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U. S. Nuclear Regulatory Commission
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SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES)
DOCKET NO. 50-445
CPSES UNIT 1 CONDITION MONITORING REPORT FOR THE EIGHTH REFUELING OUTAGE (1RF08)

Gentlemen:

Enclosed is the condition monitoring report pursuant to the guidance provided in the Nuclear Energy Institute (NEI) 97-06, Rev. 1, Section 3.1.7.

This communication contains no new licensing basis commitments regarding CPSES Units 1 and 2.

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TXU

Should you have any questions or need additional information please contact Obaid Bhatty at (254) 897-5839.

Sincerely,

C. L. Terry

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COMANCHE PEAK STEAM ELECTRIC STATION UNIT 1 EIGHTH REFUELING OUTAGE (1RF08) CONDITION MONITORING REPORT SUMMARY

1.0 INTRODUCTION

In accordance with NEI 97-06 Revision 1, a condition monitoring assessment which evaluates structural and leakage integrity characteristics of Steam Generator (SG) eddy current indications is to be performed following each inspection. This evaluation provides an assessment of the Comanche Peak Steam Electric Station (CPSES) Unit 1 steam generator tube structural and leakage integrity based on the 2001 EOC-8 eddy current inspection results. Condition monitoring is "backward looking" and compares the observed EOC-8 steam generator tube eddy current indication parameters against structural and leakage integrity commensurate with draft RG 1.121. This report documents the condition monitoring of the NDE results from the CPSES Unit 1 eighth refueling outage (1RF08) inspection, performed in March/April 2001.

The CPSES Unit 1 SGs are Westinghouse Model D4 SGs with mill annealed Alloy 600 tubing, full depth mechanical (hardroll) expanded tube to tubesheet joints, and carbon steel tube support plates with drilled tube holes and drilled flow holes. A small number of tubes in each SG are expanded in the tubesheet using the WEXTEX explosive expansion process.

2.0 OVERALL CONCLUSIONS

During the CPSES 1RF08 steam generator tube inspection, no indications exceeding the structural integrity limits for either axial or circumferential degradation (i.e., burst integrity ≥ 3 times normal operating primary to secondary pressure differential across SG tubes) were detected; therefore, no tubes were identified to contain eddy current indications that could potentially challenge the Reg. Guide 1.121 tube integrity recommendations. Based on the observed indications at 1RF08, the CPSES Unit 1 SGs are expected to meet all structural and leakage integrity requirements at 1RF09.

3.0 PRE-OUTAGE EVALUATION OF SG DEGRADATION STATUS

CPSES 1RF08 Inspection Plan

The CPSES 1RF08 inspection plan exceeded both the Technical Specification minimum requirements as well as the recommendations of EPRI TR-107569-V1R5, PWR Steam Generator Examination Guidelines: Revision 5, Volume 1: Requirements. The 1RF08 initial inspection plan included;

1) 100% full length bobbin examination in Rows 3 and greater in all 4 SGs, 100% bobbin inspection in the hot and cold leg straight sections of Rows 1 and 2
2) 100% hot leg top of tubesheet (TTS) +Pt examination in all 4 SGs
3) 100% Row 1 and 2 U-bend mid-range +Pt examination in all 4 SGs
4) 20% Row 1 high frequency +Pt examination in all 4 SGs

5) Rotating probe examination of mixed residuals (> 1.5 volts as measured by bobbin) and hot leg dented intersections ≥ 5 volts (as measured by bobbin) according to the requirements of GL 95-05
6) Rotating probe examination of freespan bobbin coil indications for flaw confirmation and characterization
7) 100% +Pt inspection of all dented TSP intersections ≥ 2 volts at the H3 TSP
8) 20% +Pt inspection of hot leg and cold leg straight length freespan dings > 5 volts plus 20% +Pt inspection of freespan dings > 5 volts between H11 and AVB1 and AVB4 and C11
9) 20% +Pt freespan paired ding inspection between the top 2 TSPs
10) Tube plug visual inspection

The inspection plan was developed to specifically address the areas of active degradation as well as areas expected to be affected based on recent industry experience as well as experience from the CPSES 1RF07 outage in September 1999.

Based on a reported C-3 condition in SGs 2, 3, and 4 due to the detection of >45 circumferentially oriented ODSCC indications, the top of tubesheet +Pt inspection program was expanded to include 20% of the cold leg TTS expansion transitions in these SGs. No degradation was reported in this expansion program.

Pre-Outage Degradation Assessment

A pre-outage degradation assessment pursuant to EPRI TR-107621 R1 was performed for CPSES 1RF08. This degradation assessment identified the degradation modes which could occur at CPSES Unit 1 and evaluated the adequacy of the eddy current techniques applied for detection and sizing of these mechanisms.

Per EPRI TR-107569-V1R5, "PWR Steam Generator Examination Guidelines: Revision 5 Volume 1: Requirements", an active degradation mechanism is:

1. A combination of ten or more new indications of degradation (≥20% TW) and previous indications of degradation which display an average growth rate ≥25% of the repair limit per cycle in any one SG or,

2. One or more new or previously identified indications of degradation, including cracks, which display a growth rate equal to the repair limit in one cycle of operation.

Based upon the likelihood of indications, the degradation assessment classified degradation mechanisms as active, relevant, or potential, with correspondingly decreasing likelihood of initiation and potential impact upon SG tube integrity. The degradation assessment concluded that the following degradation mechanisms are active (as defined by EPRI TR-107569-V1R5) in the CPSES Unit 1 SGs.

- Axial ODSCC at TSP intersections
- Circumferential and Axial ODSCC at the hot leg TTS expansion transition

Degradation Structural Limits

The CPSES 1RF08 pre-outage degradation assessment identified length and depth based structural limits for freespan axial and circumferentially oriented degradation. Lower bound length and depth based structural limits were developed for volumetric degradation modes (i.e., AVB wear, TSP wear) based on previously published industry data and correlations. The degradation assessment provides the structural limits and NDE uncertainties to support the condition monitoring evaluation.

3.1 1RF08 Identified Degradation Mechanisms

Indications suggestive of the following degradation mechanisms were detected in the CPSES 1RF08 inspection:

- Axial ODSCC at TSP intersections (not confirmed by +Pt)
- Axial ODSCC at the Hot Leg TTS expansion transition
- Circumferential ODSCC at the Hot Leg TTS expansion transition
- Axial PWSCC at the Hot Leg TTS expansion transition
- Axial ODSCC at freespan dings <5V
- Freespan Volumetric indications
- AVB wear
- Wear at non-expanded preheater baffle intersections
- Wear due to loose parts or foreign objects

The 90-day report for axial ODSCC at TSP intersections has been documented in a separate ARC report1, as part of analyses required per NRC Generic Letter 95-05.

Identified axial ODSCC and circumferential ODSCC indications at the TTS were, in general, not sufficient in magnitude to warrant in situ testing. One indication had a PDA value that exceeded the screening value and was pressure tested. Additionally, the largest amplitude circumferential ODSCC indication in this SG was also pressure. No leakage or burst was reported. An assessment of circumferential ODSCC flaw structural integrity is provided in SG-01-04-003 (Proprietary). As the largest reported1RF08 circumferential ODSCC amplitude was 0.35 volts, the implied burst capability of this flaw is approximately 8000 psi, using a lower bound through the +Pt amplitude vs. burst pressure data. The flaw amplitudes and arc lengths of the identified circumferential ODSCC degradation at the TTS were consistent with or below previously observed limiting indication levels that were in situ tested at 1RF06 and 1RF07. Pressure testing decisions were made based on 1RF08 PDA levels and flaw amplitudes. Comparison with previous in situ pressure test results are used for information purposes only.

Table 1 presents a summary of the number of repaired tubes in each SG and identifies the mechanism that necessitated the repair. A summary of all repaired tubes, including tubes plugged for degradation, tubes preventively plugged, and tubes permitted to remain in service by application of the voltage based alternate repair criteria per GL 95-05, and F*, is provided in Table 2.

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1 Refer to TXU Electric letter to the NRC logged TXX-01125 dated July 25, 2001.

Disposition Techniques for Identified Degradation Mechanisms

Depth measurement of AVB wear indications and non-expanded preheater baffle plate wear using the bobbin coil is acceptable per industry standards, and these indications were sizedand compared against the 40% depth repair criteria. ODSCC indications at the TSP intersections were sized based on voltage using the bobbin coil according to guidance contained in GL 95-05. Indications greaterthan or equal to 1 volt by bobbin were RPC inspected for flaw confirmation, even though only those DSIs >1 volt are required to be +Pt inspected per GL 95-05. Indications identified in exclusion zones related to tube collapse potential near TSP wedges were RPC inspected, and if confirmed, were repaired regardless of voltage. No bobbin indications at TSP intersections were reported in exclusion zones. No mixed residual indications >1.5 volts by bobbin were detected, therefore, none were RPC inspected.

All(one) crack-like indications in the expansion transition down to the F* distance were repaired upon detection since depth sizing techniques at this location are not approved for justification of continued operation.

To reduce the potential for an axially oriented ODSCC indication to be obscured by baffle wear, all newly reported occurrences of preheater baffle wear by bobbin were RPC inspected. No ODSCC was detected.

Indications previously called volumetric, have in the past been reviewed, and determined to be attributed to deposits, MBMs, dings and bulges, or tube material property changes which sometimes occur after power operation. SVI calls by RPC not associated with loose parts that did not have a corresponding bobbin MBM signal in the baseline, were conservatively repaired at 1RF08. All loose part wear signals were conservatively repaired at CPSES.

Any tube scheduled for a particular test (such as full length bobbin), that could not be tested due to a restriction in the tube or due to poor data quality, was conservatively repaired.

Table 1:
Summary of CPSES 1RF07 Plugging Repair Statistics: Number of Tubes Repaired for Observed Degradation Only **

Degradation Mode	HL sludge pile (>1" above TTS)	HL TTS Exp. Transition down to F*	CL TTS Exp. Transition down to F*	Hot Leg TSP	Freespan	U-bend	Baffle Wear		Total
SG 1									
Axial ODSCC	0	0	0	0	0	1	0		1
Axial PWSCC	0	0	0	0	0	0	0		0
Circ. ODSCC	0	2	0	0	0	0	0		2
Wear	0	0	0	0	4	0	0		4
Volumetric	0	1	0	0	0	0	0		1
Sub Total	0	3	0	0	4	1	0		8
SG 2									
Axial ODSCC	0	0	0	0	0	0	0		0
Axial PWSCC	0	0	0	0	0	0	0		0
Circ. ODSCC	0	47	0	0	0	0	0		47
Wear	0	0	0	0	0	0	0		0
Volumetric	0	0	0	0	5	0	0		0
Sub Total	0	47	0	0	5	0	0		52
SG 3									
Axial ODSCC	0	1	0	0	0	0	0		1
Axial PWSCC	0	1	0	0	0	0	0		1
Circ. ODSCC	0	78	0	0	0	0	0		78
Wear	0	0	0	0	0	0	2		2
Volumetric	0	0	0	0	0	0	0		0
Sub Total	0	80	0	0	0	0	0		82
SG 4									
Axial ODSCC	0	0	0	0	0	0	0		0
Axial PWSCC	0	0	0	0	0	0	0		0
Circ. ODSCC	0	51	0	0	0	0	0		51
Wear	0	0	0	0	0	0	1		1
Volumetric	0	0	0	0	1	0	0		1
Sub Total	0	51	0	0	1	0	0		53
Overall Total	0	181	0	0	5	1	3		190

**:Preventive tube repairs with no observable degradation are not included.

Table 2
Summary of Repaired Indications and Indications Justified for Continued Operation by Application of ARCs: CPSES 1RF08, April 2001
Values Apply to 1RF08 Inspection Only

SG	Tubes Repaired by Plugging	Tubes Repaired for Crack-like Defects	Tubes Repaired for Volumetric Signals Including Wear	Tubes Preventively Plugged	Tubes Permitted to Remain in Service by TSP ARC	Tubes Permitted to Remain in Service by F*	Total Tubes Permitted to Remain in Service by ARCs (5)
1	11	3	5	3 (1)	23 (23 indications)	0	23
2	58	47	5	6 (2)	23 (23 indications)	0	23
3	85	80	2	3 (3)	19 (19 indications)	0	19
4	55	51	2	2 (4)	171 (197 indications)	0	171
Total	209	181	14	14	236 (262 indications)	0	236

(1) Includes 1 tube repaired due to a restriction and 2 tubes repaired due to foreign object interaction but no wear

(2) Includes 1 tube repaired due to a restrictions, 1 tube repaired due to PVN in the expansion transition, and 4 tubes preventively repaired due to foreign object interaction but no wear

(3) Includes 1 tube repaired due to data quality and 2 tubes repaired due to PVN in the expansion transition

(4) Includes 2 tubes repaired due to data quality

(5) The actual number of tubes returned to service may be less than the listed value based on plugging for other reasons

4.0 CONDITION MONITORING EVALUATION

4.1 Condition Monitoring Evaluation of Active Degradation Mechanisms as Classified by the Pre-Outage Degradation Mechanism

4.1.1 TTS Circumferential Flaw ODSCC Condition Monitoring Evaluation

Structural integrity of circumferential indications at the TTS is defined by EPRI TR-107197,"Depth Based Structural Integrity of Circumferential Indications". The controlling parameter with regard to structural integrity of circumferential indications is the percent degraded area, or PDA. The PDA represents the percentage of degraded cross sectional area of the tube.

The burst correlation for circumferential indications is documented in EPRI TR-107197, "Depth Based Structural Analysis Methods for SG Circumferential Indications". The burst curve was used to develop the 100%TW critical crack angle value of 277° for CPSES Unit 1 at 3ΔP conditions. Screening of indications for selection as in situ test candidates was performed at CPSES Unit 1 using a methodology that is consistent with EPRI Report TR-107620-R1, "Steam Generator In Situ Pressure Test Guidelines".

For in situ testing purposes, screening limits are applied to identify the most relevant subset of indications for testing. For proof test screening of circumferential indications, the first screen is crack angle ≥ 187°, and the second screen is average voltage (in Eddynet multiscan mode), or voltage integral, ≥ 0.30 volts. Indications exceeding both screens are depth profiled to determine percent degraded area (PDA). Indications with PDA ≥ 47% in hardroll expanded tubes, 55% in WEXTEX expanded tubes, determined by +Pt depth profile analysis are proof tested. PDA sizing uncertainties for hardroll expanded tubes are taken from SG-01-03-003, "Performance Evaluation of Segment Method for Circumferential ODSCC Sizing in Hardroll Expansion Joints, March 2001", which presents results of a multiple analyst blind test sizing performance demonstration for a new method of circumferential ODSCC PDA sizing in hardroll expansions. At 95% probability, 50 % confidence, the PDA sizing uncertainty is 28%, and represents a large improvement in the PDA sizing uncertainty compared to the data presented by EPRI TR-107197. PDA sizing uncertainties for WEXTEX expanded tubes are taken from EPRI TR-107197.

For the two tubes pulled at 1RF07 with reported circumferential ODSCC at the TTS, the Table 3 provides results of the profiling efforts for these tubes using the segment method.

Table 3
Summary of Comanche Peak 1RF08 Circ ODSCC Pulled Tube Sizing Performance

Tube	Arc DE	Arc NDE	Max Depth DE	Max Depth NDE	PDA DE	PDA NDE Segment	PDA NDE EPRI
R22 C89	360°	330°	58%	77%	44%	48.75%	20.6%
R7 C84	360°	330°	48%	93%	32.6%	30.55%	2.8%
Avg Error (DE-NDE)		30°		-32%		-1.35%	26.6%

As seen from this data, the segment method represents a large improvement in the sizing performance for circumferential ODSCC compared to the PDA sizing results for these tubes using the method described in EPRI TR-107197. Arc length measurement uncertainty has also been reduced using the recently developed procedure for evaluation of circumferential ODSCC indications. Maximum depth uncertainty for the segment method suggests that for conditions at CPSES 1 (negligible OD deposits), the segment method has been shown to conservatively estimate the flawed maximum depth.

A total of 178 circumferential indications were identified at 1RF08. Based on phase angle analysis, all were judged to be representative of ODSCC. Of these 178 indications, all were observed in hardroll expansion tubes. A total of 96 circumferential indications at the hot leg TTS were identified at 1RF07, and a total of 88 circumferential indications at the hot leg TTS were identified at 1RF06. While the number of TTS circumferential ODSCC indications has increased, the trend of nearly all indications exhibiting a precursor signal in history continues. The relative severity of these indications is judged to be small based on the low +Pt amplitudes and highly segmented morphology based on pulled tube examination.

Maximum +Pt flaw amplitude is a reasonable assessment tool for determining the relative structural integrity characteristics of circumferential ODSCC indications. SG-01-04-003 presents a summary of the maximum +Pt amplitude vs. burst pressure for the hardroll ODSCC pulled tube database. Figure 1 presents a histogram plot of the 1RF08 circumferential ODSCC maximum +Pt amplitudes. The maximum observed +Pt amplitude from 1RF08 represents a burst pressure of approximately 8000 psi using a lower bound to the data. Based on a correlation of maximum +Pt amplitude and burst pressure, the predicted burst pressure of a 0.35 volt indication at LTL material properties is 9000 psi. Figure 2 presents a histogram of the 1RF07 circumferential ODSCC maximum +Pt amplitudes. Figure 2 indicates a slightly larger peak flaw amplitude for 1RF07 vs. 1RF08 and slightly larger mean flaw amplitude for 1RF07 vs 1RF08. Figures 1 and 2 do not suggest that an increase in growth rates has occurred for Cycle 8 compared to Cycle 7.

A total of 12 tubes with circumferential ODSCC were depth profiled at 1RF08. The largest reported PDA from profiling was 50.5% (R18 C84 in SG 4). PDA values for the1RF08 profiled flaws ranged from 20.2% to 50.5%, with an average of 36% PDA.

R18 C84 SG 4 exceeded the in situ screening PDA value of 47%, and thus was required to be in situ pressure tested. The arc length was reported at 270°, which also exceeded the arc length screening value of 187°. The second flaw tested (R2 C72) had the largest +Pt amplitude (0.31 volts) in the SG for which pressure testing was required. PDA of this flaw did not exceed the screening value. No leakage at a pressure differential of 2955 psi or evidence of burst at 4395 psi was reported. Intermediate proof test hold points of 3434 psi and 3914 psi were used. Hold times at these pressures and the proof pressure was 2 minutes.

Based on the PDA sizing uncertainty data from SG-01-03-003 (Proprietary), and the distribution of material property values from WCAP-12522 for ¾" x 0.043 mill annealed tubing, the burst pressure for the limiting PDA (R18 C84) was developed at 90% probability, 50% confidence, 95% probability, 50% confidence, and 95% probability, 95% confidence. The burst pressures for these 3 cases are 5866 psi, 5507 psi, and 5326 psi. Thus the condition monitoring limits were satisfied for the EOC-8 conditions. Using the as-reported PDA value of 50.5%, the predicted burst pressure using LTL material property values is 6307 psi.

Unit 1 In Situ Pressure Testing History

At 1RF06, ten circumferential ODSCC indications at the hot leg TTS were in situ pressure tested. The eddy current parameters for these indications were comparable to or slightly more limiting than the 1RF07 and 1RF08 circumferential flaw parameters. Maximum +Pt amplitude in situ tested at 1RF06 was 0.48 volts, while the maximum PDA determined using the segment method was found to be 56.9%. As the segment method was not available at 1RF06, the reported PDA value was reproduced at a later date.

The arc lengths of the indications in situ tested at 1RF07 were 339°, 292°, and 260°, maximum depths were 69% to 74% based on the shallowest phase angle response for the entire signal, and PDAs ranged from 51% to 40% based on +Pt depth profile. Maximum +Pt voltage tested at 1RF07 was 0.32 volts.

No leakage or burst was reported for any circumferential ODSCC in situ pressure test at CPSES Unit 1.

The voltage integral values were not obtained for the 1RF06, 1RF07, or 1RF08 indications. Review of the indications profiled in available industry data and for recent inspections at other plants indicate the voltage integral value is typically ½ of the peak flaw voltage.

UT data were also collected for the tubes that were in situ pressure tested at 1RF07. The UT results indicate a maximum depth for R22 C89 of about 58% TW, with an arc length of about 317°. The maximum depths reported by UT are inconsistent with the large maximum depths reported from +Pt analyses reported for these tubes. Experience has shown that the +Pt coil has a tendency to overestimate the depths of shallow ODSCC flaws, particularly for the segment sizing method.

Tubes R22 C89 and R7 C84 in SG 4 were removed from the SG to examine the circumferential degradation observed. The degradation was initiated from the OD, and the total crack angles were approximately 360° for both tubes. For R22 C89, the maximum depth was 58%, while the PDA, or average depth was 44%. For R7 C84, the maximum depth was 48%, while the PDA was 32.6%. For both tubes, the circumferential ODSCC was highly segmented, with multiple non-degraded ligaments between the individual initiation sites. This segmentation effectively increases the burst capability of circumferential indications. The laboratory burst pressures were >10,000 psi for both tubes, well above the burst pressure to PDA correlation. The "burst" actually occurred in the freespan region of tube above the transition region as the segmented crack morphology and cold work introduced by the hardroll expansion effectively produced a localized region where burst capability of the flaw exceeded the burst capability of the non-degraded tube region in the freespan. Burst testing of the transition region was conducted in a freespan mode.

4.1.2 Expansion Transition Axial Flaw ODSCC Condition Monitoring Evaluation

Structural integrity of axial flaws is established based on reported NDE length and depth. The Westinghouse axial flaw burst prediction program, WEAKLINK, is used for estimation of burst capability of axial flaws.

At the CPSES 1RF08 inspection, 1 axial ODSCC indication at the expansion transition was reported in SG 3 with a peak amplitude of 0.12 +Pt volts. The flaw was profiled, and the length was 0.15", while average depth was 25.6%. Burst pressure for the as reported flaw using LTL material properties is 9405 psi, tearing pressure is 8962 psi. Applying the 95% probability, 50% confidence average depth and length sizing uncertainties from the degradation assessment, and using LTL material properties, the burst pressure is 8863 psi, tearing pressure is 8401 psi.

4.1.3 TSP ODSCC Condition Monitoring Evaluation

Only 1 indication exceeding 1.0 volt was reported by bobbin (R28 C51 at H3 in SG 4). This indication was not confirmed by +Pt and thus left in service. Two additional tubes had DSI amplitudes of 1.0 volts. Both were tested with +Pt, neither confirmed. The largest bobbin DSI voltages for each SG are provided below in Table 4:

Table 4
1RF08 TSP ODSCC Degradation Summary

	SG 1	SG 2	SG 3	SG 4
Number Ind.	23	23	19	196
Number ≥ 1 volt	0	0	0	3
Max 1RF08 Voltage	0.55	0.70	0.80	1.09
Absolute Average Voltage Growth Cycle 8 (per Cycle)	-0.030	0.001	0.029	-0.006
Average % Voltage Growth Cycle 8 (per EFPY)	-6.4%	0.1%	5.3%	-1.0%

This data shows that SG 4 appears to be the most susceptible SG with regard to ODSCC initiation. For all SGs, the average absolute voltage growth is -0.005 volts.

The voltage based structural limit for TSP ODSCC indications is 4.79 volts for a SLB ΔP of 2560 psi (with safety factor applied).

Mixed residual indications with a bobbin voltage > 1.5 volts are RPC inspected. No mixed residuals >1.5 volts were detected.

4.2 Condition Monitoring Evaluation of Degradation Modes Classified as Relevant in the Degradation Assessment

The degradation assessment concluded that the following mechanisms did not meet the criteria to be classified as active mechanisms, and therefore were categorized as relevant mechanisms.

- Axial ODSCC in the freespan
- Axial and circumferential ODSCC in freespan dings
- Axial PWSCC at the top of tubesheet expansion transition
- Axial PWSCC in small radius U-bends
- AVB wear
- Tube wear at non-expanded preheater baffles
- Tube wear due to foreign objects/loose parts

4.2.1.a Freespan ODSCC Condition Monitoring

No freespan ODSCC in the absence of an external stress riser was reported at 1RF08

4.2.1.b Freespan Volumetric Indications Condition Monitoring

In SG 4, one possible freespan indication (DFI) was reported by bobbin below the C1 baffle. +Pt examination suggested a pit-like indication. During the 1RF07 inspection, 2 nearly identical indications were noted in SG 4. The 115 mil pancake coil data suggested that these indications were coincident with a vertical line of freespan dings, and most likely are attributed to a small gouge on the tube OD.

Boththe indications in 1RF07 and the indication reported in 1RF08 were conservatively repaired, even though the bobbin history suggested no growth in amplitude or phase shift over this period. Review of the baseline bobbin data for this tube indicates a freespan bobbin signal similar to the observed 1RF08 signal. This elevation is not expected to support a pitting mechanism due to the reduced sludge or OD scale at this elevation. Furthermore, pitting degradation is strongly correlated to high concentrations of copper species in sludge piles. CPSES has no copper in the secondary feedtrain.

In SG 1, one freespan volumetric indication was reported at 0.92" above the hot leg top of tubesheet. The +Pt amplitude was extremely small, at 0.08 volts. Depth from phase was reported at 26%. No PLP signal was associated with this indication. Based on the axial and circumferential involvement measurements, a best estimate of the actual flaw dimensions is 0.11" axial, and 40° arc involvement. If this signal is representative of a morphology similar to a flat bottom wear scar, since numerous foreign object wear signals were reported, the maximum depth could be estimated to be as large as 60%, although neither the +Pt amplitude nor depth from phase support this value. If a morphology similar to a flat bottom wear scar is assumed, the predicted burst pressure using LTL material property values is 8141 psi. Using an elliptical wastage model, the burst pressure using LTL material property values is 7466 psi. Therefore, condition monitoring requirements are satisfied. The location of this indication is not near the T-slot region, and thus not expected to have sludge pile influence.

4.2.2 ODSCC at Freespan Dings Condition Monitoring

<u>Axially Oriented Indications:</u>

Axial ODSCC at freespan dings was detected in the last three outages in two units with Model E2 SGs. As the CPSES Unit 1 SGs and the Model E2 SG share similar secondary side structure designs, the potential exists that similar indications could be reported in a Model D4 SG. The CPSES 1RF08 inspection monitored freespan ODSCC initiation. Bobbin indications in the freespan were RPC inspected if the low frequency differential bobbin phase angle response was less than 155° at ding locations. This calling criterion was specifically developed to identify axial ODSCC at freespan dings. A total of 3 DNI calls were reported by bobbin. Two were reported as NDD by +Pt and one was confirmed as an axial ODSCC indication. The indication was reported in R49 C44 SG 1 at H11 +32.93". Maximum flaw amplitude was 0.63 volts. Flaw length from profiling was 0.19", with an average depth of 68.8%. Burst pressure for theas- reported flaw using LTL material properties is 7485 psi, tearing pressure is 7315 psi. Applying the 95% probability, 50% confidence average depth and length sizing uncertainties from the degradation assessment, and using LTL material properties, the predicted burst pressure is 6171 psi, tearing pressure is 5483 psi. Therefore, condition monitoring requirements are satisfied. Bobbin review indicates the 130 kHz differential amplitude and phase in 1RF08 were 0.66 volts, 153 degrees, while the 1RF07 bobbin data indicates a 130 kHz differential amplitude and phase of 0.53 volts, 161 degrees. It can therefore be concluded that this flaw was present in the 1RF07 inspection, but the 130 kHz differential phase was less than the reporting criteria. Thus, this flaw did not initiate and grow to the reported length and average depth in less than one cycle.

Qualification of the bobbin probe as a detection tool was performed by Westinghouse, and this program achieved a POD of 90% at 90% confidence for flaws ≥ 60% depth, for freespan dings ≤ 5 volts. Qualification was performed using a dataset comprised entirely of laboratory cracked specimens. A 20% sampling of hot leg and cold leg straight section dings and U-bend dings from H11 to AV1 and C11 to AV4 > 5 volts were inspected by +Pt since the mechanism was not considered active at this voltage level in the CPSES Unit 1 SGs.

With regard to PWSCC, a 20% sample of all hot leg dings from the hot leg top of tubesheet to H3, the first TSP above the flow distribution baffle, and all dents at H3 ≥ 2 volts were +Pt inspected. No degradation was observed.

<u>Circumferentially Oriented Indications:</u>

At the 1999 inspection of a Model E2 SG, OD circumferential indications were reported in the freespan region several inches below the top cold leg TSP. The indications were reported coincident with a circumferentially oriented ding, known as a ding pair. The ding pair is believed to be resultant from out of plane rotation of the tube while engaged with the top TSP during tube insertion. The geometry of this type of ding has been studied by Westinghouse and found to be significantly different from the dings that have historically resulted in axial ODSCC. Based on this similar plant experience, 20% of the hot and cold leg paired dings between the top two TSPs were inspected with +Pt at 1RF08. No degradation was observed.

4.2.3 Axial PWSCC at the Top of Tubesheet Expansion Transition Condition Monitoring

Structural integrity of axial flaws is established based on reported NDE length and depth. The Westinghouse axial flaw burst prediction program, WEAKLINK, is used for estimation of burst capability of axial flaws.

During the 1RF08 inspection one axial PWSCC indication at the expansion transition was reported in SG 3. Maximum +Pt amplitude was 0.63 volts, flaw length from profiling was 0.13", and average depth was 36%. The predicted burst pressure for the as reported flaw using LTL material properties is 8788 psi, tearing pressure is 8655 psi. Applying the 95% probability, 50% confidence average depth and length sizing uncertainties from the degradation assessment, and using LTL material properties, the burst pressure is 7228 psi, tearing pressure is 6899 psi. Therefore, condition monitoring requirements are satisfied.

4.2.4 Small Radius U-bend PWSCC

No small radius U-bend PWSCC indications were reported.

4.2.5 Tube Wear at AVBs, Preheater Baffles, and Due to Losse Parts/Foreign Objects

Tube wear due to foreign object interaction was reported in SGs 1 and 2. The tubes with wear indications were located at the top of tubesheet and in upper bundle regions. In all cases, the wear mechanism could be tracked in previous inspections. As the wear morphology could not be judged to be consistent with an available sizing standard, these indications were repaired by plugging. The wear mechanisms observed generally had small bobbin amplitudes, i.e., less than 1 volt in the primary mix channel. As a comparison, the volumetric wall loss associated with the 40% depth, 0.187" diameter flat bottom hole of the ASME standard is approximately 3 volts. Based on flaw geometry characterization with RPC and relation to laboratory wear scars, the axial extents of the wear indications were about 0.26" max, with a maximum circumferential involvement of about 50 degrees. The uniform thinning burst model of NUREG-0718 can be used to estimate the burst pressure. At up to 83% TW degradation for a 0.26" axial involvement, burst pressure using LTL material properties exceeds the CPSES 1 3ΔP value of 3816 psi. At 85% TW, the bobbin amplitude would be expected to be substantially larger than 3 volts. At the approximated maximum depth of 50%, a 0.26" axial length uniform thinning flaw has a predicted burst pressure using LTL material properties of 7587 psi.

Tube wear at non-expanded baffles represents a low growth mechanism. The largest reported depth at 1RF07 was 37% TW. This indication was also the largest reported depth at 1RF08 of 43%. The growth associated with this indication was 7% TW for Cycle 7, 6% for Cycle 8. The average and 95% confidence growth rates for all baffle wear indications combined for Cycle 8 is 1.39% and 6.02%, respectively, while the largest reported growth was only 11% TW. Using the uniform thinning burst equation, TSP wear of up to about 69% TW would be expected to provide structural integrity at the CPSES 1 3ΔP value of 3816 psi. The largest baffle wear average growth was reported in SG 3, with a value of 2.50% per cycle using all growth values, 2.68% per cycle if negative growths are set to 0. The largest reported growth in SG 3 was 10%.

The maximum AVB wear depth reported was 32% TW in SG 3. The growth associated with this indication was 0% TW. The largest reported AVB wear growth reported was 8% TW.

4.3 Condition Monitoring Evaluation of Degradation Modes Classified as Potential in the Degradation Assessment

The final degradation classification addressed in the degradation assessment are potential degradation modes. Potential degradation modes are modes not seen in CPSES Unit 1, but represent a potential to occur based on experience at other plants or in laboratory testing.

The only degradation mode classified as potential for CPSES 1RF07 is cold leg TTS SCC. Due to the reported C-3 condition in SGs 2, 3, and 4, a 20% cold leg TTS +Pt inspection program was implemented. No degradation was reported in this program.

4.4 Summary of Limiting Indications

Table 5 presents a summary of the limiting indications for the 1RF08 inspection. All indications had predicted burst capabilities of greater than the $3\Delta P_{NormOp}$ value of 3816 psi using LTL material properties. Discussion is provided which indicates the predicted burst capabilities are greater than 3816 psi using the methodology provided by the ERPI tube integrity guidelines.

Table 5
Summary of Limiting Indications at 1RF08 Using As-Reported Data and LTL Material Properties

Mechanism	Max Length	Max Depth	Avg. Depth	Calculated Burst Pressure	SLB Leakage gpm (95%,Nom,BestEst)
Circ ODSCC at hot leg TTS	330°	91%	50.5% (+Pt profile)	6307 psi *	0 (in situ test)
Axial ODSCC at TTS	0.15"	34%	25.6%	9405 psi	0, 0, 0
Axial PWSCC at TTS	0.13"	56%	36%	8788 psi	0, 0, 0
Axial ODSCC at TSP	N/A	1.09 volts	N/A	>8000 psi	0, 0, 0
Baffle Wear	0.75"	43%	43% (assumed equal to max depth)	6575 psi	0, 0, 0
AVB Wear	0.40"	32%	32% (assumed equal to max depth)	8135 psi	0, 0, 0

*: Successfully proof tested at a test pressure of 4395 psig. No leakage reported at 2955 psig.

4.5 SLB Leakage Discussion

For all degradation mechanisms observed at 1RF08, any potential for SLB leakage at end of Cycle 9 conditions is judged to be negligible. The circumferential ODSCC indications at the TTS are of sufficiently low magnitude that no leakage contribution is expected. Based on the available industry database, SLB leakage is not expected for maximum +Pt amplitudes of about 1 volt. The +Pt amplitudes of the in situ leak tested circumferential flaws was 0.19 and 0.31. The largest +Pt amplitude observed for all SGs was 0.35. At 1RF06, three flaws with +Pt amplitudes of 0.47 volts were in situ tested with no leakage. No leakage was reported at a maximum pressure of 2925 psi in either the 1RF06, 1RF07, or 1RF08 in situ testing campaigns.

The only axial ODSCC flaw at the TTS had a +Pt amplitude of 0.12 volts, with a maximum depth of 34% TW. At such low amplitude, this flaw would not have contributed to leakage at SLB conditions. The only axial PWSCC flaw at the TTS had a +Pt amplitude of 0.66 volts, with a maximum depth of 56%. Maximum +Pt amplitudes for axial PWSCC indications at the TTS in 7/8" hardroll expanded tubes of up to 6 volts did not leak during in situ test. Extending this point to ¾" OD tubing would suggest a lower leakage threshold for axial degradation at the TTS of about 5 volts, when the amplitude response is adjusted by the ratio of tube ODs. For both tube sizes, the voltage calibration is consistent. That is, for both tube sizes, the 100% TW axial notch +Pt amplitude response is set to 20 volts.

The limiting axial ODSCC indication at a hot leg TSP intersection had a bobbin amplitude of only 1.09 volts, and did not confirm by +Pt. At such low voltage, it is judged that this flaw would not have contributed to leakage at SLB conditions.

<u>In Situ Testing Summary:</u>

The in situ testing performed for the 1RF08 outage supports the conclusion that postulated SLB condition primary to secondary leakage will remain below 1 gpm for all SGs.

Using the available database of hardroll pulled tubes with circumferential ODSCC at TTS expansions, +Pt amplitudes of 1.33 volts for ¾" OD tubes and 2.18 volts for 7/8" tubes showed no leakage during in situ test or during destructive examination at simulated SLB conditions. The maximum reported +Pt amplitude for circumferential ODSCC at the TTS was 0.35 volts for 1RF08. Maximum +Pt amplitude can also be used for assessment of general structural integrity characteristics. The two pulled tube indications discussed above had burst pressures of 4670 psi and 7980 psi, respectively, when normalized to LTL material property values at 650° F.

4.6 1RF07 Pulled Tubes

Four tubes (2 for TTS degradation, 2 for TSP degradation) were removed at 1RF07 (Fall 1999) for destructive examination based on field NDE results. This discussion is included to provide insight to the circumferential ODSCC morphology observed at the top of tubesheet region.

Tubes R22 C89 and R7 C84 were removed for examination of circumferential flaws at the hot leg top of tubesheet. R22 C89 was judged a limiting indication based on reported arc length and maximum depth. R7 C84 was judged to be representative of a less severe indication, and was selected based on the high incidence of low Row circumferential cracks, compared to other D4 SGs. Tubes R25 C81, R7 C84, and R22 C89 were burst at the TTS (R25 C81 was pulled to satisfy GL 95-05 requirements). Laboratory +Pt examination suggested the presence of a shallow circumferential indication on tube R25 C81, which was called NDD in the field. Burst tests were performed at the TTS as well as freespan. In the TTS burst configuration, the roll transition region was configured as a freespan condition. A tubesheet simulant collar was placed at approximately 2" below the BRT. A TSP simulant was located at the approximate location of the FDB and 1H TSP. For tubes R25 C81, R7 C84, and R22 C89, the TTS burst pressures were equal to or within 100 psi of the freespan burst pressures, suggesting that the circumferential degradation had no significant impact upon structural integrity. Additionally, all three tubes burst in the freespan in an axial direction, just above the TTS position. No degradation was reported at this location by eddy current or destructive examination. The increase in tube material properties due to hardrolling and highly segmented nature of the crack network produced a condition where the flawed expansion transition had a greater burst capability than the non-degraded area of the freespan tube. Circumferential crack depths were determined bytensile loading the tubes in the axial direction to cause separation of the circumferential crack faces. Maximum depths were determined, and found to be approximately 58%TW for R22 C89, 48% for R7 C84, and 43% for R25 C81. Approximate average depths for these tubes are 44% for R22 C89, 31% for R7 C84, and 29% for R25 C81. Large numbers of non-degraded ligaments were observed (>45) in each flaw network, and likely influenced the burst results. R22 C89 was found to contain many short, oblique cracks, oriented at about 20° to horizontal, located in parallel planes at several elevations within about 100 mils of the transition. The large number of non-degraded ligaments also may partly explain the low voltages of these indications.

The flow stresses (sum of yield + ultimate divided by two) were quite consistent, and ranged from 77.5 ksi to 74.5 ksi for the 4 pulled tubes. At an average depth of 44%, the calculated burst pressure of the circumferential flaw in R22 C89 is approximately 7700 psi. The tube burst in the freespan above the roll transition at about 10,900 psi. The effect of the numerous ligaments and short individual cracks with oblique angles is clearly represented by this difference.

4.7 1RF08 Condition Monitoring Conclusion

Based on the CPSES 1RF08 inspection results, no tubes contained indications which represented a challenge to structural or leakage integrity and all condition monitoring requirements are satisfied. The relative severity levels of the observed degradation was judged consistent with or bounded by the levels associated with the 1RF07 inspection.

4.8 Degradation Mechanism Classification for 1RF09

Based on the 1RF08 inspection results, the following mechanisms are considered active per the ERPI Rev.5 ISI Guidelines:

- Circumferential ODSCC at hot leg TTS expansion transitions
- Axial ODSCC at hot leg TTS expansion transitions
- Axial PWSCC at hot leg TTS expansion transitions
- Axial ODSCC at hot leg TSP intersections
- Axial ODSCC at freespan dings.

As depth sizing methods are not considered qualified for continued operation justification, all crack like indications are considered active mechanisms.

Based on the 1RF08 inspection results, the following mechanisms are considered non-active per the ERPI Rev.5 ISI Guidelines:

- Tube wear at nonexpanded preheater baffles
- Tube wear at AVB intersections
- Tube wear due to foreign objects/loose parts

Based on accepted depth sizing techniques for preheater baffle wear and AVB wear, the reported growth statistics do not classify these mechanisms as active. The largest reported baffle or AVB wear growth for Cycle 8 was 11%TW. The foreign objects/loose parts wear observed could not be considered to be within the qualification scope of the available bobbin analysis techniques. Supplemental evaluations performed using rotating probes and comparison against known wear scars suggest a maximum growth rate of less than the repair limit, and average growths bounded by 20% TW per cycle. The maximum depth of the foreign object/loose part wear indications was judged to be less than 50% TW (actual).

5.0 Potential New Degradation Mechanism Assessment

In SG 1, a bobbin DNI call was confirmed as axial ODSCC by +Pt. The ding amplitude was approximately 2.18 volts, and the bobbin technique was shown to perform as intended. The bobbin data from 1RF07 was reviewed and it was determined that evidence of a flawed signal could be observed based on the reported 130 kHz phase of 161°. Thus, the flaw did not initiate and grow to the reported length and average depth dimensions in less than one cycle.

In SG 3, an axial PWSCC indication was reported at the hot leg top of tubesheet expansion transition. As CPSES Unit 1 was shotpeened prior to operation, the observance of PWSCC in the hardroll expansions should be well reduced compared to the historical performance of similar SGs.
The reported flaw length of 0.13" is well below the 100%TW critical flaw length of 0.48".
Review of the 1RF07 +Pt data for this tube indicates a precursor signal was evident, thus the indication did not initiate and grow to the reported length and average depth in less than one cycle.

While these two mechanisms are new to CPSES Unit 1, they are not new to the industry. Freespan ding ODSCC has been reported and tracked for multiple outages at two US plants with Model E2 SGs. Once the bobbin detection program for axial ODSCC in dings was applied in the Model E2 plants, historical review of previous outages data indicated that all of the flaws reported at the first outage that implemented the technique would have been reported if the technique had been available. Some of the indications could be tracked to two previous outages, while others showed initial rotation below the calling criteria limit as far as three outages prior. Thus it can be concluded that ding ODSCC flaws do not rapidly initiate and propagate to structurally significant lengths and depths in less than one cycle. The laboratory flaws developed to support the bobbin ding technique show that the flaws rarely extended beyond the ding.

Axial PWSCC at hardroll expansion transitions was quite prevalent prior to the development of ameliorative measures such as rotopeening and shotpeening. Tube pull data from other Model D

plants indicates that the flaws typically do not extend past the hardroll transition, and thus become somewhat self limiting with regard to length. Previous investigation also has shown that the hardroll process tends to anchor the lower crack tip and prevent crack opening, thus effectively increasing the burst pressure and leakage restriction characteristics of these flaws compared to flaws of equal length located in the freespan.

Thus it can be concluded that the presence of these new mechanisms do not represent a structural or leakage integrity challenge at end of Cycle 9 conditions.

Figure 1

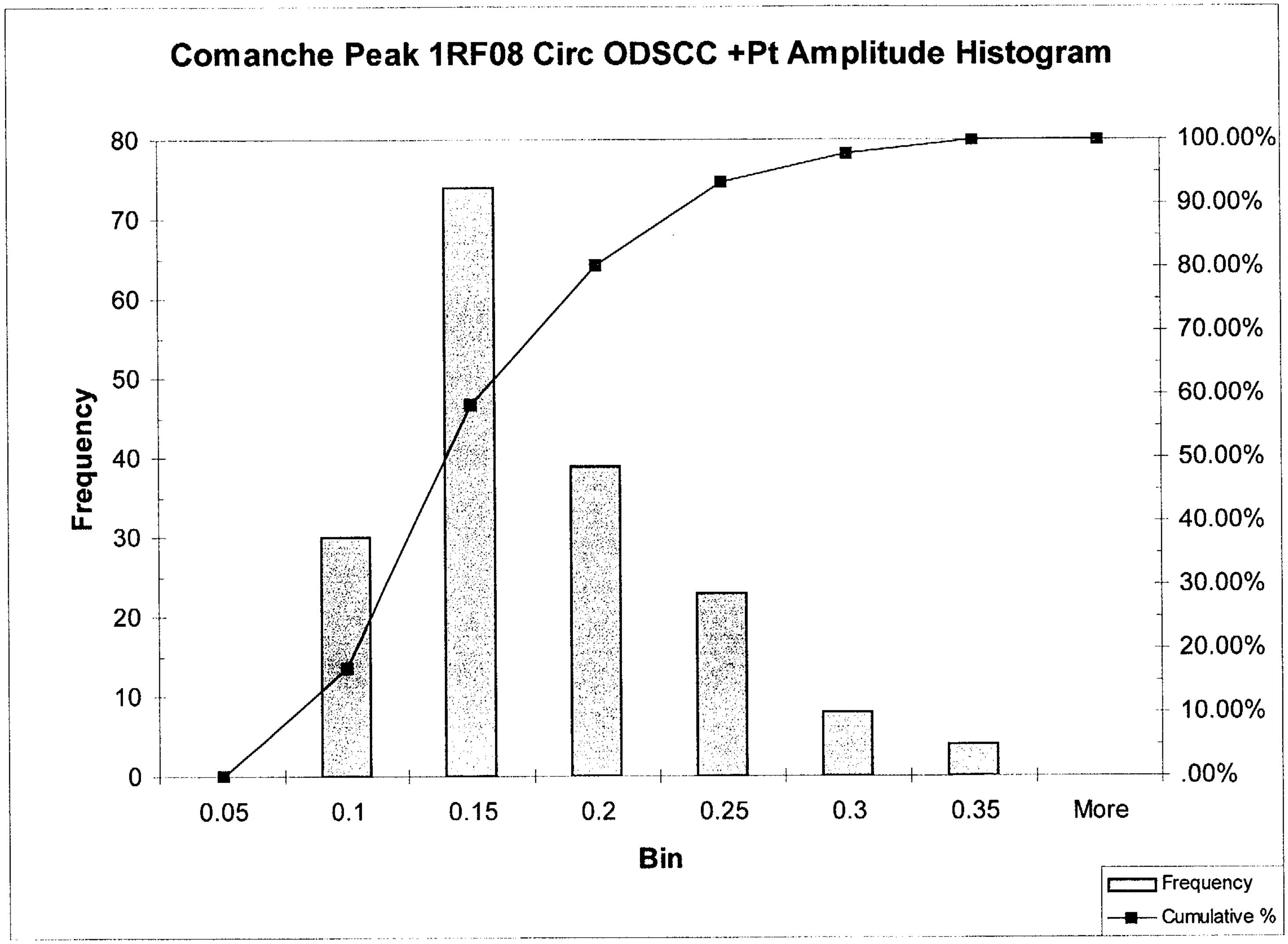
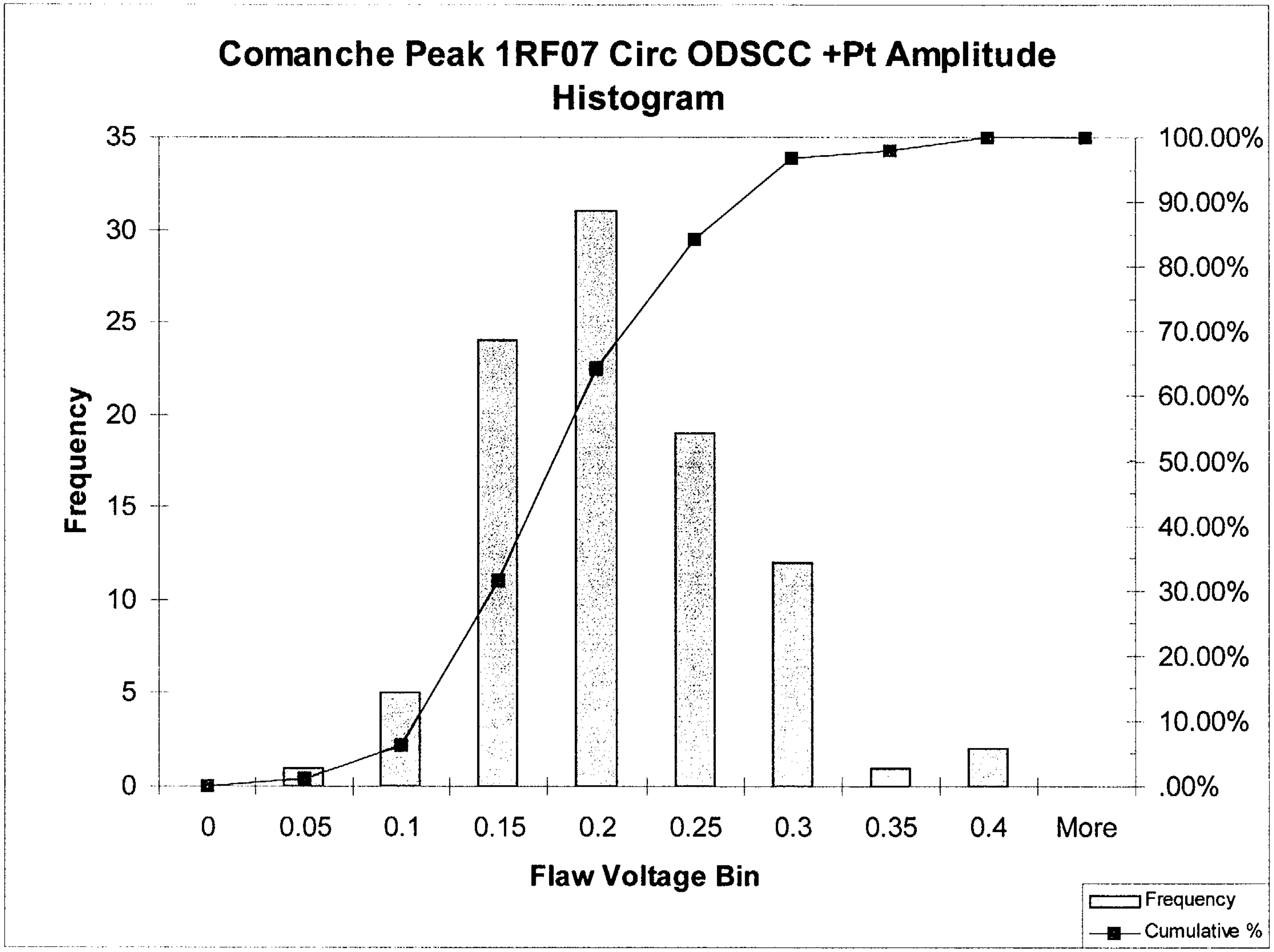

Comanche Peak 1RF08 Circ ODSCC +Pt Amplitude Histogram
Frequency
80
70
60
50
40
30
20
10
0
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
.00%
0.05
0.1
0.15
0.2
0.25
0.3
0.35
More
Bin
Frequency
Cumulative %

Figure 2


Comanche Peak 1RF07 Circ ODSCC +Pt Amplitude Histogram
Frequency
35
30
25
20
15
10
5
0
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
.00%
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
More
Flaw Voltage Bin
Frequency
Cumulative %