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Ref: #10CFR50.54

CPSES-200501565
Log # TXX-05135

July 27, 2005

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES)
DOCKET NOS. 50-445 AND 50-446
SUBMITTAL OF THE RESULTS OF POST IRRADIATION
EXAMINATION OF FUEL CLADDING FOLLOWING
UNIT 2 CYCLE 8 OPERATION WITH ELEVATED PH

REF: (1) Letter logged TXX-02037 from C. L. Terry to the NRC, dated February 18, 2002.
(2) Letter logged TXX-04016 from M. R. Blevins to the NRC, dated January 27, 2004.

Gentlemen:

Per Reference 1 above, TXU Generation Company LP (TXU Power) committed to provide the NRC with the post irradiation examination (PIE) results and associated data for fuel corrosion monitoring of fuel at Comanche Peak Unit 2 for a demonstration elevated pH program. The report summarizing the PIE results obtained following Unit 2, Cycle 7 operation at an intermediate elevated pH$_t$ level of 7.3 was provided in Reference 2.

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The specific actions to which TXU Power committed are delineated as follows:

| Commitment Number | Commitment |
|---|---|
| 27258 | In addition, TXU Generation Company LP will provide the following information, consistent with the guidance provided in WCAP-15604-NP, Revision 1, "Limited Scope High Burnup Lead Test Assemblies," October 2001 |

| | |
|---|---|
| Utility Name: | TXU Generation Company LP |
| Plant Name: | Comanche Peak Steam Electric Station, Unit 2 |
| Cycle LTA Inserted: | Cycle 7 |
| No. of LTAs: | 8 |
| LTA Burnup: | Fresh assemblies inserted in Cycle 7; maximum burnup at discharge < 60 GWD/MTU. |
| Planned Post Irradiation Examinations (PIEs): | Clad oxide measurements and visual examinations |
| Schedule for PIE and Release of Results: | PIEs are currently planned to be conducted following Cycle 7 and Cycle 8 of Unit 2 operation (nominal 18 month cycle length). |

A summary of the PIE and associated data results will be provided within 90 days after completion of each outage following Unit 2 Cycle 7 and Cycle 8.

TXU Power hereby responds to the above commitment. Attached is a report summarizing the PIE results following Unit 2, Cycle 8 operation at an elevated $pH_t$ of 7.4. This level represents the final phase of the demonstration elevated pH program at Comanche Peak. The data associated with the PIE results are provided on the enclosed compact disk. With the submission of this report and data, TXU Power considers the above commitment closed.

This communication contains no new licensing basis commitments regarding CPSES Units 1 and 2. Should you have any questions, please contact Mr. J. D. Seawright at (254) 897-0140.

Sincerely,

TXU Generation Company LP

By: TXU Generation Management Company LLC
Its General Partner

Mike Blevins

By: ____________________
Mitchell L. Lucas
Vice President Nuclear Engineering

JDS

Attachment - Elevated pH Program for Comanche Peak Steam Electric Station - Final Report

Enclosure - Compact Disk containing data associated with PIE Results

c - B. S. Mallett, Region IV (attachment only)
M. C. Thadani, NRR (attachment only)
Resident Inspectors, CPSES (attachment only)

# TXU Power

# Elevated pH Program for Comanche Peak Steam Electric Station

Final Report

July 2005

# TXU Power
# Comanche Peak Unit 2
# Elevated pH Program - Final Report – July 2005

## Introduction

Constant-elevated reactor coolant pH chemistry control and its benefit in terms of crud management may potentially be used to reduce plant radiation levels and avoid operational and economic issues associated with PWR axial offset anomaly (AOA). The demonstration of crud management through this principle has been successful in both research and operating experience for plants operating with relatively low reactor coolant boron levels. However, the potential risk of corrosion enhancement to fuel cladding or structural components must be carefully evaluated for modern plants and core designs utilizing higher reactor coolant boron concentrations which thereby require much higher lithium concentrations to achieve elevated pH.

## Background

The primary purpose for the investigation of operation at an elevated reactor coolant pH level was to address the increase in plant radiation fields with plant age. The results of on-going attempts to optimize reactor coolant chemistry control programs prompted the initiation of the current program to qualify operation at an at-temperature reactor coolant $pH_t$ of 7.4 with lithium concentrations up to 6 ppm, which is believed to be the optimum chemistry for crud management.

For many plants, the more recent phenomenon of Axial Offset Anomaly (AOA) is a significant impediment to further optimization of reactor core designs for economic performance. AOA is the result of a combination of factors including fuel rod sub-cooled boiling, crud deposition, and boron hideout inside the crud deposits. Primary chemistry controls have been identified as one potential means of reducing AOA susceptibility. Elevated pH, held constant throughout the fuel cycle, is known to reduce the source, transport, and deposition of corrosion products on nuclear fuel. However, the increased boron requirements for modern core designs require significant increases in lithium concentration to attain desired constant-elevated pH conditions. Therefore, a comprehensive engineering evaluation followed by fuel clad oxide measurements of the possible impact of these lithium increases on fuel clad corrosion susceptibility was necessary.

The assessment of risk for lithium enhanced corrosion of nuclear fuel clad was performed independently by Westinghouse and Framatome ANP for their respective fuel and clad materials to be employed in the demonstration program at Comanche Peak Steam Electric Station. Westinghouse performed evaluations for Zircaloy-4 and ZIRLO™ clad fuel, while Framatome ANP performed evaluations for optimized low tin Zircaloy-4 clad fuel. The two vendor evaluations of fuel related corrosion provided similar conclusions and identified similar parametric factors important to the evaluation. Risk associated with the demonstration, at plant-specific conditions, was judged to be small.

In addition, Westinghouse performed the evaluation for the potential of increased risk of stress corrosion cracking of system structural components. Assessment of risk for increased corrosion susceptibility to structural components identified steam generators as the most susceptible component. The effect of increasing lithium to 6 ppm was judged to be relatively small when compared to factors such as material properties, temperature and stress.

All assessments caution that the results of this evaluation are specific to the proposed core designs for the demonstration and that the potential for lithium enhanced corrosion should be evaluated on a plant and cycle specific basis, prior to instituting an elevated lithium program.

## CPSES Demonstration Elevated pH Project

The elevated pH demonstration program at Comanche Peak Steam Electric Station (CPSES) consists of a two phased approach for achieving the desired constant reactor coolant $pH_t$ of 7.4. The demonstration project includes tasks specific to each phase, beginning with the pre-demonstration assessment activities. The phases of the demonstration and post-operation assessments are as follows:

- Assess the influence of operating with a $pH_t$ of 7.4 with a maximum lithium concentration of 6 ppm on fuel cladding oxide growth relative to the plant specific core design, and vendor specific fuel cladding.
- Assess the influence of operating with a $pH_t$ of 7.4 with a maximum lithium concentration of 6 ppm on primary system materials susceptibility to primary water stress corrosion cracking (PWSCC).
- Demonstrate one cycle (U2C7) of operation with a constant $pH_t$ of 7.3 and perform interim evaluation of both operating cycle data and refueling outage (2RFO7) inspection results.
- Demonstrate one cycle (U2C8) of operation with a constant $pH_t$ of 7.4, and perform evaluation of both operating cycle and refueling outage (2RFO8) inspection results.

Two major assessment tasks were performed to evaluate potential impact of the specified chemistry conditions on expected performance of nuclear fuel and reactor coolant system materials. Results of the pre-demonstration task were supportive of the proposed demonstration and no significant issues or risks were identified. Corrosion enhancement of the fuel cladding was not predicted for the proposed power histories, and the expected oxide thickness was well within the fuel cladding corrosion allowances of the respective fuel designs.

The potential for minor increases in susceptibility to PWSCC was identified and particularly for the Comanche Peak Unit 1 steam generator tube materials, which have Alloy 600 MA tubing. Comanche Peak Unit 2 steam generators use Alloy 600 TT tubing, which has proven to be more resistant to PWSCC. The assessment conclusions found, at most, a minor effect of the proposed chemistry changes, which were judged acceptable and low risk.

It was decided to implement the proposed chemistry changes in two steps starting with one operating cycle where the conditions were limited to constant $pH_t$ of 7.3 and a maximum lithium concentration of 5 ppm. Assuming expected results, the chemistry conditions for the next operating cycle would be revised to constant $pH_t$ of 7.4 and a lithium limit of 6 ppm.

Each phase of operation included detailed tasks for chemistry monitoring and fuel surveillance to verify expected conditions, evaluate results and to capture lessons learned. Some of these tasks were directed at secondary objectives and chemistry parameters that were considered relevant indicators of changes in crud behavior.

The impact of elevated constant pH on radiation fields has been a long-term interest to the industry and capturing these effects is a key objective of the demonstration. Due to the decay of radionuclides in existing ex-core deposits, it is expected that trends may not reach a new equilibrium or dose plateau until after three or more cycles at the optimum pH.

Post demonstration fuel surveillances were planned to capture the effect of elevated pH and higher lithium concentrations on corrosion oxide thickness for both Framatome ANP Low Tin Zircaloy-4 and Westinghouse ZIRLO™ fuel clad materials. This plan included evaluation of power histories for both low and high duty assemblies. Full height visual inspections and evaluation of crud deposits is another key objective of the fuel surface examinations.

During the refueling outage following Cycle 6 operation (2RF06), oxide measurements were performed on selected irradiated fuel assemblies which were to be reloaded into Cycle 7 in order to benchmark the oxide thickness of these assemblies prior to implementing the elevated pH program. The demonstration program at CPSES Unit 2 began in the spring of 2002 by increasing the reactor coolant $pH_t$ to 7.3 for Unit 2, Cycle 7 with a maximum lithium concentration of 5 ppm. During the refueling outage following Cycle 7 (2RF07), oxide measurements were again performed on selected irradiated fuel assemblies to assess the impact of one cycle of operation at a reactor coolant $pH_t$ of 7.3. Based on the satisfactory results of the oxide measurements obtained in 2RF07, reactor coolant $pH_t$ was increased to 7.4 in the fall of 2003 for Unit 2, Cycle 8 for the final phase of the program. This report provides a summary of the results of the oxide measurements performed following Cycle 8 (2RF08) with one full cycle of operation of CPSES Unit 2 at an elevated $pH_t$ of 7.3 and one cycle of operation at an elevated $pH_t$ of 7.4.

## Description of Work Scope

Including: Fuel Assembly Identification Numbers
Measuring Equipment and Calibration and Accuracy

Eleven fuel assemblies from Cycle 8 were included in this inspection. The fuel assembly ID, the number of cycles operated, and the fuel vendor for each assembly are given below.

| | | |
|---|---|---|
| HH39 | 3rd burn | Framatome ANP |
| JJ23, JJ83 | 2nd burn | Framatome ANP |
| JW01, JW05, JW06, JW07 | 2nd burn | Westinghouse |
| KK04, KK30, KK35, KK52 | 1st burn | Westinghouse |

Full-face camera inspections were performed on all four faces of each assembly. Fuel cladding corrosion thickness was measured on the outward-facing surface of peripheral fuel rods. Six peripheral rods were measured on two faces of each assembly. Measurements on all rods were performed along all the spans between the spacer grids. A high magnification camera recorded visual images of the fuel rods as the oxide measurements were performed.

Measuring Equipment Description, Calibration, and Accuracy

The oxide measuring system is an eddy current system. The system is used to electronically process signals from an eddy current probe that is positioned against the fuel rod. Like all similar electronic instruments, the accuracy is diminished at the extreme ends of the operating range. To minimize this phenomenon, the calibration of the instrument is checked periodically throughout the data collection process. Very thin oxide layers (less than 5 microns) may sometimes be recorded as negative values. Values of the measured oxide thickness at these levels are considered to be insignificant when compared to the more limiting grid spans at the top of the fuel assembly. Negative readings are considered to be very thin oxide (less than 5 microns).

Crud is typically present in varying degrees on the fuel rod clad surface. If the crud is light and loosely attached, the probe will usually pass through unaffected. However, if the crud is thick and higher-density, the probe will skim over the surface of the crud-affected areas. This will cause the recorded values to have both an oxide thickness component and a crud thickness component. The system used for these measurements has no method for distinguishing between corrosion thickness and crud thickness. Cleaning (by brushing with Scotch-brite pads) and re-measuring the rods may provide some information about the magnitude of any crud component. However, all deposited crud may not be removed and it is difficult to visually determine the effect tenacious crud deposits may be having on the oxide data results.

No brushing was performed during this inspection campaign.

## Results

Including: Visual Inspection Results
Oxide Measurement Results

Assembly Visual Inspections

Full-face visual inspections were performed on all assemblies selected for peripheral fuel rod corrosion measurements. All four faces of the assemblies were viewed. The visual inspections were primarily focused on characterizing the crud and corrosion accumulation. Since corrosion on all assemblies appeared normal and uniform, this section will discuss the observed crud patterns.

Crud observations are described using similar terminology as was used in prior inspection campaigns. The terms "thin" and "heavy" are used only as relative terms to distinguish between the types of crud observed during these oxide measurement campaigns. The crud observed during this inspection manifested itself as a uniform, very thin brown crud, a localized dark crud, or a localized heavy brown crud. The uniform thin brown crud was observed on every assembly at the top half of Span 7 (span numbering starts from the bottom). Presence of a thin layer of crud at this position is very common. Some types of localized crud types can affect the oxide thickness values.

After observing the crud on all assemblies, it appears that the dark crud is a precursor for the heavier brown crud. Locations of dark crud deposition are much smaller in area and probably have not yet achieved enough accumulation for the crud color to become apparent. The localized heavy brown crud was not observed in prior inspection campaigns. It formed in larger patches that had greater thickness and covered more of the rod surface than the dark crud. The heaviest deposition occurred just below grids 6 and 7. At these locations, accumulation was greatest and surface texture of the crud could be observed in some assemblies. At all other areas, the brown crud surface was smooth and appeared to be less thick. This type of brown crud appeared on assemblies that had high relative powers in Cycle 8 and appeared on both first-burn and second-burn assemblies.

Assembly HH39 (3rd burn F-ANP) did not have any significant crud deposition. It operated on the core baffle for all three cycles. Localized crud deposition would not be expected on this assembly due to its low relative power.

Assemblies JJ23 and JJ83 (2nd burn F-ANP) showed differences in localized crud deposition. Assembly JJ23 had mostly dark crud, with the heavy brown crud showing up only on Face 1 (Side C) in Span 6 in small spots just below Grid 7. Assembly JJ23 had rods with relative powers around 1.00 for Cycle 8. Assembly JJ83 had a significant accumulation of heavy brown crud in Spans 5 and 6 on Face 3 (Side A). This face had rods with very high relative powers of 1.27 for Cycle 8. Heavy brown crud was also observed on a few rods in Spans 5 and 6 of Face 4 (Side B).

Assemblies JW05 and JW07 (2nd burn Westinghouse symmetric partners) had heavier brown crud in Span 6 of almost all faces. Dark crud was observed in Span 5 on most faces. These assemblies had fuel rod relative powers around 1.10 for Cycle 8.

Assemblies JW01 and JW06 (2nd burn Westinghouse symmetric partners) did not show any heavy brown crud. Overall, the crud deposition was much less, with dark crud appearing only in Span 6 on some faces. This would be expected as these assemblies had fuel rods with much lower relative powers (around 0.80).

The 'KK' assemblies (1st burn Westinghouse) showed the localized dark crud and the heavier brown crud. The greatest crud deposition occurred on Assemblies KK30 and KK35. These assemblies had dark crud and heavier brown crud in Spans 5 and 6. They also both had dark crud appearing on some fuel rods in Span 7, the only times that localized crud appeared in that span. Assemblies KK04 and KK52 showed much less crud accumulation. Almost all localized crud appeared in Span 6, with a few minor spots in Span 5.

Oxide Measurement Summary

One third-burn F-ANP assembly had measured fuel rods with burnup ranging from 33,700 to 39,100 MWD/MTU. Peak oxide thickness for these rods ranged from 24 to 35 microns.

Two second-burn F-ANP assemblies had measured fuel rods with burnup ranging from 35,200 to 49,200 MWD/MTU. Peak oxide thickness ranged from 27 to 79 microns. Peak corrosion values for assembly JJ83 were probably affected by crud. There was some evidence of oxide blistering on Face 2 of assembly JJ23, which also corresponded to the greatest oxide thickness.

Four second-burn Westinghouse assemblies had measured fuel rods with burnup ranging from 29,400 to 48,400 MWD/MTU. Peak oxide thickness ranged from 13 to 68 microns. Peak corrosion values for assemblies JW05 and JW07 were possibly affected by crud.

Four first-burn Westinghouse assemblies had measured fuel rods with burnup ranging from 25,000 to 28,200 MWD/MTU. Peak oxide thickness ranged from 9 to 24 microns. Peak corrosion values for assemblies KK30 and KK35 were possibly affected by crud.

Comparison to Previous Inspection Results

Although the overall amount of crud deposited on the fuel assemblies is not high, the amount of localized crud deposition has increased relative to prior campaigns. The localized dark crud observed from Cycle 7 formed in thin axial strips along the length of the fuel rods. The heavy brown crud observed in Cycle 8 covered larger areas of the rod, but for the most part was thinner than the dark crud seen in Cycle 7. Near the top of the spans 5 and 6, the brown crud typically became thicker and below grids 6 and 7 had significant thickness. So, overall, the Cycle 7 crud may be characterized as limited and thick, and the Cycle 8 brown crud characterized as more widespread but thinner. However, it is difficult to quantify the crud thickness without performing extensive crud scraping and analysis.

Corrosion performance did not seem to change for Framatome ANP assemblies from Cycle 6 to Cycle 8. Corrosion for first-burn Westinghouse assemblies increased slightly from Cycle 7 to Cycle 8, however most first burn measurements agreed well within best estimate predictions and all were well within upper bound predictions. The peak thickness of 79 microns for the Framatome ANP fuel occurred on Assembly JJ23, Face 2, Rod 14 (location D17). This value is similar to what was obtained in the previous inspections at EOC-6 and EOC-7. Maximum values from those inspections were 85 and 94 microns, respectively. The total burnup for this fuel rod after two cycles of operation was 48,800 MWD/MTU. Fuel rods with the peak corrosion from the two previous inspections also occurred after two cycles of operation and had burnups of 51,600 MWD/MTU and 50,000 MWD/MTU. Two other fuel rods from EOC-7 had peak corrosion thickness of 92 microns with 48,800 MWD/MTU burnup.

Averages of peak corrosion values for fuel rods with similar burnups and cycles of operation were calculated and compared. The average peak corrosion for the Framatome ANP fuel has remained fairly stable from Cycle 6 through Cycle 8. Despite having peak corrosion thickness of 98 in Cycle 7 and 79 in Cycle 8, it can be concluded that the corrosion levels for the F-ANP fuel assemblies have not changed significantly. The data also shows that oxide results from the Framatome ANP fuel do not show any significant difference between the three campaigns after having operated at different lithium concentrations.

The corrosion measurements for the second-burn Westinghouse assemblies are within the ZIRLO™ experience range for the same levels of burnup. The peak oxide thickness of 68 microns for the Westinghouse fuel occurred on Assembly JW05, Face 2, Rod 10 (location H17). The total burnup for this fuel rod after two cycles of operation was 48,400 MWD/MTU. This is the only group of Westinghouse ZIRLO™ assemblies to operate for two cycles at Comanche Peak, so comparison to assemblies operating in an environment of low lithium concentration is not possible. However, the burnup for this assembly is similar to the burnup achieved by the Framatome ANP peak corrosion assemblies.

The data shows a slight increase in the peak oxide thickness for Westinghouse first-burn fuel when comparing Cycle 7 to Cycle 8. Data shows that peak corrosion thickness increased from 10 microns to 18 microns, however it also shows that the average burnup was slightly higher for Cycle 8. It is difficult to conclude whether an 8 micron change is statistically significant or just the result of normal measurement variation.

## Conclusions and Comments

Corrosion thickness for Framtome ANP assemblies appears to have remained fairly consistent between Cycle 6 and Cycle 8. There is no indication of any increases based on the changes to coolant chemistry.

Measured corrosion thickness for first-burn Westinghouse assemblies increased slightly between Cycle 7 and Cycle 8. At this point, it is difficult to conclude whether this increase is the result of a causal factor specific to Cycle 8 or just normal variation in corrosion performance. In any case, all first-burn data fit well with the Westinghouse ZIRLO™ experience. Higher burn Westinghouse assemblies only exist for Cycle 8, so no comparisons can be made to earlier inspection measurements.

Crud deposition from Cycle 8 was higher than that observed during the previous two inspections although the overall amount of crud on fuel assemblies in Unit 2 still remains relatively low. Very little localized crud was observed during Cycle 6. A dark, localized crud appeared more often in Cycle 7. In Cycle 8, a more widespread brown crud was observed on many fuel rods and assemblies.

High magnification video also showed the possible presence of oxide blisters on Face 2 of Assembly JJ23. However, the quality of the recorded video does not allow a conclusive judgment. Fuel rods from this face exhibited the highest corrosion values during this inspection. It is not unexpected for oxide blistering to be present at these corrosion levels.

Based on the results above, it was concluded that continued operation of Unit 2 at an elevated $pH_t$ of 7.4 was acceptable for Cycle 9 and beyond.