Westinghouse Electric Corporation
Energy Systems

Nuclear Services Division
Box 355
Pittsburgh Pennsylvania 15230-0355

February 28, 1996
CAW-96-934

Document Control Desk
US Nuclear Regulatory Commission
Washington, DC 20555

Attention: Mr. William T. Russell, Director

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: "EPRI ARC Database for 3/4" and 7/8" Diameter Tubes and Updated ARC Correlation for 7/8" Diameter Tubes" (Proprietary)

The proprietary information for which withholding is being requested is further identified in Affidavit CAW-96-934 signed by the owner of the proprietary information, Westinghouse Electric Corporation. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.790 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying Affidavit by Tennessee Valley Authority.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-96-934, and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo, Manager
Regulatory & Engineering Networks

JJM/bbp

Enclosures

cc: Kevin Bohrer/NRC(12H5)

CAW934/NSD092

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Nicholas J. Liparulo, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Nicholas J. Liparulo, Manager
Regulatory & Engineering Networks

Sworn to and subscribed
before me this 28 day
of February, 1996

Notary Public

Notarial Seal
Rose Marie Payne, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Nov. 4, 1996
Member, Pennsylvania Association of Notaries

(1) I am Manager, Regulatory & Engineering Networks, in the Nuclear Services Division, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Energy Systems Business Unit in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in letter NSD-SGD-1212, "EPRI ARC Databases for 3/4" and 7/8" Diameter Tubes and Updated ARC Correlation for 7/8" Diameter Tubes", dated February 26, 1996 (Proprietary), being transmitted by the Tennessee Valley Authority Company letter and Application for Withholding Proprietary Information from Public

Disclosure, to the Document Control Desk, Attention Mr. William T. Russell. The proprietary information as submitted for use by the Tennessee Valley Authority Company for the Sequoyah Units 1 and 2 is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of steam generator tube integrity evaluations.

This information is part of that which will enable Westinghouse to:

(a) Perform steam generator tube integrity evaluations.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting requirements for licensing documentation.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar methodologies and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing testing and analytical methods and performing testing.

Further the deponent sayeth not.

Enclosure 3

"EPRI ARC Database for 3/4-Inch and 7/8-Inch Diameter Tubes

and Updated ARC Correlation for 7/8-Inch Diameter Tubes"

(Non-Proprietary)

Attachments : Non-Proprietary Class 3 Version

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	T S P	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3]			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
									Pressure Differential										
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE79.WP5

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE78.WP5

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[2] (l/hr)	SLB Leak Rate (l/hr)[2] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[3] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 x Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE76.WP5

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate
and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max. Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE1N.WP1

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[2] (l/hr)	SLB Leak Rate (l/hr)[2]			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[3] (in.)		Pressure Differential 2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLEN.WP1

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate(3) (l/hr)	SLB Leak Rate (l/hr)(3) Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure(4) (psi)	Correlation Application(5)		
			Volts(1)	Depth		Max Depth	Length(2) (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE7B.WPF

Table 1
7/8-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

NOTES:
1. All voltages normalized to the recommended values of this report.
2. Crack network length for burst crack, with through wall crack length given in parentheses.
3. N.O. leak rates are adjusted to ΔP = 1450 psi per Appendix B of Reference 1. SLB leak rates are adjusted to reference ΔP's shown.
4. Normalized to 150 ksi flow stress (sum of yield and ultimate stress).
5. Column indicates application of specimen in leak rate and/or burst correlations. 0 = No, 1 = Yes
6. Data excluded from application to correlations based on EPRI data exclusion criterion 2.
7. N.R. = Not Reliable data.
8. 98% deep for 0.22"; >95% deep for 0.35".
9. N.M. = Not Measured; value of 169.8 ksi in parenthses assumed for burst pressure adjustments when measurements not available.
10. Average of multiple measurements.
11. Burst test conducted within TSP. Burst pressure not used in ARC database.
12. Inferred from destructive exam depth, leak test not performed. Corrosion depth too shallow leakage at SLB conditions.
13. Data excluded from application to correlations based on EPRI data exclusion criterion 1.

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RFC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLEH WP5-2

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	T S P	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max. Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE24 WPS-4

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE34 WPS-5

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE4 WPS-6

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil		RPC Volts	Destructive Exam		Normal Operation Leak Rate[2] (ℓ/hr)	SLB Leak Rate (ℓ/hr)[3]			Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5]		
			Volts[1]	Depth		Max Depth	Length[2] (in.)		Pressure Differential 2335 psi	2560 psi	2650 psi						Prob. of Leak	Leak Rate	Burst

TABLE54 WPS-7

Table 2
3/4-Inch Diameter Pulled and Model Boiler Tube Leak Rate and Burst Pressure Measurements

Plant Letter & Name	Specimen No. or Row/Col.	TSP	Bobbin Coil Volts[1]	Bobbin Coil Depth	RPC Volts	Destructive Exam Max. Depth	Destructive Exam Length[2] (in.)	Normal Operation Leak Rate[3] (l/hr)	SLB Leak Rate (l/hr)[3] Pressure Differential 2335 psi	SLB Leak Rate 2560 psi	SLB Leak Rate 2650 psi	Burst Pressure (psi)	Yield Stress S_y (ksi)	Ultimate Stress S_u (ksi)	2 × Flow Stress S_y+S_u (ksi)	Adjusted Burst Pressure[4] (psi)	Correlation Application[5] Prob. of Leak	Correlation Application[5] Leak Rate	Correlation Application[5] Burst

NOTES:
1. All voltages normalized to the recommended values of this report.
2. Crack network length for burst crack, with through wall crack length given in parentheses.
3. N.O. leak rates are adjusted to ΔP = 1300 psi per Appendix B of NP-7480-L, Volume 2. SLB leak rates are adjusted to reference ΔP's shown.
4. Normalized to 150 ksi flow stress (sum of yield and ultimate stress).
5. Column indicates application of specimen in leak rate and/or burst correlations. 0 = No, 1 = Yes
6. Leak rate inferred from destructive examination crack morphology. Corrosion depth too shallow for leakage at SLB conditions.
7. N.R. = Not Reliable data.
8. Burst tests performed with TSP constraint; data not used in ARC burst correlation.
9. Conservatively calculated with CRACKFLO code; included per NRC directive.
10. Data excluded from application to correlations based on EPRI data exclusion criterion 2.
11. Burst test showed insignificant extension at the corrosion crack tips. Therefore, burst pressure is a minimum value since burst is defined to include crack extension.
12. Data excluded from application to correlations based on EPRI data exclusion criterion 1.
13. Data meets EPRI data exclusion criterion 3.
14. Second throughwall crack 30 degrees from burst crack.

1.0 Updated ARC Correlations for 7/8" Tubes

This section reports on the evaluations performed which utilized the results of leak rate and burst testing of tube sections removed from SGs at utility sites in the United States after the publication of the original EPRI database for 7/8" diameter SG tubes (NP-7480-L, Volume 1). The results of the destructive examinations of the tube sections were reported in utility specific reports, and will be summarized in the complete data update report to follow. The additional pulled tube data germane to the APC correlations, and the bobbin amplitudes for APC applications, will be contained in a table in the complete update report to be issued at a later date. The additional data consist of results from pulled tube sections from Beaver Valley 1 (SG-95-06-006, May 1995), Farley 2 (SG-95-07-010, July 1995), Sequoyah 1 (SG-96-01-007, January 1996), and Farley 1 (SG-96-01-003, January 1996).

The results of the leak and burst tests are compared herein to the database of similar test results for 7/8" outside diameter SG tubes, and the effect of including the new test data in the reference database is evaluated. In summary, the applicable test data are consistent with the database relative to the burst pressure, the probability of leak, and the leak rate as function of bobbin amplitude correlations for 7/8" diameter tubes. The comparisons and evaluations follow.

Suitability for Inclusion in the Database

The morphology of the degradation of each indication considered herein was reviewed relative to the EPRI guidelines for inclusion/exclusion of tube specimen data in the alternate plugging criteria (APC) database. The findings of the reviews were recorded in documents prepared for each utility as the data were obtained. The details of the reviews will be included in a comprehensive report to be issued at a later date dealing with multiple tube sizes. None of the reviews revealed information that would lead to a conclusion that the data considered in this section should not be included in the database. Therefore, the correlations reported herein should be considered applicable to the use of APC for indications in 7/8" diameter tubes in Westinghouse SGs and constitute the analyses of the updated database.

1.1 Free Span Burst Correlation

The burst pressure database used in this report for 7/8" tubes consists of the EPRI recommended database, plus test results from tube R11C60-1 removed from D.C. Cook Unit 1. The results for this tube section were abnormally high, but the degradation morphology did not meet all of the exclusion criteria developed for degradation with abnormally high burst pressures, hence it was retained in the correlation database. The results from ten (10) burst tests, performed on tube specimens which exhibited a non-zero bobbin amplitude at a TSP elevation location, were considered for evaluation. A plot of the burst pressures of the additional specimens is depicted on Figure 1-1 relative to the burst pressure correlation devel-

oped using the reference database and relative to a 95% confidence band to contain 90% of the population of burst pressures.

1. A visual examination of the data relative to the EPRI database indicates that the burst pressures measured fall within the scatter band of the reference data.

2. Nine, i.e., 90%, of the data points fall within a 95%/90% tolerance interval (approximate) about the regression line (95% confident to contain 90% of the underlying normal population).

3. One, i.e., 10%, of the data points falls outside of the 95%/90% tolerance band about the regression line.

In summary, the visual examination doesn't indicate any significant departures from the reference database. Although the burst pressure is less than would have been expected for one of the indications, the appearance of one such indication in the additional ten data points is not significantly improbable Moreover, the bobbin amplitude for this indication increased from 4 volts before removal to 12 volts after, thus, the burst pressure could have been reduced as a consequence of mechanical deformation from the tube removal activities. Since the regression line for this analysis represents the mean and median burst pressure to be expected from the parent population, it would be expected that additional data should fall about half above and half below the line. For the additional data analyzed, six (6) values were above the line and four (4) values below the line. For ten values drawn at random from the population of bursts, the probability that the split would be five above and five below is about 25%, and the probability that the results would be split six/four in either direction is 41%. Thus, distribution relative to above or below the regression line is not unusual. In addition, the average difference in the observed burst pressure relative to the predicted burst pressures is only 1.1%. Finally, although the tube data are from SGs at multiple plant sites, an examination of the normalized residuals relative to the predictions of the reference correlation equation was performed. The results of this analysis are shown on Figure 1-2 where the distribution of observed deviates is compared to those expected from a normal distribution. There doesn't appear to be any significant systematic departure from normality.

Since the additional burst pressure data were not indicated to be from a separate population from the reference data, the regression analysis of the burst pressure on the common logarithm of the bobbin amplitude was repeated with the additional data included. A comparison of the regression results obtained by including these data in the regression analysis is provided in Table 1-1. Regression predictions ob-

tained by including these data in the regression analysis are shown on Figure 1-3. The appropriate regression equation for future ARC analyses is,

$$P_B = 7.592 - 2.370 \log(Volts), \quad \textbf{(1-1)}$$

with a SLB structural limit of 8.6 volts. The changes to the correlation are:

1. The intercept of the burst pressure, P_B, as a linear function of the common logarithm of the bobbin amplitude regression line is increased by 0.48%. This has the effect of increasing the predicted burst pressure as a function of the bobbin amplitude.

2. The absolute slope of the regression line is increased by 2.19%, i.e., the slope is more steep. This has the effect of decreasing the burst pressure as a function of bobbin amplitude for indications greater than about 3 volts.

3. There is an increase in the standard error of the residuals of 1.38%. The effect of this change would be reflected in a slightly larger deviation of the 95% prediction line from the regression line.

The net effect of the changes on the SLB structural limit ($1.43 \cdot \Delta P_{SLB}$), using 95%/95% lower tolerance limit material properties, is to decrease it by 0.2 volts, i.e., from 8.8 volts to 8.6 volts. The increase in the slope relative to the increase in the intercept, and the increase in the standard error coupled with the fact that the structural limit is also decreased indicates that the probability of burst would also increase for bobbin indications over the structural range of interest. Based on the relatively small change in the structural limit, the change in the probability of burst would also be expected to be small.

1.2 Probability of Leak Correlation

As for the burst pressure correlation, there are ten (10) additional data pairs that were considered relative to the reference database and the probability of leak (POL) correlation to the common logarithm of the bobbin amplitude. Figure 1-4 illustrates the additional data relative to the reference correlation. All of the specimens except one exhibited POL behavior commensurate with expectations indicated by the reference database and regression curve. The single exception was an indication with a bobbin amplitude of 4.03 volts that exhibited leakage, thus becoming the indication with the second lowest voltage of the indications that leaked in the database.

Based on the reference curve, the POL for the leaking indication is 0.133, thus, roughly 1 in 7 indications with an amplitude of 4.03 volts would be expected to leak. Had the expectation been 1 in 20, statistically anomalous behavior could have been suspected. The indication that leaked was the same indication that

exhibited a lower than expected burst pressure. It is strongly suspected that this indication experienced ligament tearing during the tube pull as indicated by the maximum 96% corrosion depth resulting in post-pull Argon leakage at 200 psid and the increase in bobbin amplitude from 4.03 to 12.2 volts. However, since it is difficult to prove that the wall thickness ligament would not have torn during postulated SLB conditions, the indication is to be retained in the EPRI database. In conclusion, data examinations revealed no significant evidence of irregular results, i.e., outlying behavior is not indicated.

In order to assess the quantitative effect of the new data on the correlation curve, the database was expanded to include the additional data points and a *Generalized Linear Model* regression of the POL on the common logarithm of the bobbin amplitude was repeated. A comparison of the correlation parameters with those for the reference database is shown in Table 1-2. These results indicate:

1. A 9.7% increase (smaller negative value) in the *logistic* intercept parameter.

2. A 6.2% decrease in the *logistic* slope parameter.

3. The absolute values of the parameters' covariance matrix changed by 26.5% to 34.5%. These changes may have a significant impact on the POL values used during the Monte Carlo Simulations, but may not have a significant impact on the 95% confidence bound on the total estimated leak rate from a single SG.

4. The Pearson standard error decreased by 7.2% from 0.640 to 0.594. This is a negative indicator since the ideal value would be 1.0, but is not judged to be significant.

An additional evaluation was performed which demonstrated that most of the changes in the distribution parameters are a result of including the 4.03 V indication that leaked. In order to assess whether or not these changes are significant, the reference correlation and the new correlation were also plotted on Figure 1-4. An examination of Figure 1-4 reveals a moderate change in the correlation up to about 5 V, with a 31% increase at 4.03 V. A tabular summary of POL predictions before and after including the additional data point is provided as Table 1-3. For indications with amplitudes less than 1.0 volt, the POL increases by a factor of 2 to 4. The POL for indications of 3 volts increases by about 50%, while the change in the POL is not significant for indications of 8 volts and greater.

When the total leak rate is determined using the leak rate to bobbin volts correlation, the resulting value can be quite insensitive to the form of the POL function. So, the effect of the changes in the parameter values and variances would be expected to be small or insignificant relative to the calculation of the 95% confidence bound of the total leak rate from a SG. However, when the leak rate is

considered as independent of the voltage, as for the current APC database, the increase in POL will more directly affect the estimated total leak rate.

1.3 Free Span SLB Leak Rate Correlation for 7/8" Tubes

As previously noted, only one of the specimens exhibited leakage at SLB operating conditions. The test leak rate value corresponded to 2.19 lph at the SLB temperature and pressure difference conditions. The correlation of leak rate to bobbin voltage exhibits a *p*-value of 6.5% for the slope parameter using the reference database, and a value of 6.4% with the additional data point. Based on the requirements stipulated in NRC Generic Letter 95-05 for voltage based plugging criteria, the use of the correlation in performing Monte Carlo simulations to estimate the total leak rate from a SG is not considered to be justified. Figure 1-5 illustrates the new data point relative to the distribution predicted mean using the reference database and relative to a lower 95% confidence limit for a predicted leak rate from the distribution. Also illustrated on Figure 1-5, is the relation of the data point to the regression fit (median of the log-normal distribution) and to the expected leak rate (mean of the log-normal distribution) based on the regression analysis of the leak rate on the bobbin amplitude.

The common logarithm (log) of the test leak rate, 0.340, is lower than the mean log leak rate for the reference database, 0.576, but is well within one standard deviation of that value. The effects of including the data point in the database on the estimated parameters of the leak rate distribution are tabulated in Table 1-4. The estimated mean and standard deviation of the population of leak rates are decreased, hence, predicted leak rates from Monte Carlo simulations and the 95% confidence bound on the total leak rate from a single SG will be reduced. For clarification, the values listed in Table 1-4 for the mean, μ, and standard deviation, σ, of the population of leak rates are derived from the sample values of the log leak rate. These are the expected leak rate parameters to result from a simulation of the log leak rates using the NRC accepted leak rate simulation method as described in WCAP-14277.

1.4 Summary/Conclusions

The review of the effect of the additional data indicates that the SLB structural limit burst pressure will not be significantly changed by the inclusion of the data. Therefore, it is likely that the conclusions relative to EOC probability of burst and based on the correlation obtained using the reference database would not be significantly affected.

The probability of leak correlation to the common logarithm of the bobbin amplitude is moderately changed by the inclusion of the data, leading to the expectation of predicting slightly larger 95% confidence bound leak rates. At the same time, the mean and standard deviation of the leak rate distribution are decreased, leading to the expectation of lower 95% confidence bound leak rates. It may be

expected that the increase in the POL will be at least partially offset by the decrease in the predicted leak rates.

Table 1-1: Effect of Additional Data on the 7/8" Tube Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = \alpha_1 + \alpha_2 \log(Volts)$$

Parameter	Reference Database Value	Database with additional	New / Old Ratio
α_1	7.5557	7.5920	1.0048
α_2	-2.3194	-2.3700	1.0219
r^2	82.7%	81.84%	0.9900
σ_{Error}	0.817	0.828	1.0138
N (data pairs)	70	80	
p Value for α_2	$5 \cdot 10^{-27}$	$1 \cdot 10^{-30}$	$9 \cdot 10^{-4}$
Reference σ_f	68.78 ksi[(1)]		

Notes: (1) This is the flow stress value to which all data was normalized prior to performing the regression analysis. This affects the coefficient and standard error values. The corresponding values for a flow stress of 75.0 ksi can be obtained from the above values by multiplying by 1.0904.

Table 1-2: Effect of Additional Data on the 7/8" Tube Probability of Leak Correlation

$$\Pr(Leak) = \left\{1 + e^{-\left[\beta_1 + \beta_2 \log(V)\right]}\right\}^{-1}$$

Parameter	Reference Database	Database with additional	Change
β_1	-6.8974	-6.2269	-9.7%
β_2	8.3507	7.7739	-6.9%
V_{11} (1)	3.4998	2.2911	-34.5%
V_{12}	-3.8456	-2.6004	-32.4%
V_{22}	4.5821	3.2955	-26.1%
DoF(2)	97	107	
Deviance	25.09	28.90	15.2%
Pearson SD	64.0%	59.4%	-7.2%

Notes: (1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation.
(2) Degrees of freedom.

Table 1-3: Effect of Additional Data on 7/8" Tube Probability of Leak Predictions			
Bobbin Amplitude (Volts)	EPRI/NRC Database POL	w/ additional Database POL	New / Old Ratio
0.100	$2.39 \cdot 10^{-7}$	$8.31 \cdot 10^{-7}$	3.48
0.200	$2.95 \cdot 10^{-6}$	$8.63 \cdot 10^{-6}$	2.93
0.300	$1.28 \cdot 10^{-5}$	$3.39 \cdot 10^{-5}$	2.64
0.500	$8.18 \cdot 10^{-5}$	$1.90 \cdot 10^{-4}$	2.33
0.600	$1.58 \cdot 10^{-4}$	$3.52 \cdot 10^{-4}$	2.22
0.800	$4.50 \cdot 10^{-4}$	$9.29 \cdot 10^{-4}$	2.07
1.000	$1.01 \cdot 10^{-4}$	$1.97 \cdot 10^{-3}$	1.95
2.000	0.0123	0.0201	1.63
3.000	0.0515	0.0746	1.45
4.030	0.1367	0.1793	1.31
5.000	0.2572	0.3115	1.21
8.000	0.6557	0.6886	1.05
10.000	0.8105	0.8245	1.02
15.000	0.9490	0.9486	1.00
20.000	0.9814	0.9799	1.00
30.000	0.9957	0.9948	1.00
40.000	0.9985	0.9980	1.00
50.000	0.9993	0.9991	1.00

Table 1-4: Effect of Inclusion of Additional Data on the Reference Leak Rate Database for 7/8" Tube APC Applications

Parameter	Leak Rate (lph)		Log(Leak Rate)[1]	
	Reference Database	w/ additional Database	Reference Database	w/ additional Database
Sample Size	26	27	26	27
Sample μ	13.74	13.32	0.5764	0.5696
Sample σ	21.13	20.84	0.8338	0.8188
p Value			6.5%	6.4%
The following are based on the lognormal distribution sample parameters.				
Population μ	23.9 lph	22.0 lph	These values are biassed to be higher than expected.	
Population σ	149.1 lph	128.0 lph		
Upper 95% Pred.	100.6 lph	92.5 lph	These ranges are biassed to be wider than expected.	
Lower 95% Pred.	0.143 lph	0.149 lph		

Notes: 1. It has been previously shown that a log-normal distribution can be used to describe the population of leak rates.

Figure 1-1: Burst Pressure vs Volts for 7/8" Alloy 600 SG Tubes

Additional Data, Reference σ_f = 68.8 ksi @ 650°F

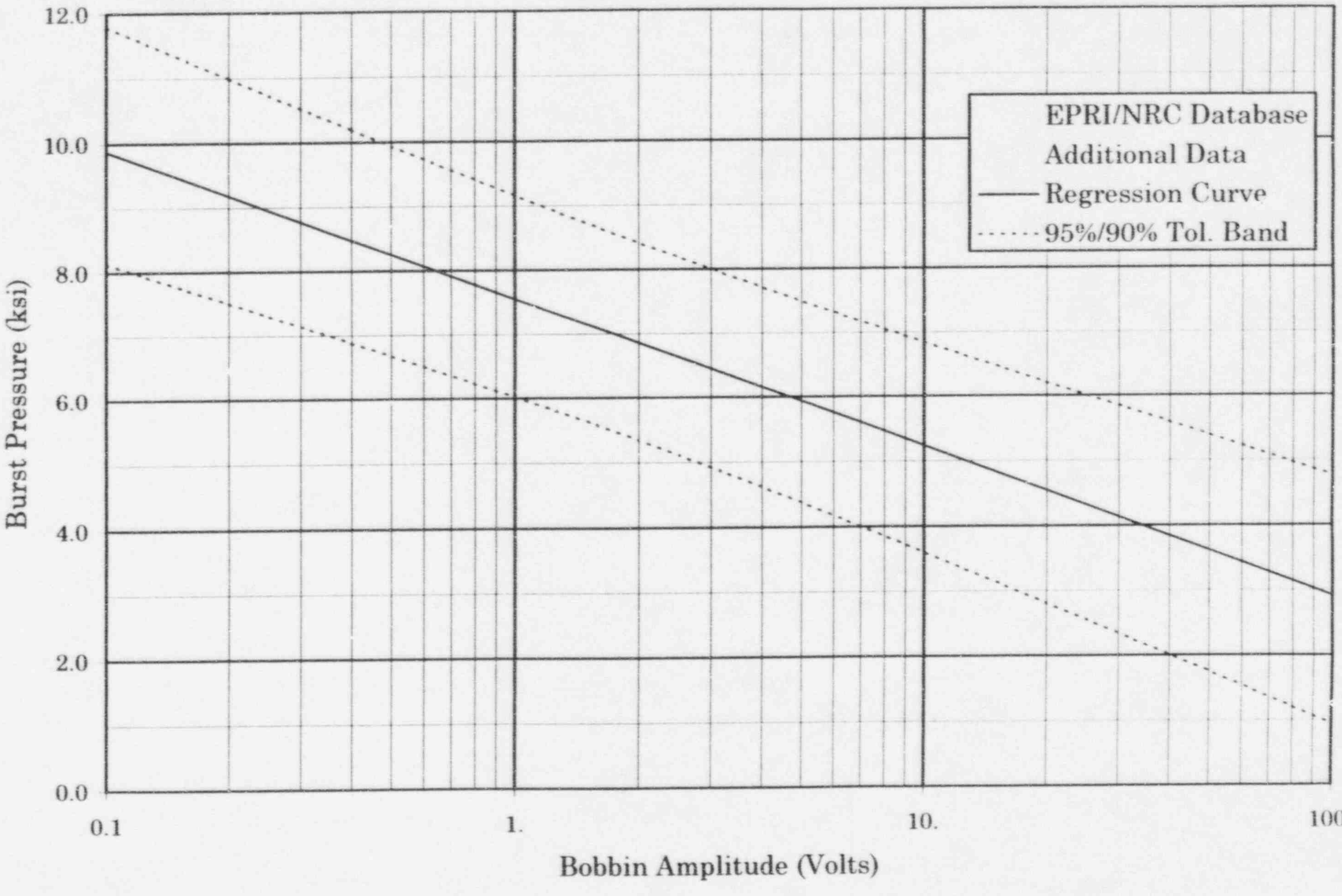
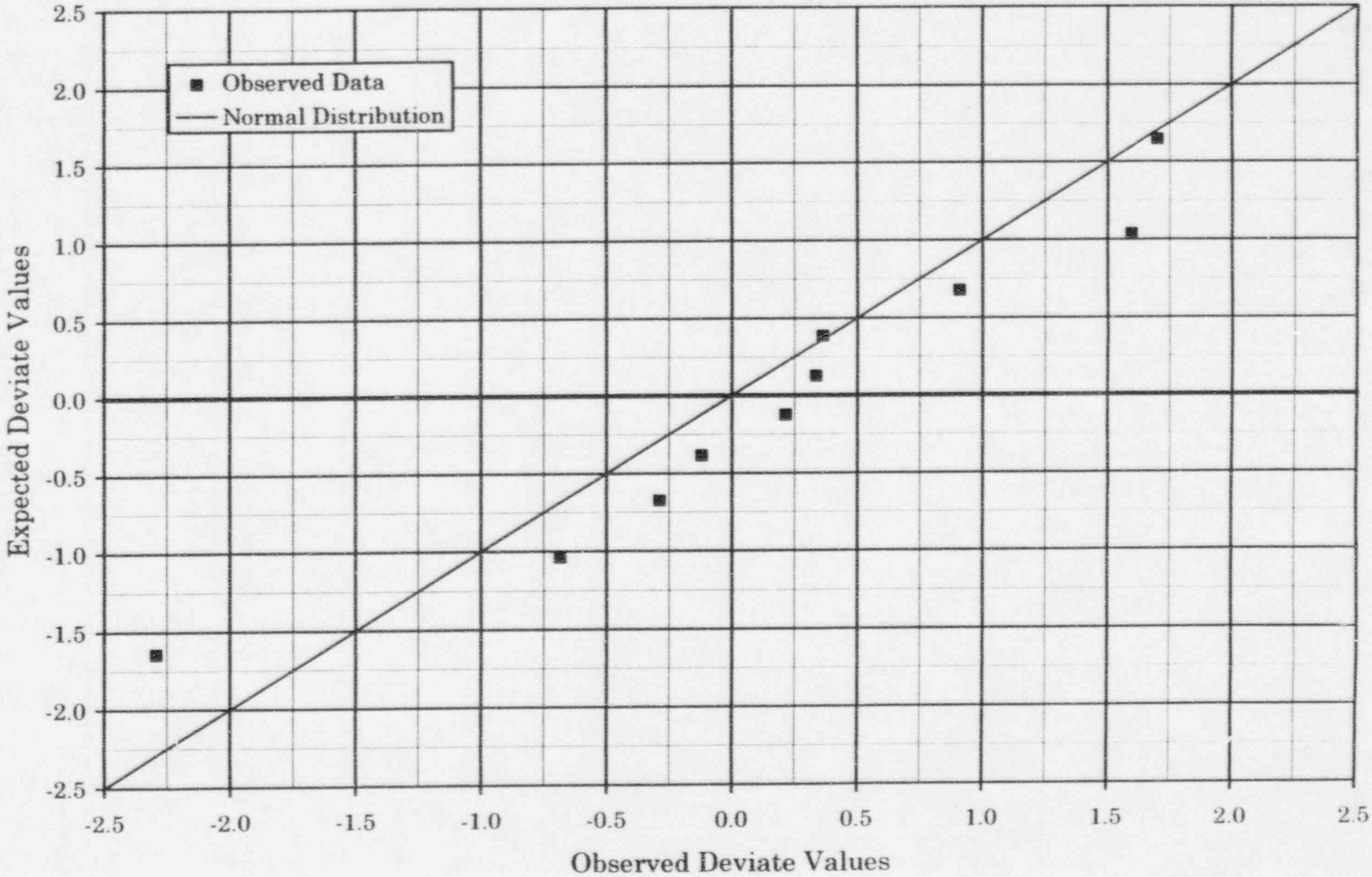


Figure 1-2: Burst Pressure for 7/8" Diameter Tubes

Deviate Analysis of Additional Data



[78BV_296.xls] New.Devs

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Figure 1-3: Burst Pressure vs Volts for 7/8" OD Alloy 600 SG Tubes

NRC/EPRI Database, Reference σ_f = 68.8 ksi @ 650°F

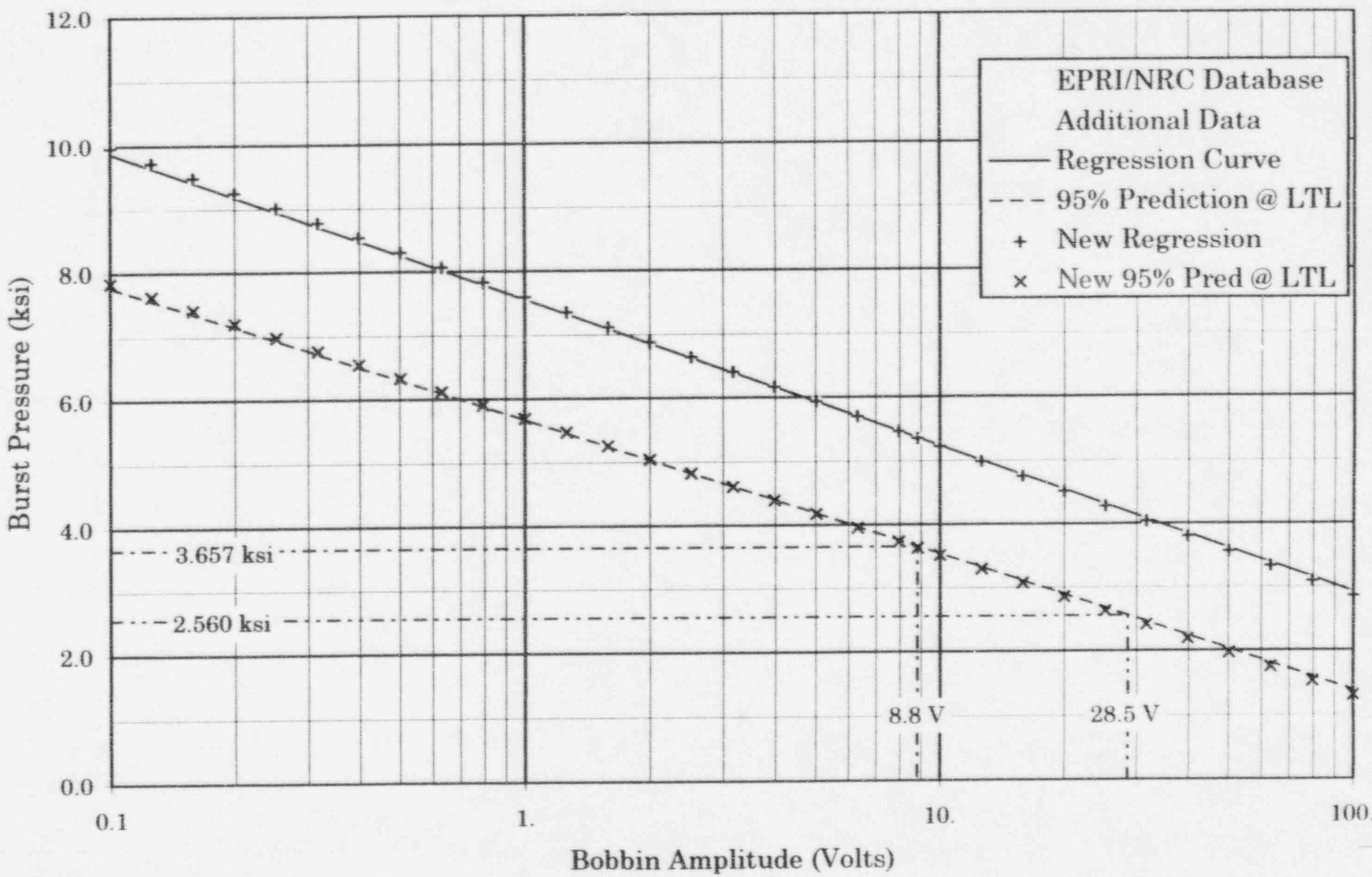


Figure 1-4: Probability of Leak for 7/8" SG Tubes
Effect of Inclusion of Additional Data

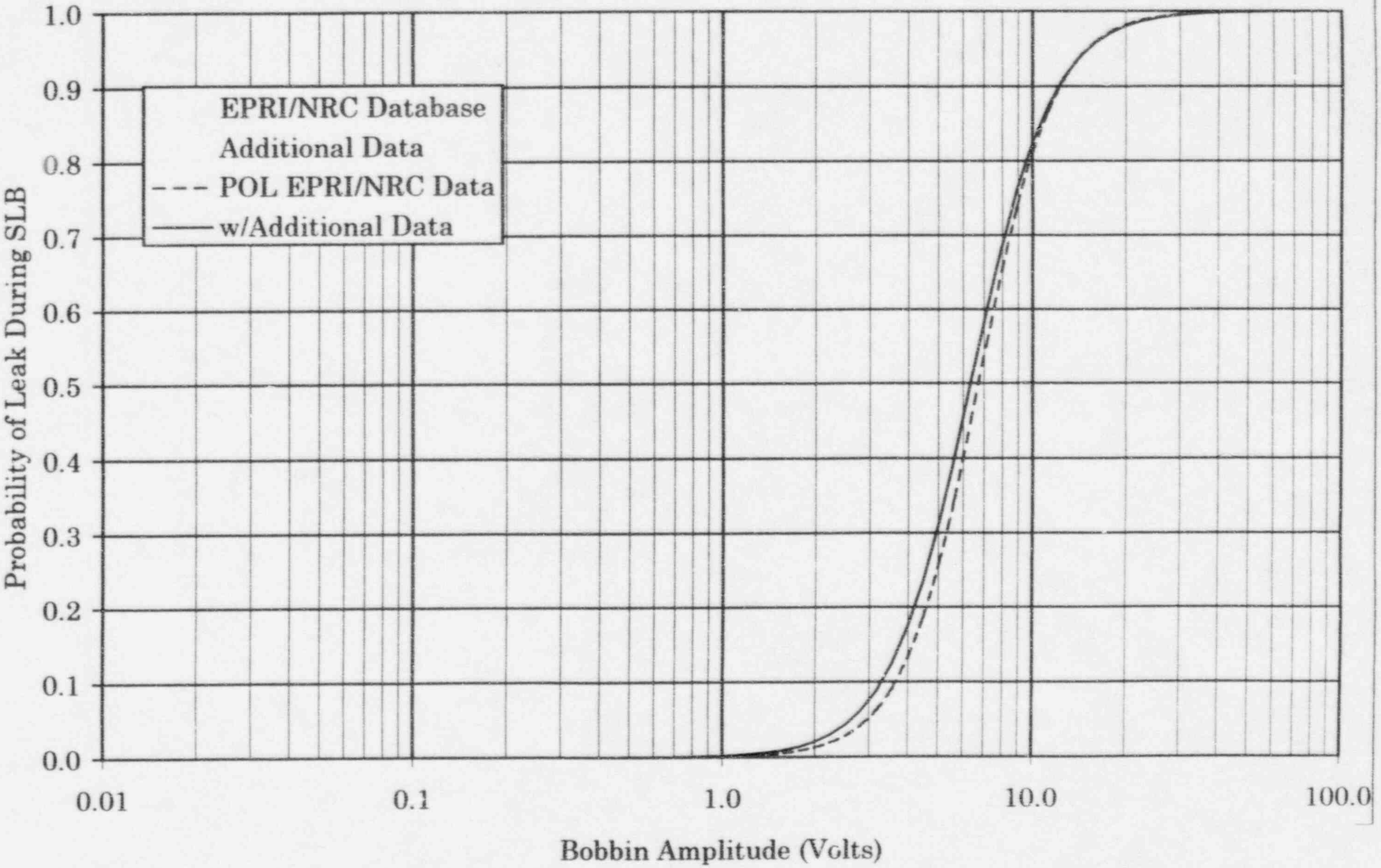
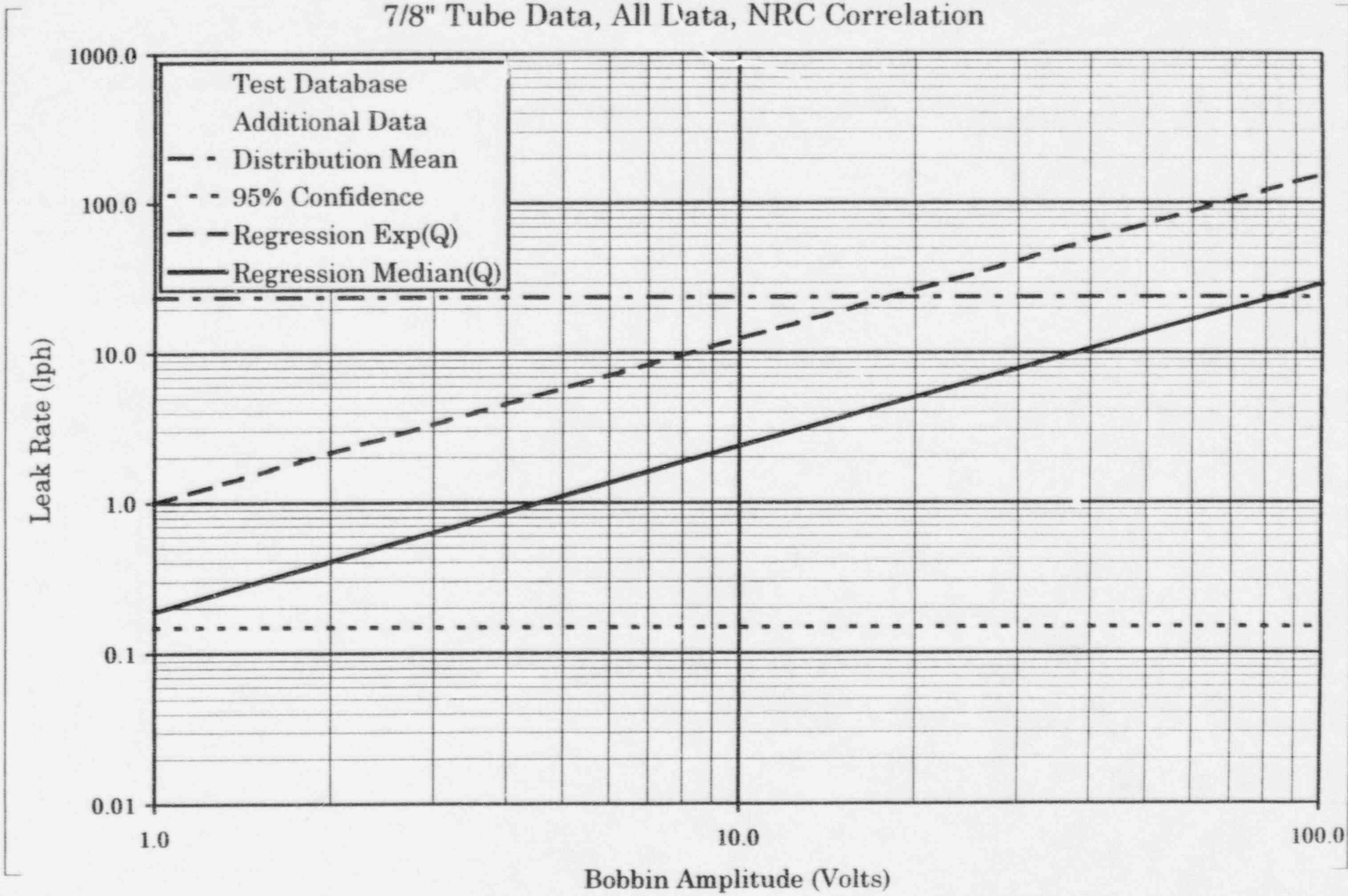


Figure 1-5: Leak Rate vs Bobbin Amplitude

7/8" Tube Data, All Data, NRC Correlation



Enclosure 4

Relevant Information

From TVA Letter Dated February 9, 1996,

"Special Report On Steam Generator (SG) Activities

Completed During The Unit 1 Cycle 7 Refueling Outage"

TABLE 3
SQN Unit 1 Cycle 7
PWSCC SAIs AND MAIs AT DENTED TUBE SUPPORT PLATES

< 5 VOLT DENTS					All Tubes will be plugged			
			Dent Size		Detected	"+ POINT "		
SG	Row	Col	>= 5 Volts	< 5 Volts	w/ Bobbin	% WALL	AXIAL EXT	INSIDE TSP
1	9	92		2.89	NDD	27	0.42	YES
3	11	71		2.02	YES	99	1.10	NO
3	21	33		3.3	NDD	34	0.36	YES
3	13	37		3.51	NDD	20	0.22	YES
3	14	71		3.74	YES	70	0.86	NO
4	1	18		2.96	YES	45	0.63	YES
4	3	53		2.95	YES	87*		YES
4	5	64		1.78	YES	94*		YES
4	9	32		4.98	YES	81*		YES
<5 VOLT DENT EXPANSION								
3	4	63		4.1	NDD	55	0.40	YES
3	26	63		4.6	NDD	20	0.27	YES
3	26	68		3.54	NDD	35	0.36	YES
3	26	77		2.49	NDD	30	0.31	YES
3	38	66		2.94	NDD	20	0.31	YES
<5 VOLT DENT EXPANSION								
4	8	48		3.52	NDD	20	0.27	YES
4	11	73		2.43	NDD	20	0.27	YES
4	17	63		4.5	NDD	35	0.27	YES
4	19	49		3.5	YES	20	0.31	YES
4	28	15		2.26	NDD	35	0.31	YES
4	30	15		2.4	NDD	20	0.27	YES
4	42	32		4.2	YES	30	0.27	YES
>5 VOLT DENTS								
1	12	51	5.6		NDD	48	0.42	YES
2	10	31	7.8		NDD	38	0.36	YES
3	8	11	5		NDD	22	0.72	YES
3	14	61	10.8		NDD	35	0.62	NO
3	14	80	15.6		NDD	50	0.36	YES
3	17	64	6.9		NDD	35	0.63	YES
3	18	61	10.5		NDD	55	0.49	NO
3	21	68	8.6		NDD	40	0.36	NO
3	33	70	6.6		NDD	25	0.22	YES
4	16	45	50.7		NDD	45	0.27	NO
4	17	46	22.7		YES	80	0.80	NO
4	26	20	5.3		YES	45	0.63	YES
4	32	20	5.2		YES	35	0.54	YES
4	34	16	5.48		NDD	44	0.27	YES
4	35	25	13.3		YES	40	0.49	YES
4	36	53	6.89		NDD	80	0.27	YES
4	36	57	5.92		NDD	65	0.31	YES
* Bobbin Coil % Throughwall								
j:\shared\u1c7\u1c7sai.xls								

ALTERNATE PLUGGING CRITERIA RESULTS

A report in accordance with Technical Specification Change 95-15 commitment for Alternate Plugging Criteria was prepared by Westinghouse Electric Corp. to provide results, distributions, and evaluations within 90 days of unit restart for the implementation of Alternate Plugging Criteria at SQN Unit 1. The Westinghouse report is Attachment 1.

DAMAGE MECHANISM ASSESSMENT AND TUBE PULL

The damage mechanism occurring on the inside diameter at the TTS transition and dented tube support plate intersections is Primary Water Stress Corrosion Cracking (PWSCC). Alloy 600 PWSCC is influenced by tensile stress, operational temperature, and a susceptible metallurgical structure in the presence of normal primary coolant water.

The metallurgical condition of all tubes with PWSCC detected at the WEXTEX expansion transitions was evaluated for the mechanical properties (tensile, yield, percent elongation, and Rockwell B hardness) relative to the average of all tubes in the SG. Generally, higher carbon contents in Alloy 600 imply a higher susceptibility to PWSCC.

Comparison of Carbon Content and Mechanical Properties					
	Carbon	Tensile	Yield	Elongation	Hardness
	(%)	(KSI)	(KSI)	(%)	(B)
Average of All SQN SGs	0.034	102.26	56.35	38.40	87
Average of all tubes with TTS PWSCC	0.03	101.90	56.04	39.00	87

Tube with TTS expansion zone PWSCC in the SQN Unit 1 SGs do not have significantly different mechanical properties than the average tubes in the SQN SGs.

An assessment of the location of TTS PWSCC cracks was obtained by evaluating, by zones, the distribution of cracks (axial and circumferential) within the SGs and is listed below:

	Number of Cracks in Zones									
	Zone 1		Zone 2		Zone 3		Zone 4		Total in SG	
SG	Axial	Circ.	Axial	Circ.	Axial	Circ.	Axial	Circ.	Axial	Circ.
1								4	0	4
2		2		1	2	5	4	33	6	41
3								18	0	18
4	1						3	19	4	19
Total	1	2		1	2	5	7	74	10	82
Total / zone	3		1		7		81		92	
Percent	3.3%		1.1%		7.6		88.0%			

Results of the SQN U1C7 examinations show zone 3 and 4 contained 95.6% of all axial and circumferential expansion zone PWSCC. Zone 3 and 4 , being located in the center section of the SG, would operate at a higher temperature and be insulated by the sludge pile further raising the tube temperatures and driving the kinetics of TTS PWSCC.

A sample of tubes from each SG with TTS PWSCC were reviewed for internal diameter tubesheet expansion transition profiles. Evaluations of the expansion transition profiling plots identified the majority of the circumferential PWSCC detected was associated with oversized tubesheet hole conditions that produce transitions with changes in diameter of greater than 15 mils and/or irregularly shaped (sharp or uneven) transitions. The table below is a sample of tubes from each SG with circumferential PWSCC.

Irregular Tubesheet Profile Evaluation			
SG	**Tubes with PWSCC and Profile data**	**Tubes with Oversized holes and/or Irregular Expansions**	**Percent of Tubes with Oversized holes and/or Irregular Expansions**
1	2	1-OH 0-IR	1 of 2 50%
2	21	17-OH 1-IR	18 of 21 86%
3	9	3-OH 0-IR	3 of 9 33%
4	6	5-OH 0-IR	5 of 6 83%
Totals	**38**	**26-OH** **1-IR**	**27 of 38** **71%**

The tube pulled for top of tubesheet Primary Water Stress Corrosion Cracking will be discussed in this section. Tubes pulled for alternate plugging criteria will be discussed in the section on Alternate Plugging Criteria.

One tube (R15 C23) was pulled from Steam Generator 2 for a top of tubesheet inside diameter (ID) circumferential indication. The TTS region fractured during the tube pulling process. Field eddy current data (3 coil RPC) for the TTS region of R15 C23 determined an ID circumferential indication measuring 336° circumferential extent. The +Point probe measured the same location to have multiple circumferential indications with a total circumferential involvement of 316°. Figure 3 is the crack profile by blind NDE (3 coil RPC) verses actual destructive examination results. NDE results show good correlation with metallurgical Scanning Electron Microscopy (SEM) results.

Due to the fracturing of the tube during the pulling process, leak and burst testing were not able to be performed.

The calculated burst pressure from the destructive analysis results is approximately 7800 psi, which is well within the structural integrity requirements of Regulatory Guide 1.121.

SEM fractography was performed on the fracture face of tube R15 C23. The ID origin corrosion averaged 26% throughwall around the circumference with a maximum depth of 88%. The corrosion was comprised of 5 separate macrocracks. SEM examinations showed no nearby, separately nucleated, corrosion cracks parallel to the fracture face on the tube ID surface. Depth profiling of the indication is presented in Table 4. This simple corrosion morphology is typical of primary water stress corrosion cracking. There were no markings on the tube OD to identify the TTS relative to the fracture face and significant tube elongation prevented a precise dimensional analysis of the pre-pull fracture face elevation.

Based on the pulled tube analysis, NDE characterization of the TTS expansion transition conditions, chemistry, and metallurgical condition of the Alloy 600 tubes, it was concluded that the damage mechanism is PWSCC originating in the WEXTEX expansion transitions. In addition, 95.6% of the time indications occur in zones 3 and 4, and have a higher probability in tubes with oversized diameter tubesheet hole conditions.

FIGURE 3
ROW 15 COL 23 SG 2

Sequoyah R15C23; Circumferential Crack ,TTS
(As-Read by Analyst)

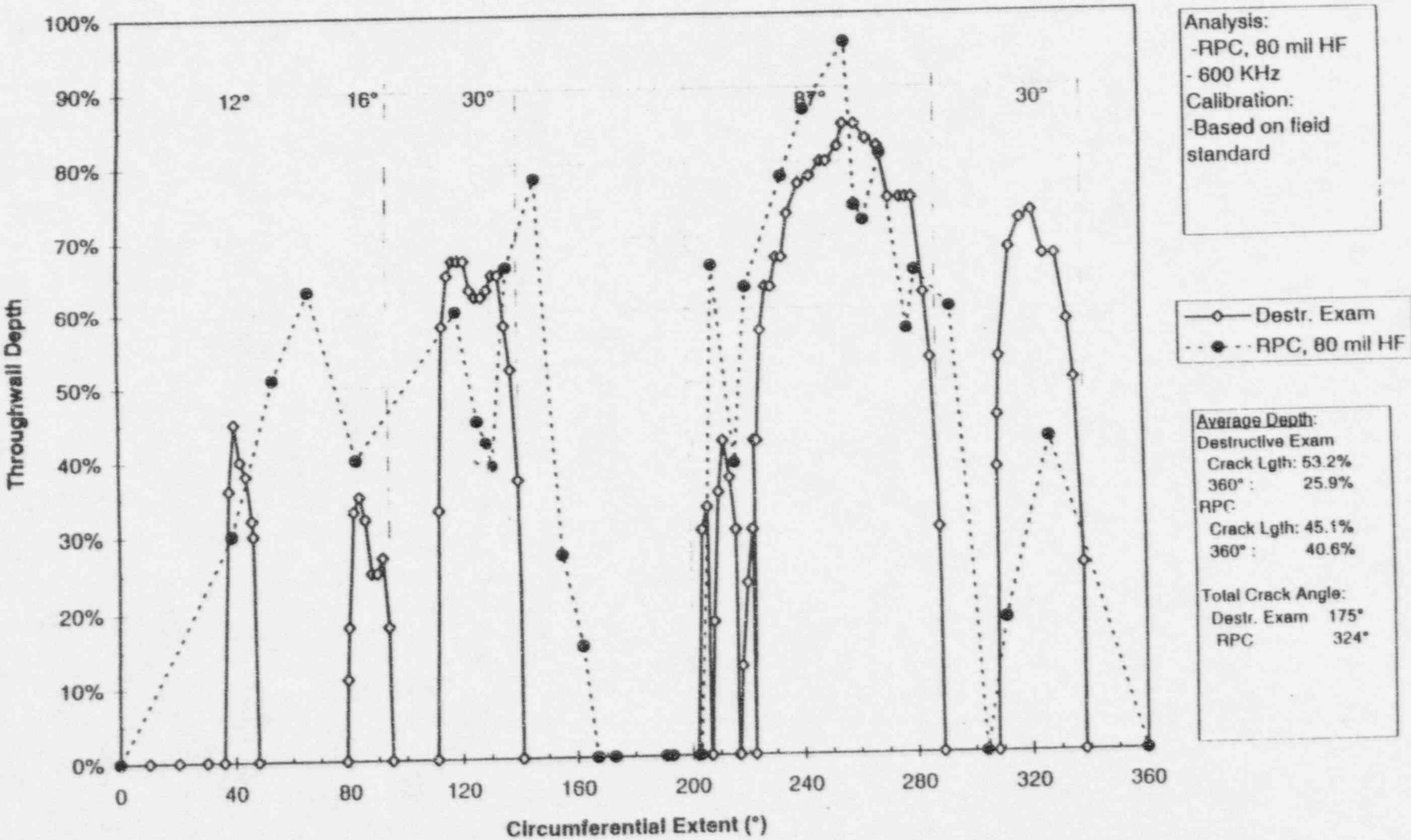


TABLE 4
ROW 15 COL 23 SG 2

Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Depth Profiles for ID Origin Corrosion

Tube No., Location	Length vs. Depth (degrees / % throughwall)	Ductile Ligament Location / Width (inches)	Comments
R15C23,	00/00		
Near TTS	10/00		
	20/00		
	30/00		
	(36/00) <== Macrocrack 1 Tip		
	40/41		Macrocrack 1 Length
	(46/00) <== Macrocrack 1 Tip		= 10 degrees
	50/00		
	60/00		
	70/00		
	(79/00) <== Macrocrack 2 Tip		
	80/16		Macrocrack 2 Length
	(90/23)		= 16 degrees
	(94/00) <== Macrocrack 2 Tip		
	100/00		
	110/00		
	(111/00)<== Macrocrack 3 Tip		Macrocrack 3 Length
	120/66		= 31 degrees
	130/67		
	140/44		
	(142/00)<== Macrocrack 3 Tip		
	150/00		
	160/00		
	170/00		
	180/00		
	190/00		
	200/00		
	(202/00)<== Macrocrack 4 Tip		

Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Depth Profiles

Tube No., Location	Length vs. Depth (degrees / % throughwall)	Ductile Ligament Location / Width (inches)	Comments
R15C23, Near TTS	(204/34) (206/00)<== Ligament 1 210/42 (211/41) (216/00)<== Ligament 2 220/25 (221/00)<== Ligament 3 230/63 240/75 250/77 (253/00)<== Ligament 4 260/81 (264/88)<== Maximum Crack Depth 270/75 280/72 (288/00)<== Macrocrack 4 Tip 290/00 300/00 (308/00)<== Macrocrack 5 Tip 310/50 320/69 330/64 (338/00)<== Macrocrack 5 Tip 340/00 350/00 (Average Macrocrack Depth = 26% Throughwall over 360 degrees; There were no 100% throughwall areas; Max. Crack Depth = 88% Throughwall at 264 degrees.)	<== Ligament 1 / 0.005" wide <== Ligament 2 / 0.008" wide <== Ligament 3 / 0.003" wide <== Ligament 4 / 0.012" wide	Macrocrack 4 Length = 86 degrees Macrocrack 5 Length = 30 degrees

TABLE 4 (CONTINUED)
ROW 15 COL 23 SG 2

CIRCUMFERENTIAL GROWTH RATES

To determine a circumferential crack growth rate, a review was performed of past examinations for all tubes identified at the SQN Unit 1 Cycle 6 outage where PWSCC was initiated. This review was performed with knowledge that a defect was present and to determine if the defect was present in previous examinations. The table below is comparative data for 79 tubes with circumferential indications previously examined with RPC during the prior outage. The average circumferential crack growth rate from Cycle 6 to Cycle 7 was 47.5°, with a minimum of 0° and a maximum of 185°.

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	Row	Column	Location	U1C7-deg	U1C6-deg	DELTA
1	15	64	HTS	79	46	33
1	15	66	HTS	89	63	26
1	25	42	HTS	89	88	1
1	28	43	HTS	63	33	30
2	4	39	HTS	74	NDD	74
2	7	22	HTS	80	74	6
2	9	72	HTS	106	69	37
2	10	36	HTS	141	123	18
2	10	37	HTS	79	50	29
2	12	19	HTS	78	50	38
2	12	19	HTS	64	42	22
2	12	34	HTS	87	NDD	87
2	13	26	HTS	101	NDD	101
2	13	32	HTS	114	NDD	114
2	15	22	HTS	75	NDD	75
2	15	23	HTS	336	284	52
2	15	38	HTS	93	NDD	93
2	16	38	HTS	162	60	62
2	17	21	HTS	80	66	14
2	17	26	HTS	75	NDD	75
2	18	26	HTS	117	63	54
2	18	28	HTS	76	57	19
2	18	36	HTS	88	NDD	88
2	19	23	HTS	60	NDD	60
2	19	25	HTS	100	56	44
2	19	26	HTS	80	73	7
2	19	49	HTS	185	NDD	185
2	19	51	HTS	112	NDD	112
2	21	27	HTS	59	NDD	59
2	21	30	HTS	160	144	16

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	Row	Column	Location	U1C7-deg	U1C6-deg	DELTA
2	22	29	HTS	87	63	24
2	23	30	HTS	68	48	20
2	24	40	HTS	71	NDD	71
2	25	34	HTS	93	67	26
2	25	66	HTS	91	71	20
2	28	52	HTS	85	NDD	85
2	28	54	HTS	162	NDD	162
2	29	38	HTS	92	NDD	92
2	29	49	HTS	74	NDD	74
2	29	54	HTS	101	27	24
2	29	59	HTS	70	NDD	70
3	4	53	HTS	114	NDD	114
3	4	54	HTS	45	40	5
3	6	53	HTS	63	NDD	63
3	6	53	HTS	66	NDD	66
3	6	57	HTS	63	NDD	63
3	7	49	HTS	173	NDD	173
3	7	73	HTS	80	NDD	80
3	8	18	HTS	70	65	5
3	8	52	HTS	113	105	8
3	8	58	HTS	39	NDD	39
3	8	75	HTS	154	162	0
3	9	76	HTS	74	71	3
3	11	61	HTS	51	52	0
3	15	66	HTS	70	NDD	70
3	16	45	HTS	171	55	116
3	18	50	HTS	58	NDD	58
3	26	48	HTS	50	51	0
3	26	63	HTS	49	NDD	49
3	30	58	HTS	51	40	9
4	7	77	HTS	76	66	10
4	8	30	HTS	70	63	7
4	12	26	HTS	35	37	0
4	12	28	HTS	67	61	6
4	12	31	HTS	61	NDD	61
4	13	39	HTS	93	84	9
4	13	47	HTS	96	NDD	96
4	14	41	HTS	281	271	10
4	14	52	HTS	51	70	0
4	15	38	HTS	105	NDD	105
4	15	48	HTS	55	NDD	55
4	16	32	HTS	67	58	9
4	18	27	HTS	68	56	12

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	Row	Column	Location	U1C7-deg	U1C6-deg	DELTA
4	18	41	HTS	205	201	4
4	18	46	HTS	76	73	3
4	19	38	HTS	92	NDD	92
4	19	39	HTS	45	NDD	45
4	19	61	HTS	50	41	9
4	20	46	HTS	64	67	0

Avg. = 47.50633

CORRECTIVE ACTIONS TO PREVENT REOCCURRENCE OF PWSCC RELATED TO TUBESHEET EXPANSION

The corrective actions that have been implemented to address top of tubesheet PWSCC was shotpeening. Shotpeening was implemented in the Unit 1 Cycle 5 outage on all non plugged tubes from the tube end throughout the explosive expansion region to 2 inches above the top of the tubesheet. Shotpeening applies compressive stresses on the inside surface with an effective depth of 4 to 7 mils. The expansion region internal surface stresses were changed from 40-45 ksi tensile stresses to 60 ksi compressive stresses. The change in stress state to compressive will provide margin against initiation of future PWSCC. Pre-existing cracks with depths greater than 4 mils will not be ameliorated by shotpeening and will have a reasonable probability of progressing to detectable flaws in future fuel cycles. Based on SQN Unit 1 and industry experience, it is projected that less than 5 percent of the tubes in SQN Unit 1 will be affected over the life of the plant, by expansion transition PWSCC. TVA's SQN Unit 1 SGs were the first explosively expanded tubesheet transitions in the world to be shotpeened. TVA has taken a aggressive approach by implementing shotpeening to prevent long-term SG tube degradation of SQN SGs due to PWSCC in the tubesheet expansion region. A number of tubes that experience expansion transition PWSCC during the U1C7 outage resulted from preexisting indications that were most probability greater than 4 mils during the initial shotpeening. The number of tube presently affected by expansion transition PWSCC is significantly below the 5 percent projection over the plant life.

During the U1C7 refueling outage SQN implemented SG chemical cleaning to address outside diameter stress corrosion cracking (ODSCC). TVA predicted that circumferential cracking would occur at dented tube support plates based on SQN Unit 1 and other plant experience. Chemical cleaning was implemented as a preventative measure to address circumferential cracking at dented tube support plates. The process that was used is the Westinghouse pressure pulse chemical cleaning which used the EPRI/SGOG chemical formulations. Qualification of the process was performed by Westinghouse and TVA to verify effectiveness in cleaning tube support plate crevices. TVA has taken an aggressive approach to ODSCC at the top of tubesheet and at both dented and non dented tube support plate intersections. TVA had the foresight to implement chemical cleaning based on a predictive model of ODSCC and to prevent early SG replacement.