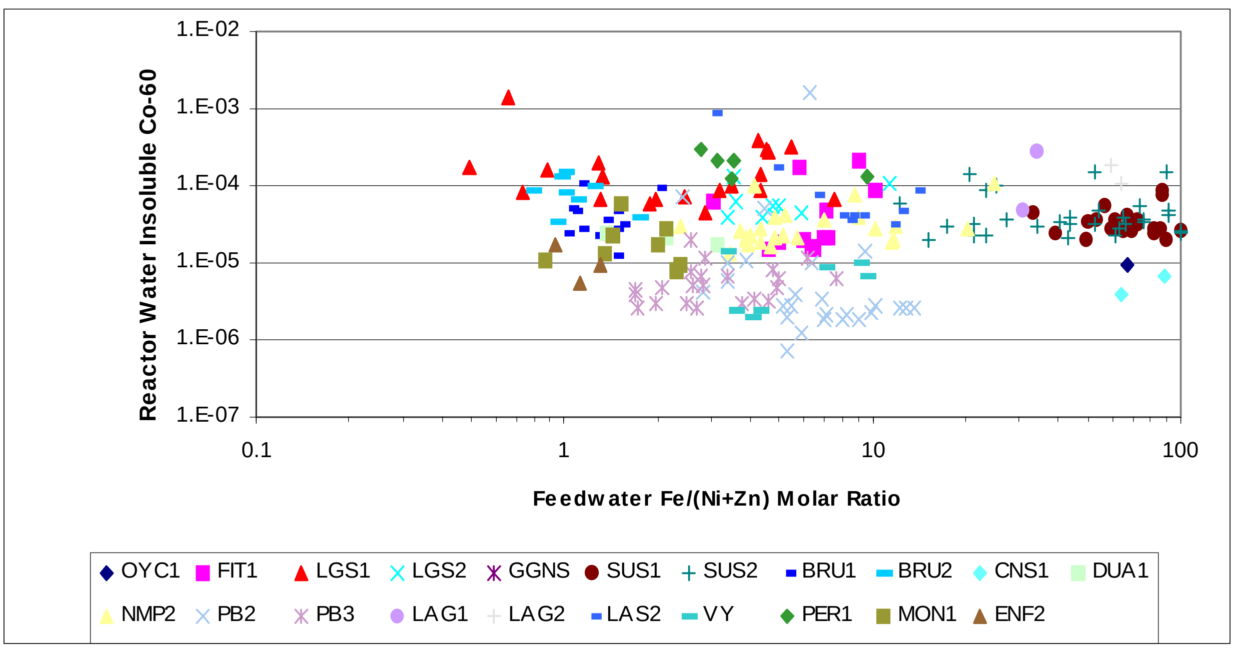

Figure 38-16
Insoluble Co-60 vs. Fe/(Ni+Zn) Molar Ratio

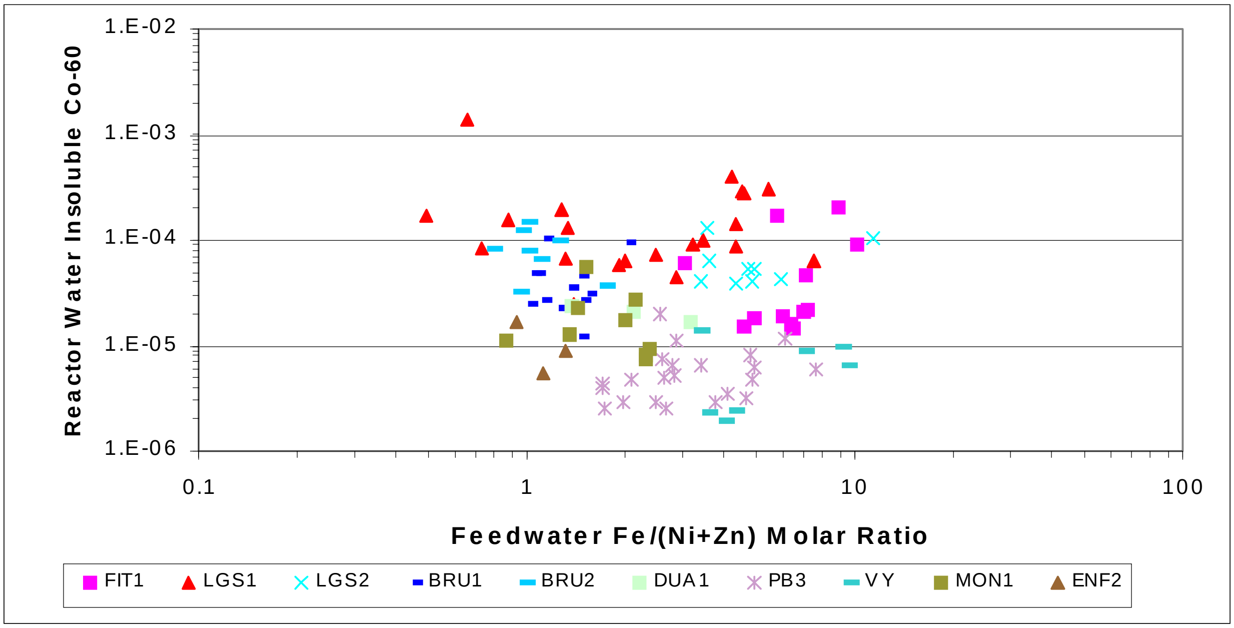

Figure 38-17
Insoluble Co-60 vs. Fe/(Ni+Zn) Molar Ratio (Selected Plants)

Iron Addition

The Japanese experience showed that low feedwater iron caused increased drywell dose rates and prompted development and implementation of iron / nickel ratio control to reduce dose buildup. The iron / nickel ratio is controlled by injecting iron into the feedwater.

Three U.S. BWR plants are actively injecting iron to raise the feedwater iron concentration. These plants are listed in Table 38-5. Discussions of feedwater iron addition at Limerick and WNP-2 follow.

Table 38-5
U.S. BWR's Currently Injecting Iron in the Feedwater

Plant	Cond. Pol. Type	Type of Iron Injected	Feedwater Iron Concentration (ppb)	
			Before Fe Addition	After Fe Addition
Limerick 1	F + DB	Iron Oxide	~0.2	0.5
Limerick 2	F + DB	Iron Oxide	~0.2	0.5
WNP-2	F/D	Iron Oxalate	<0.5	1.0

Limerick 1 and 2

At Limerick, operation with low feedwater iron coincided with increases in reactor water Co-58, Co-60 and Zn-65 during operation and sharp increases in Co and Zn activity during shutdowns. Hot spots due to activated crud particles were detected, including the 1C RWCU pump internal casing dose rate increase from a previous contact measurement of 5 R/hr to 100 R/hr, and a 100 R/hr hot spot on the Unit 1 bottom head drain line. Another problem associated with increased reactor vessel crud was sticking control blades during plant startups and power increases for both Unit 1 and Unit 2. Increased zinc and chrome activity was also detected in liquid effluents.

In response, Limerick decided to implement feedwater iron addition and to switch to DZO. Initial attempts at increasing feedwater iron including partial bypass of the filters (caused unacceptable ΔP rise across deep beds) and the use of larger pore size filters (quickly fouled and produced low effluent iron) were unsuccessful. It was decided to inject iron into the feedwater to achieve 0.5 - 1.0 ppb using the existing GEZIP mechanical skid. Iron oxide was selected over iron oxalate due to the low pH of the oxalate.

Both Limerick Units were converted to DZO in January of 1997, and iron injection was started in February, 1997 for Unit 1 and March, 1997 for Unit 2. The GEZIP skid performed well with no significant operating or maintenance problems. No changes in reactor water anionic impurities have been detected.

Limerick reactor water Co-58 and Co-60 indicate some decrease and less fluctuation since iron addition was started. The Unit 1 bottom head drain line dose rate was 10 R/hr during the last drywell entry, down from 100 R/hr previously. RWCU pump dose rates have leveled off. It is expected that Zn-65 levels will decrease over time as the inventory in the primary system is removed.

Future plans are focused on upgrading the injection skid to ensure reliability and reduce manpower. Upgrades being considered include a larger pump to allow lower oxide concentrations and possibly a larger tank to allow less frequent additions (now at least every other day).

WNP-2

WNP-2 had a trend of increasing annual collective radiation dose, peaking at about 900 person-Rem in 1994. Increasing trends in reactor water Co-60 were also observed. Two programs were initiated in 1996:

1. Iron Addition - Started in July, 1996 (increased feedwater Fe to about 1 ppb).

2. DZO Addition - Started in September, 1996 (reactor water Zn about 10 ppb)

A decreasing trend in reactor water total Co-60 was observed, starting in September, 1996. By January, 1997, total Co-60 had decreased from 1-2 E-3 μCi/ml (July, 1996) to about 5-7E-5 μCi/ml. Prior to the addition of iron and DZO, cobalt deposition on recirculation piping was about equal to the rate of decay. After about one year of iron and DZO addition, the recirculation system Co-60 activity dropped at a rate slightly greater than the natural rate of decay (about 16%), indicating less deposition. A decrease in recirculation piping contact dose rates was also measured.

A recirculation system chemical decontamination is planned for the 1997 outage, with expected dose reductions of 40 person-Rem for 1997 and an additional 32 person-Rem through the year 2000. Results and updated data will be requested.

Some issues with the iron injection practice remain. Iron oxalate is currently being injected, and a benefit is that the chemical feed equipment requires low maintenance. However, the process used to manufacture the red fuming iron oxalate uses nitric acid, and nitrate excursions have been experienced in reactor water. Increased feedwater conductivity has also been measured due to iron oxalate addition.

At present, iron is added to the feedwater to achieve about 1 ppb at the final feedwater sample point. Toward optimizing iron injection, the plan is to run for periods with final feedwater iron concentrations of 0.5 ppb, 1 ppb and 1.5 ppb. With the current iron oxalate addition, it is not possible to achieve 1.5 ppb feedwater iron due to feedwater conductivity and reactor water nitrate issues. A possibility is to feed some iron oxide along with the iron oxalate.

Iron oxalate was estimated to cost about $60,000 per year. Iron oxide, if used instead of iron oxalate, would cost about $2,000 per year. The main concern with iron oxide addition is whether the insoluble form can be injected reliably without causing high maintenance on the injection equipment.

With iron oxalate addition, the iron measured in the feedwater is almost totally insoluble. Testing has not been performed to determine (speciate) the insoluble iron forms.

Plants Equipping to Raise Feedwater Iron

Hope Creek and Susquehanna 1 and Susquehanna 2 are in the process of designing and installing condensate filters upstream of the original deep bed condensate polishers. As part of these modifications, provisions to add iron to the feedwater are included.

Hope Creek is planning to inject iron oxalate. The approach is to mix the iron oxalate with DZO and oxalic acid in the same mixing tank and to inject the solution. As of 10/97, laboratory testing was being performed to determine the concentrations required to keep the iron and zinc in solution while providing the desired relative injection rates.

Iron oxalate will also be injected at Susquehanna 1 and 2. Iron oxalate was selected based on the simplicity of the injection equipment design, and the expected low trouble-free operation and low maintenance. The initial plan is to control feedwater iron at the lower end of the 0.5 – 1.5 ppb target range. The impact on reactor water cobalt activation products will be monitored and the iron addition will be adjusted accordingly.

39

OVERVIEW OF FIELD EXPERIENCE WITH FILTERS

The use of pleated filter septa in Boiling Water Reactor (BWR) condensate filters evolved from the Electric Power Research Institute (EPRI) BWR Feedwater Iron Reduction Program. Under the program, non-precoat filters and special iron removal cation ion exchange resins were explored as alternative means of reducing feedwater iron concentrations. Although the special resins were successful in achieving low effluent iron concentrations, they produced unacceptable reactor water sulfate levels. Therefore, high efficiency condensate filters currently are the singular practical means of consistently achieving feedwater iron levels in the range of 0.5 to 1.5 ppb.

Since the non-precoated pleated septa demonstrated an ability to provide effluent iron concentrations < 1.5 ppb, many users of precoated yarn septa undertook trials of pleated septa using reduced precoat doses. As consequence, pleated filter septa are now used in non-precoat and precoat applications.

One septa supplier, Pall, is offering a non-pleated septa with melt blown polypropylene media that may be used with or without precoats. Another supplier, Graver, offers a septa with yarn windings above the pleated media for precoat and non-precoat applications. All current domestic suppliers (Graver, Memtec and Pall) have indicated they are continuing their development efforts related to BWR filter applications.

The dramatic increase in the use of iron reduction septa in condensate polishing systems at BWR plants is illustrated in Figure 39-1. In the non-precoat applications, iron reduction septa are exclusively pleated septa. For the precoat applications, the preponderance of septa were also pleated. However, recently the Pall Corporation has introduced a polypropylene melt blown cylindrical septa as an alternative option for precoat applications.

All of the precoat applications of iron removal septa were retrofits to vessels originally designed for use of cylindrical non-pleated septa. For vessels with top tubesheets, new tubesheets were required since the pleated septa have larger diameters than the cylindrical septa they replaced. New tubesheets were not required for bottom tubesheet vessels.

In non-precoat applications, iron removal septa were retrofits to existing vessels, and supplied as original equipment in new filter vessels added to condensate polishing systems for the specific purpose of reducing feedwater iron. Of the 65 vessels with iron removal septa in non-precoat applications, 29 are in new filter systems.

The initial use of pleated filter septa in a domestic BWR condensate non-precoat application was at Perry during August 1991 using Graver's polyester upright pleated septa that have since been replaced with other pleated septa. Pleated filter septa were initially used in a domestic BWR condensate precoat application at Hatch starting in January 1995 using Pall polyaramid fold-over pleated septa that also have been replaced with other iron reduction septa.

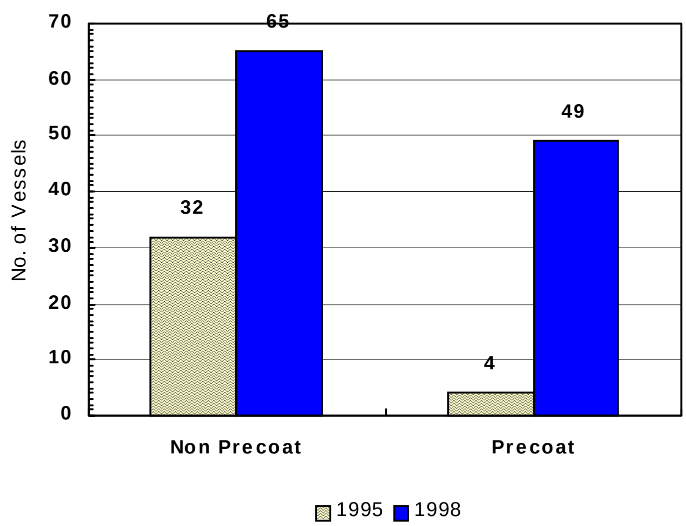

Figure 39-1
Trend In Iron Reduction Septa Use

The type and characteristics of the iron reduction filter septa used thus far in BWR condensate applications, several of which have been discontinued, are listed in Table 39-1. All of the septa include pleated filter media except for the Pall non-pleated melt-blown polypropylene septa.

For precoat applications; the Pall polyaramid, the Falban, and the Graver, with yarn windings over pleated media, septa use precoat retention media over the pleated filter media. There is a slight difference between the Memtec non-precoat and precoatable septa. The pleat height on the precoatable septa is slightly shorter than on the non-precoat septa to accommodate precoat materials in the volume between the surrounding open protective cage and the pleated media.

A list of the domestic BWR plants using iron removal septa with precoats is provided in Table 39-2. The Pall polyaramid pleated septa at Duane Arnold were replaced by yarn wound non-pleated septa in August 1997. This is a temporary situation, plant personnel are in the process of selecting pleated filter septa replacements since feedwater iron increased after removing the pleated septa. Initial use of the pleated septa at Fermi is scheduled for the fourth quarter of 1998.

All plants, except for Duane Arnold and Hatch, use all powdered ion exchange resin precoat materials. The all resin precoat materials are pre-mixed formulations, except at Monticello where the cation and anion resins are mixed in the precoat tank prior to application.

The precoat materials used at Duane Arnold and Hatch are pre-mixed formulations of fibers and ion exchange resins. At Hatch various pre-mixed formulations from several suppliers are used on the iron removal septa.

Table 39-1
Filter Septa Evaluated In BWR Condensate Polishing Trials

Mfg.	**Type**	**Media Material**	**Rating (:m)**	**Application**	**Initial Use**	**Application Status**
Falban	Pleated	?	4-5	Precoat	Jan-98	Continued
Graver	Upright Pleat	Polyester	0.6	Non-	Aug-91	Continued
Graver	Upright Pleat	Polyester	1	Non-	Dec-95	Continued
Graver	Wound Yarn + Pleats	Polypropylene + Polyester	0.6	Precoat	Apr-97	Continued
Memtec	Upright Pleat	Polysulfone	0.5	Non-	Sep-95	Discontinued
Memtec	Upright Pleat	Polypropylene	2	Precoat	May-95	Continued
Memtec	Upright Pleat	Polypropylene	4	Precoat	May-95	Continued
Memtec	Upright Pleat	Polypropylene	10	Precoat	Mar-96	Continued
Memtec	Upright Pleat	Polypropylene	2	Non-	May-95	Continued
Memtec	Upright Pleat	Polypropylene	4	Non-	May-95	Continued
Memtec	Upright Pleat	Polypropylene	10	Non-Precoat		No Applications
Pall	Fold-Over Pleat	Polyaramid	1.4	Precoat	Jan-95	Discontinued
Pall	Fold-Over Pleat	Polyaramid	1.4	Non-Precoat	Oct-94	Discontinued
Pall	Fold-Over Pleat	Polyolefin	1	Precoat	Jan-97	Continued
Pall	Fold-Over Pleat	Polyolefin	1	Non-Precoat	Dec-95	Continued
Pall	Non-Pleated	Melt-Blown Polypropylene	5	Precoat	Jun-97	Continued

Table 39-2
BWR's With Precoated Iron Removal Septa

Plant	Current Septa	Septa Type	Vessels With Septa	Precoat Material Type	Precoat Dosage lb/10"	Septa per Vessel	Length of Septa (in.)	Flow/10" (gpm/in.)	Flow per Vessel @60°F (gpm)	Type of BW
Browns Ferry 2	Memtec	Polypropylene Pleated	5 of 9	All Resin	0.033	302	60	1.643	2978	Surge
Browns Ferry 3	Memtec	Polypropylene Pleated	4 of 9	All Resin	0.033	302	60	1.643	2978	Surge
Cooper 1	Memtec	Polypropylene Pleated	3 of 7	All Resin	0.062	302	70	1.286	2718	Steady State
Duane Arnold	Pall	Polyaramid Pleated	1 of 5	Fiber/ Resin	0.090	336	58	1.457	2840	Surge
Fermi 2	Memtec	Polypropylene Pleated	1 of 8	All resin	0.033	310	60	1.302	2423	Surge
Hatch 1	Memtec	Polypropylene Pleated	1 of 7	Fiber/ Resin	0.090	302	80	1.335	3226	Surge
	Pall APF-2	Nonpleated	2 of 7	Fiber/ Resin	0.090	302	80	1.335	3226	
	Falban (Italy)	Pleated	1 of 7	Fiber/ Resin	0.090	302	80	1.335	3226	
Hatch 2	Memtec	Polypropylene Pleated	1 of 7	Fiber/ Resin	0.090	302	80	1.264	3055	Surge
	Pall	BPF-4 Pleated	1 of 7	Fiber/ Resin	0.090	302	80	1.264	3055	
	Graver	Dual Guard Yarn/Pleats	2 of 7	Fiber/ Resin	0.090	302	80	1.264	3055	
	Falban (Italy)	Pleated	1 of 7	Fiber/ Resin	0.090	302	80	1.264	3055	
Monti-cello	Memtec	Polypropylene Pleated	3 of 5	All resin	0.028	302	60	1.515	2746	Surge
Peach Bottom	Memtec	Polypropylene Pleated	7 of 10	All resin	0.028	302	70	1.362	2880	Surge
Peach Bottom	Memtec	Polypropylene Pleated	7 of 10	All resin	0.028	302	70	1.362	2880	Surge
Quad Cities 1	Memtec	Polypropylene Pleated	5 of 7	All resin	0.050	302	60	1.545	2800	Surge
Quad Cities 2	Memtec	Polypropylene Pleated	4 of 7	All resin	0.050	302	60	1.545	2800	Surge

Additional information on domestic BWR condensate applications of iron removal septa is provided in Table 39-3, including challenge severity index values for filter run lengths (RLI) and the impact of ion exchange performance on reactor water chemistry (IXI). In both instances, the higher the index value the greater the challenge to the iron removal septa.

Table 39-3
Details On Pleated Septa In BWR Condensate Applications

Plant	Avg. Fe			Use of Pleated Septa			Index	
	FW (ppb)	CDI (ppb)	Tubesheet Location	Vessel w/ Pleated Septa	No. of Septa per Vessel	Lengths (in.)	RLI	IXI
Browns Ferry 2	2	23.8	Bottom	5 of 9	302	60	64.41	0
Browns Ferry 3	1.4	21.8	Bottom	4 of 9	302	60	58.91	0
Cooper 1	2.4	17	Bottom	3 of 7	302	70	28.1	0.23
Duane Arnold	1.4	11	Top	1 of 5	336	58	23.45	?
Fermi 2	0.4	8.4	Top	1 of 8	310	50	20.5	0.026
Hatch 1	1.5	15	Bottom	4 of 7	302	80	26.74	0.008
Hatch 2	1.5	15	Bottom	5 of 7	302	80	23.98	0.008
Monticello	0.9	11.4	Bottom	3 of 5	302	60	26.2	0.023
Peach Bottom 2	1.2	23.1	Bottom	7 of 10	302	70	42.85	0.006
Peach Bottom 3	1.2	26.4	Bottom	7 of 10	302	70	48.94	0.006
Quad Cities 1	3	14	Bottom	5 of 7	302	60	33.43	0.023
Quad Cities 2	2.9	14	Bottom	4 of 7	302	60	33.43	0.023

In general the run length performance of pleated septa from a single supplier used in similar vessels with similar backwash methods has been consistent with the challenge severity index concept. For example, the performance of Memtec pleated septa at

Browns Ferry has been inferior to that at Peach Bottom in terms of run lengths and problems encountered. Browns Ferry has the highest RLI value of those listed in Table 39-3. The RLI value for Peach Bottom, although lower than at Browns Ferry, is also high. However, the Peach Bottom value shown is based on 1997 average influent iron values which were strongly influenced by unusually high concentrations during the first three months of 1997. For much of their lives, the pleated septa at Peach Bottom have operated with an influent iron concentration of about 15 ppb, which equates to a RLI of about 27.8, that is, less than half of the values at Browns Ferry.

Table 39-4 gives a list of domestic and Mexican plants at which iron removal septa are used without precoats. All of the plants, except Brunswick and Limerick, use the septa in top tubesheet filter vessels. This is in direct contrast to the situation for precoated septa where only 2 of the 12 plants have top tubesheet filter vessels.

Full scale field use of the septa types shown in Table 39-4, as of 6/1/98, have not yet started at Clinton, Hope Creek, Laguna Verde 2 or Susquehanna. That is, extensive full scale operating experience with these type septa has been gained only at 5 of the 11 units listed; Brunswick 1 and 2, Limerick 1 and 2, and Perry.

Additional information on the domestic and Mexican BWR non-precoat condensate applications of iron removal septa, all of which use pleated filter media, is given in Table 39-5. In particular, challenge severity index values for RLI and DSI (the potential impact on reactor water chemistry of organosulfur releases from condensate demineralizer resin beds) are provided.

The DSI values are noteworthy in being high for most BWR plants that have not added filters to their condensate polishing systems. That is, the plants that elected to use iron removal septa rather than low cross-linked cation resins to reduce feedwater iron appear to have made a wise selection between the two alternative methods.

Based on the two plants with septa from the same supplier used in the same type filter vessels, actual performance appears to be consistent with the RLI values. In Table 39-5, the RLI values for the Memtec pleated septa at Perry and Laguna Verde 1 are reasonably close. During periods in which comparable influent irons prevailed, the septa achieved run lengths of 50 to 80 full power days to endpoints of 4 to 6 psi at Perry, while run lengths at Laguna Verde 1 have been reported as about 60 days to a 5 psi endpoint.

The Perry influent (CDI) iron concentration shown in Table 39-5 is the average for a period in 1997 during which piping and MSR problems resulted in unusually high (for Perry) iron inputs to the condenser. CDI iron concentrations are normally 8 to 10 ppb at Perry. At the normal low CDI iron concentrations, run lengths in excess of 60 days were achieved to endpoints generally less than 3 psi.

Table 39-4
Non Precoat Septa Applications

Plant	Current Septa	Septa Type	Vessels with Septa	Septa per Vessel	Length of Septa (in.)	Flow per Vessel @60°F (gpm)	Total Vessels Normally I/S	Type of BW
Brunswick 1	Graver Aegis AEA	Polyester Pleated	2	420	70	3500	4	Steady State
	Pall BPF-4	Polyolefin Pleated	2	420	70			
Brunswick 2	Graver	Polyester Pleated	4	420	70	3500	4	Steady State
Clinton	Memtec	Polypropylene Pleated	1	299	50	8667	3	Surge
	Graver Aegis AEA	Polyester Pleated	1	254	52			
	Pall BPF-4	Polyolefin Pleated	1	234	50			
Hope Creek	Pall BPF-4	Polyolefin Pleated	4	442	70	6995	4	Surge
Laguna Verde 1	Memtec	Polypropylene Pleated	7	148	70	1760	6	Surge
Laguna Verde 2	Memtec	Polypropylene Pleated	7	148	70	1760	6	Surge
Limerick 1	Pall BPF-4	Polyolefin Pleated	8	240	70	3673	8	Surge
Limerick 2	Pall BPF-4	Polyolefin Pleated	8	240	70	3673	8	Surge
Perry	Memtec	Polypropylene Pleated	8	522	50	2851	7	Surge
Susquehanna 1	Memtec	Polypropylene Pleated	6	507	50	4725	6	Surge
Susquehanna 2	Memtec	Polypropylene Pleated	6	507	50	4725	6	Surge

Table 39-5
Run Length and Sulfate Index Values For Non-Precoat Filter Applications

Plant	**Avg. Fe**			**Use of Pleated Septa**				**Index**	
	FW (ppb)	**CDI (ppb)**	**Tubesheet Location**	**Vessel w/ Pleated Septa**	**Septa Suppliers**	**No. of Septa per Vessel**	**Lengths (in.)**	**RLI (Filter Runs)**	**DSI (Resin SO_4)**
Brunswick 1	0.36	11	Bottom	4 of 4	Graver/ Pall	420	70	15.59	1.91-2.30
Brunswick 2	0.21	11	Bottom	4 of 4	Graver	420	70	15.59	1.91-2.30
Clinton	3.50	15	Top	1 of 3	Memtec	299	50	47.10	2.64-2.97
				1 of 3	Graver	254	50	65.30	
				1 of 3	Pall	234	52	71.10	
Hope Creek	4.00	22	Top	4 of 4	Pall	442	70	112.45	2.97-3.47
Laguna Verde 1	3.75	11	Top	7 of 7	Memtec	148	70	23.13	3.69
Laguna Verde 2	9.34	34	Top	7 of 7	Memtec	148	70	71.06	3.69
Limerick 1	0.54	14	Bottom	8 of 8	Pall	240	70	64.57	5.48
Limerick 2	0.55	17	Bottom	8 of 8	Pall	240	70	82.45	5.48
Perry	0.96	21	Top	8 of 8	Memtec	522	50	19.01	2.23
SSES 1	9.64	22	Top	6 of 6	Memtec	507	50	75.77	2.61-3.04
SSES 2	8.12	19	Top	6 of 6	Memtec	507	50	64.86	2.61-3.04

The twelve domestic BWR units that have only deep bed demineralizers in their condensate polishing systems are listed in Table 39-6. Nine of the units normally have feedwater iron concentrations significantly higher than the upper limit (1.5 ppb) of the current optimum target range. River Bend feedwater concentration of 3.9 ppb is an anomaly due to a URC transducer problems that have since been resolved. A more representative feedwater iron concentration for River Bend is about 1.5 ppb.

Table 39-6
Potential For Filters at BWR Condensate Deep Bed Only Plants

Criteria For High Potential

- Average FW Fe Appreciably Higher Than 1.5 ppb.
- ACSI - Resin SO_4 > 1.5
- Plant Started After 1972; Age < 25 Years
- Average CDI Fe > 15 ppb; Greater Than 90% Removal Required.

Plant	Commer. Operation Start	Condensate Temperatur Avg (°F)	Max (°F)	Avg. Fe FW (ppb)	CDI (ppb)	Deep Beds No. of Vessel On-Line	Resin Cu. Ft. Per Bed	RWCU Normal % of FW (%)	DSI (Resin	Potential For Filter Retrofit
Pilgrim	Dec-72	96	126	2.8	4.5	6	220	1	3.30	Low
J.A. FitzPatrick	Jul-75	110	125	1.7	6.6	7	195	1	2.78	Low
Grand Gulf	Jul-85	124	136	1.8	25.1	6-8	290	1	2.39-3.19	Low
River	Jun-86	118	123	3.9	22.0	10	145	1	2.11	Low
LaSalle 1	Oct-84	115	135	2.5	21	6	200	1	1.85	High
LaSalle 2	Jan-84	115	135	2.5	20	6	200	1	1.85	High
Millstone 1	Mar-71	90	130	4	15.1	6	160	2	1.32	Low
Nine Mile Point 2	Apr-88	110	125	4.0	19.7	8	220	2	1.30	Low
Nine Mile Point 1	Dec-69	105	130	2.6	12	6	170	2.74	1.12	Low
Oyster Creek	Dec-69	88	118	2.7	13.7	6	150	3	0.92	Low
Dresden 3	Nov-71	112	125	2.8	18.1	6	180	3	0.81	Low
Dresden 2	Jun-70	112	125	2.6	22.2	6	180	3	0.81	Low

Among the criteria listed at the top of Table 39-6 is the DSI (Demineralizer Sulfate Index), which rates the plant's vulnerability to sulfur release from the condensate polisher resins. The DSI is proportional to the ratio of the volume of resin in the condensate demineralizers to the RWCU flow, and as such it is indicative of a plant's vulnerability to organosulfur compounds released from the demineralizer beds. The plants with higher DSI values would be more likely to encounter reactor water sulfate problems from low crosslinked cation resins.

The other criteria listed are based on the following rationale. Plants that now have feedwater iron concentrations appreciably higher than 1.5 ppb and CDI concentrations >15 ppb are not likely to achieve the required iron removal with standard resins. For plants with less than 15 years of licensed operation remaining, it would be difficult to justify the cost of adding condensate filters to the condensate system.

Of all the units examined using the listed criteria, only the two units at LaSalle are identified as plants with high potential benefits from filter retrofits. However, other possibilities are efforts to reduce CDI iron or to improve resin cleaning.

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OVERVIEW OF FIELD EXPERIENCE WITH DEEP BEDS FOR IRON CONTROL

Of the deep bed only plants, FitzPatrick, Grand Gulf, River Bend and Oyster Creek appear to have the capability to approach the upper end of the current target feedwater iron range of 0.5 - 1.5 ppb. The Oyster Creek data clearly indicate a resin aging or crud conditioning effect, with feedwater iron control improving as the fuel cycle progresses; the average feedwater iron is 1.74 ppb for the May – September, 1997 period compared to an overall 1997 average of 2.675 ppb. FitzPatrick and River Bend use an URC (Ultrasonic Resin Cleaner) to periodically clean resins while Grand Gulf has retrofitted the ARC (Advanced Resin Cleaner) and Oyster Creek has added the JRC (Japanese Resin Cleaning) method.

Oyster Creek

All four of the above mentioned deep bed plants use standard resins (10% crosslinked cation resins, standard porosity anion resins) with the exception of one bed at Oyster Creek comprised of Dow C-500 cation resin and SBR-C anion resin. The Dow C-500 cation resin is 10% crosslinked, has a uniform particle distribution, and has an average particle size of about 500 microns. The C-500 / SBR-C mixture is less separable, and has a lower void fraction and greater cation resin surface area than standard BWR resin mixtures. Preliminary data indicate lower iron from this bed (Bed 1-7) than in the common condensate demineralizer effluent. The lower void fraction results in higher resistance to flow, and thus greater pressure drop, so this mixture may not be appropriate for plants which operate near the condensate demineralizer system differential pressure limit. The performance of this mixture at Oyster Creek will continue to be monitored.

Dresden

Low crosslinked cation resins (Dow Guardian, 8% nominal crosslink) continue to be applied at Dresden 2 and 3 to enhance crud removal. The plant has reported that the use of this crud resin has not led to an increase in reactor water sulfates. (10).

Dresden started using crud resins in late-1993, and has reported annual average feedwater iron and reactor water sulfate concentrations for Unit 2 and Unit 3 as shown in Table 40-1. The number of vessels using crud resins is also reported for each year; Dresden has seven condensate demineralizer service vessels per unit with six normally in service.

The plant attributes the high feedwater iron concentrations at both units in 1996 to poor layup conditions during an extended outage. With the exception of 1996 averages, feedwater iron concentrations have been improving while reactor water sulfate has remained below action limits.

Table 40-1
Summary of Dresden 2 & 3 Results With Crud Resins

Year	Feedwater Iron (ppb)		Reactor Water Sulfate (ppb)		Number of Crud Beds in Service	
	Unit 2	Unit 3	Unit 2	Unit 3	Unit 2	Unit 3
1994	3.7	5.8	0.96	1.6	1 - 6	0
1995	2.8	5.0	1.23	1.94	4 – 6	2 – 3
1996	6.7	6.8	1.58	0.79	4 – 5	2 – 4
1997	2.6	3.3	1.88	1.56	3	4 – 4
Note: 1997 data are through 8/97.						

During Cycle 14, from August 1996 through August 1997, Dresden Unit 2 had four of the seven condensate polishers charged with crud resins. The high annual feedwater iron average for 1996 reflects high iron at the start of the cycle, with 8 ppb during the first month of the cycle. Iron concentrations gradually decreased to about 5 ppb during October, 1996. In response to feedwater dissolved oxygen concentrations dropping below 10 ppb, oxygen injection into the condensate system was initiated in October 1996. In addition, repairs were made to the URC system after observing that beds were not being effectively clean. Subsequently, feedwater iron continued to decrease, reaching an average of 2 ppb or less in April and May, 1997. During this cycle, reactor water sulfate concentrations progressively increased from a starting level of approximately 2 ppb and increasing to an average of about 4 ppb (with a maximum of 6 ppb) in August 1997. The sulfate increase was attributed to

- Higher condensate temperatures due to reducing the number of operating circulating water pumps to reduce river discharge temperatures
- Poor bed cleanings due to URC problems

- Leaching from the 2A demineralizer bed which did not contain crud resin, with sulfate increasing when the bed was in service and decreasing happening when the bed was removed from service

Dresden continues to use some beds with low crosslinked cation resin to reduce feedwater iron concentrations. The plant offers a number of possible reasons why sulfate problems have not been experienced at Dresden:

- Dresden has a high capacity (3 % of feedwater flow) reactor water cleanup system, which normally operates at 2.5%.

- Dresden only loads approximately half of the condensate beds with crud resin and continues to use 10% crosslinked resin in the remainder of their beds

- Condensate temperature is usually moderate, with summer temperatures peaking at about 115 °F.

- Low crosslinked resins are cleaned more frequently than 10% resins to maintain iron removal performance and to minimize sulfate

- Cleaned beds are put on recycle to keep the beds filled with deoxygenated water

- Higher porosity anions resins, Dow SBR-P-C and Dow 550-A, were mixed with the low crosslinked cation resin based on the potential that this type of anion may be more resistant to organic fouling and kinetic impairment than standard porosity anion resins.

Nine Mile 2

Nine Mile Point 2 has installed one bed employing a low crosslinked cation resin (Dow Guardian, 8%) and a uniform particle size anion resin (Dow A500). This was done to help control feedwater iron because condensate inlet iron has increased from about 12 ppb to >19 ppb due to damage to the MSR (moisture separator reheater) in June, 1997. The bed was first placed in service on 1/28/98. An additional bed of these resins has been procured. This trial is being performed as part of an EPRI Tailored Collaboration project.

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SUMMARY

Iron and Dose Control

Basic data for an initial assessment of optimum feedwater iron have been collected from about two thirds of the U.S. BWR's. One clear finding is that BRAC dose rates correlate with the reactor water soluble Co-60 concentration, with BRAC increasing exponentially as soluble Co-60 increases above about 1E-4 μCi/ml. This is true for all plants, although the rate of BRAC increase is lower for plants adding zinc oxide. For feedwater iron of 5 ppb and below (down to the minimum of about 0.15 ppb reported by U.S. plants), soluble Co-60 continues to decrease as feedwater iron decreases and as the feedwater Fe/(Ni+Zn) molar ratio decreases.

In contrast, insoluble Co-60 does not continually decrease as feedwater iron decreases, but appears to go through a minimum for each plant. An overview of the data from the fleet points to a minimum for insoluble Co-60 in the range of roughly 1 – 2 ppb feedwater iron. Further analysis suggests that the Fe/(Ni+Zn) molar ratio may be a more universal control parameter for insoluble Co-60. Insoluble Co-60 appears to reach a minimum at a Fe/(Ni+Zn) molar ratio in the range of about 2 – 7.

The preliminary data evaluations presented in this Interim Report also raise a number of questions that provide a roadmap for additional in-depth study. Specific additional data are needed from selected plants to allow the in-depth analysis. Some of the questions and the data required to answer them are:

1. Why do plants with similar feedwater iron concentrations and Fe/(Ni+Zn) molar ratios have such widely differing reactor water soluble Co-60? Can this be explained simply by the cobalt (Stellite™) source term? **Data required**: Details on cobalt sources and cobalt reduction.

2. Do plants with higher insoluble Co-60 have a greater number of and/or higher dose rates from "hot spots?" Is there a threshold above which the impact of insoluble Co-60 becomes more severe, as is the case with soluble Co-60? **Data required**: Radiation surveys showing spots.

3. What role does the stability of plant operations play in controlling radiation transport and dose buildup? **Data required**: Power and SCRAM history.

4. What role does the stability of hydrogen injection play in controlling radiation transport and dose buildup? **Data required**: Hydrogen injection records (or alternate indicator such as reactor water dissolved oxygen or feedwater dissolved hydrogen).

5. Can reactor water activated corrosion products other than Co-60 be correlated to feedwater iron, BRAC, gamma scans and hot spots? **Data required**: Fractionated Co-58, Fe-59, Mn-54, etc.

A preliminary listing of plants selected to make specific comparisons for in-depth monitoring is given below along with reasons for selection. A summary listing is also provided in Table 41-1.

A listing of plants for which data on "hot spots" will be requested is also given in Table 41-2.

Low Iron Plants:

- Brunswick 1 & 2, WNP-2 and Limerick 1 & 2 were selected
- Brunswick and WNP-2 are high BRAC, Limerick is low BRAC
- Limerick and WNP-2 are injecting iron, while Brunswick is not
- Brunswick is on moderate HWC, while Limerick and WNP-2 have no HWC
- All three stations have recently started DZO addition; Limerick had been on NZO

Moderate to High Iron Plants:

- FitzPatrick, Oyster Creek and Susquehanna 1 & 2 were selected
- Feedwater iron averages were 1.7 ppb for FitzPatrick, 2.6 ppb for Oyster Creek, 8 – 10 ppb for the Susquehanna units
- BRAC dose rates are low for FitzPatrick, moderate for Susquehanna, high for Oyster Creek
- FitzPatrick and Oyster Creek apply HWC for recirc IGSCC mitigation, Susquehanna does not apply HWC

- Only FitzPatrick applies DZO, the others have no significant zinc source
- Susquehanna will be undergoing a change from high feedwater iron to low feedwater iron with iron addition, and from NWC to HWC

Replaced Recirculation Piping:

- Vermont Yankee and Cooper were selected
- Each replaced the recirculation piping with electropolished 316 SS
- Vermont Yankee BRAC rates are low and steady while Cooper's are increasing
- Neither plant applies HWC
- Vermont Yankee has a natural zinc source, Cooper does not nor is zinc added
- Average feedwater iron is 1.6 ppb for VY, 2.4 ppb for Cooper

Table 41-1
Summary of Plants Suggested For In-Depth Correlation of Iron and Radiation Data

Plant	Feedwater Iron	BRAC	HWC	Zinc	Other
Brunswick	Low	High	Moderate	DZO	Lowest Fe
WNP-2	Low (with Fe addition)	High	None	DZO	Cu from condenser
Limerick	Low (with Fe addition)	Low	None	DZO	
Cooper	2.4 ppb	Going Up	None	None	Electropolished Recirc. Pipe
VY	1.6 ppb	Low, Steady	None	Natural	Electropolished Recirc. Pipe
FitzPatrick	1.66 ppb	Low	>Low	DZO	
Oyster Creek	2.6 ppb	High	Low	No	
Susquehanna	8-10 ppb	Medium	None	No	Filters + HWC are coming

Table 41-2
Selected Plants For Data on "Hot Spots"

Plant	Insoluble Co-60 Range	Soluble Co-60 Range
Peach Bottom 2	High	Low
Susquehanna 2	High	Low
Oyster Creek	Low	High
Grand Gulf	Low	High
Cooper Nuclear	Low	High

Of the plants selected for data on hot spots (Table 42), only Peach Bottom 2 and Grand Gulf are additional to those plants listed in Table 41-1.

Filters

The current status of filters used in BWR condensate polishing systems can be summarized as follows:

- Additional operating experience with pleated filter septa have borne out the statements and speculative projections made in EPRI TR-107 297-V2 (8). Effluent irons less than 1.0 ppb continue to be consistently achieved and, except for early runs on some septa, have been less than 0.5 ppb. Useful service lives beyond two full-power service years still seem unlikely, except under the most favorable conditions. Summaries of performance for each of the monitored BWR units are presented later in this report.

- The ion exchange performance of precoats on pleated septa remains an open issue. Measurements of Na-24 removal at Quad Cities confirm the earlier pilot plant tests that gave the first indication of performance on pleated septa being inferior to that on yarn wound septa.

- The integrity of the filter septa and the suitability of attachment hardware have become concerns. The findings during resin bleedthrough incidents at Browns Ferry and joint failures at Duane Arnold raise the integrity issue. Observations on attachment hardware at Peach Bottom and Quad Cities raise the hardware suitability issue.

- The performance of the pleated septa at Limerick and Peach Bottom are especially significant. Although the pleated septa appear to be nearing the end of their useful lives, the septa at both stations have demonstrated an acceptable practical longevity. Among the non-precoat applications, only the applications at Laguna Verde 2, Susquehanna and Hope Creek will have RLI values significantly higher than that at Limerick. Only Browns Ferry has a RLI value significantly higher than that at Peach Bottom.

- The early declines in run lengths for the Memtec pleated septa at Laguna Verde Unit 1 are also significant. Prior to their use at Laguna Verde, the only sustained use of Memtec pleated polypropylene filter septa was at Perry where the septa operated for an entire fuel cycle before they were backwashed. Only recently, during 1997 when the CDI iron increased and heater drains were temporarily cascaded to the condenser were there any signs of aging on the Perry pleated septa. The application challenge severity at Laguna Verde is about twice as high as that Perry

- Of the uncertainties and problems associated with non-precoated and precoated pleated filter septa, those of the precoated septa precoat appear to be the most problematic. However, the most challenging applications of the non-precoated septa remain in the future.

- There are at least three major areas of uncertainty that bear on the practicality of precoated pleated septa. First, can problems with resin passage be acceptably solved? Second, is ion exchange performance of precoats on pleated septa sufficient to allow continued full power operations during periods of minor condenser leaks? Third, do precoats have adverse or beneficial effects on run lengths and septa useful lives?

- Additional factors, not encountered when using non-precoated, must be addressed when using precoated pleated septa. Precoat material types, doses and application techniques affect the total performance and useful lives of precoated septa. Despite the additional complications and remaining uncertainties, efforts to improve septa, precoat materials, and to develop effective operating techniques are all justified by the potential cost savings to be realized from longer run lengths and reduced precoat doses.

The filters in plants listed in Table 2-2 will continue to be monitored through 1998 to answer questions on useful life, ion exchange performance and resin leakage. The performance of condensate filters at Susquehanna 1 will also be monitored. The results will be compared to expectations relative to iron control and application challenge severity. Implementation practices and "lessons learned" will be documented to provide guidance on field implementation.

Resins

Plants with "deep bed only" condensate polishing using 10% crosslinked resins and different resin cleaning methods will continue to be monitored for iron removal performance. These plants will include:

- FitzPatrick: Standard resins with URC
- Grand Gulf: Standard resins with ARC (Advanced Resin Cleaner)
- River Bend: Standard resins with URC
- Oyster Creek: Dow C-500/SBR-C resin mixture with JRC (Japanese Resin Cleaner)

These plants appear to have the capability to approach or achieve the current feedwater iron target range of 0.5 - 1.5 ppb. As appropriate, details on resin or system management practices that may be important for iron control, such as resin cleaning frequency or preventive maintenance, will be documented.

FitzPatrick has implemented the practice of performing a gross separation of the cation and anion resins after each cleaning to return a layered bed to the service vessel, with the anion layer on the bottom for sulfate control. The plant has also extended the time between resin cleaning from 65 days to about 100 days. The impact of these changes will be monitored.

Plants using low crosslinked cation resins for enhanced iron control will also continue to be monitored. These plants are listed below along with the type of low crosslinked cation resin used and the resin cleaning method:

- Dresden: Dow Guardian (8% nominal crosslink) cation resin, current resin cleaning method is URC but planning a retrofit to ARC
- Nine Mile Point 2: Dow Guardian (8% nominal crosslink) cation resin, resin cleaning method is a combination or Air Scrub & Backwash and URC

As appropriate, details on resin and system management practices that may be important for iron and sulfate control will be documented.

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