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AUTH.NAME AUTHOR AFFILIATION
LEVINE,J.M. Arizona Public Service Co. (formerly Arizona Nuclear Power
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SUBJECT: Submits 90-day response to GL 97-05, "Steam Generator Tube Insp Techniques." Commitments made,listed.

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APS
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Palo Verde Nuclear Generating Station

James M. Levine
Senior Vice President
Nuclear

TEL (602)393-5300
FAX (602)393-6077

Mail Station 7602
P.O. Box 52034
Phoenix, AZ 85072-2034

102-04094 – JML/SAB/RMW
March 13, 1998

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: **Palo Verde Nuclear Generating Station (PVNGS)**
Units 1, 2, and 3
Docket Nos. STN 50-528/529/530
Response to Generic Letter 97-05: "Steam Generator Tube Inspection Techniques"

Dear Sirs:

Enclosure 1 provides Arizona Public Service Company's (APS) response to Generic Letter 97-05: "Steam Generator Tube Inspection Techniques".

Commitments Made in this Letter

APS will implement Nuclear Energy Institute (NEI) 97-06, *Steam Generator Program Guidelines*, for steam generator inspections that are performed after January 1, 1999.

Please contact Mr. Scott Bauer at (602) 393-5978 if you have any questions or would like additional information regarding this matter.

Sincerely,

James M. Levine

JML/SAB/RMW/rlh

Enclosure/Attachment

A001
1/1

cc: E. W. Merschoff
K. E. Perkins
J. W. Clifford
J. H. Moorman

ADD: AL DeMerick

STATE OF ARIZONA)
) ss.
COUNTY OF MARICOPA)

I, J. M. Levine, represent that I am Senior Vice President - Nuclear, Arizona Public Service Company (APS), that the foregoing document has been signed by me on behalf of APS with full authority to do so, and that to the best of my knowledge and belief, the statements made therein are true and correct.

J. M. Levine

Sworn To Before Me This 13th Day Of March, 1998.

Nora E. Meador
Notary Public

My Commission Expires

April 6, 1999

OFFICIAL SEAL
NORA E. MEADOR
Notary Public - State of Arizona
MARICOPA COUNTY
My Comm. Expires April 6, 1999

ENCLOSURE 1

Response to Generic Letter 97-05:
"Steam Generator Tube Inspection Techniques"

NRC Request 1: **Is it your practice to leave steam generator tubes with indications in service based on sizing?**

APS Response:

PVNGS may elect to leave certain steam generator tubes with non-corrosion related indications in service. The determination to leave a tube in service is made on a case-by-case basis, and is based on the sizing of the imperfection or degradation that has been identified in that tube. The terms "imperfection" and "degradation" are defined in Section 4.4.4.4 of the PVNGS Technical Specifications. All tube indications that are left in service comply with the plugging limit as defined in Technical Specification Section 4.4.4.4.a.6., i.e., the imperfection depth is less than 40% of the nominal tube wall thickness. A description of the steam generator tube examination methods and the technical basis for using these methods are provided below.

NRC Request 2: **If the response to item (1) is affirmative, submit a written report that includes, for each type of indication, a description of the associated nondestructive examination method being used and the technical basis for the acceptability of the technique used.**

APS Response:

Introduction:

The nuclear power industry recently voted to adopt an initiative requiring each facility to implement the guidance provided in NEI 97-06, *Steam Generator Program Guidelines.* Implementation of this initiative by each facility is to occur no later than that facility's first refueling outage starting after January 1, 1999. As specified in this document, each facility is required to follow the steam generator inspection guidelines contained in the latest revision of the Electric Power Research Institute (EPRI) *PWR Steam Generator Examination Guidelines.*

With respect to the detection and sizing of flaws, Appendix H, "Performance Demonstration for Eddy Current Examination," of the *PWR Steam Generator Examination Guidelines*, Revisions 3 through 5, provides guidance on the qualification of steam generator tubing examination techniques and equipment. This appendix divides the damage mechanisms associated with steam generator tubing into several categories for qualification purposes. These categories are thinning, pitting, wear, outside diameter (OD) intergranular attack (IGA)/ stress-corrosion cracking (SCC), primary-side SCC and impingement damage.

For qualification purposes, test samples are used to evaluate detection and sizing capabilities. While pulled tube samples are preferred, samples fabricated using mechanical or chemical methods may be used. However, the fabricated flaws should produce signals similar to those observed in the field in terms of signal characteristics, signal amplitude, and signal to noise ratio. Sample flaw size is verified to determine the actual through wall defect measurement as part of the Appendix H qualification process.

The procedures developed in accordance with Appendix H specify the essential variables for each technique. These essential variables are associated with an individual instrument, probe, cable, or particular on-site equipment configurations. Additionally, certain techniques have undergone additional testing and review to quantify sizing performance. The sizing data set requirements specified in Appendix H include the original detection data set for the technique, as well as additional requirements regarding the number and composition of the grading units used for characterizing sizing capability.

PVNGS Steam Generator Description:

The steam generators at PVNGS Units 1, 2 and 3 were designed and fabricated by Combustion Engineering (CE), and are currently the only operating units of the System 80 design. Each steam generator contains 11,012 - 3/4 inch OD, Alloy 600 tubes. The tubes have a nominal wall thickness of 0.042" and an average heated length of 57.75 feet. The tubes were explosively expanded into the tubesheet for the entire tubesheet thickness. The tubing was manufactured to the requirements of ASME SB-167, as supplemented by CE specification requirements. The carbon content and maximum yield strength were restricted to 0.05 percent and 55,000 psi, respectively. These requirements assured a relatively high temperature final anneal of 1806 °F. The tubes are arranged in rows, with all tubes in a given row having the same length. The rows are staggered, forming a triangular pitch arrangement. The shorter tubes, which have 180° bends, are located in the first 18 rows at the center of the tube bundle. All tubes in the subsequent rows have double 90° bends. The horizontal tube supports located along the vertical section of the tubes are of the eggcrate design. The bend and

horizontal regions of the tubes are supported by batwing and vertical lattice supports, respectively. All of the tube supports are manufactured from 409 ferritic stainless steel.

Figure 1 provides a diagram representing support structures and key locations for service-induced tube degradation in the PVNGS steam generators. Note that the horizontal support numbers on these drawings refer to the supports located immediately above the number. The letters "H" and "C" in the support numbers indicate that the support is either a hot leg (H) or cold leg (C) support.

Repair Criteria:

As indicated in References 2 and 3, APS may apply administrative repair criteria that are more conservative than those required by the PVNGS Technical Specifications. The administrative repair criteria have been developed to address PVNGS–specific tube degradation phenomenon. APS performs an engineering review of all steam generator tube indications prior to placing the steam generators back in service. All tubes with detected SCC, regardless of size or depth, are removed from service. All indications with evidence of volumetric IGA are also removed from service. Additionally, APS applies conservative administrative plugging criteria for certain wear or tube fretting indications that may be unique to PVNGS. The administrative plugging criteria for these unique indications include:

- Wear indications ≥ 20% through-wall for Stay Cylinder Batwing Wear. The affected tube population is identified in Reference 4.

- Wear indications ≥ 20% through-wall (by bobbin coil probe) for Cold Leg Corner Wear. The affected tube population is identified in Reference 5.

- Wear indications ≥ 35% through-wall for tubes with no previously identified wear. A historical review of previous steam generator tube inspection results is permitted for this evaluation.

- All tubes with detected loose parts (PLPs) meeting the following criteria are plugged:

    1. Detectable wear is present and the loose part can not be retrieved, or

    2. Detectable wear is greater than or equal to 40% through-wall regardless of whether the loose part is retrieved.

- Freespan volumetric indications identified as tube-to-tube wear indications that indicate ≥ 35% through-wall. This particular plugging criterion is based on PVNGS - specific tube pull results (Reference 6).

Degradation Mechanisms - PVNGS Steam Generators

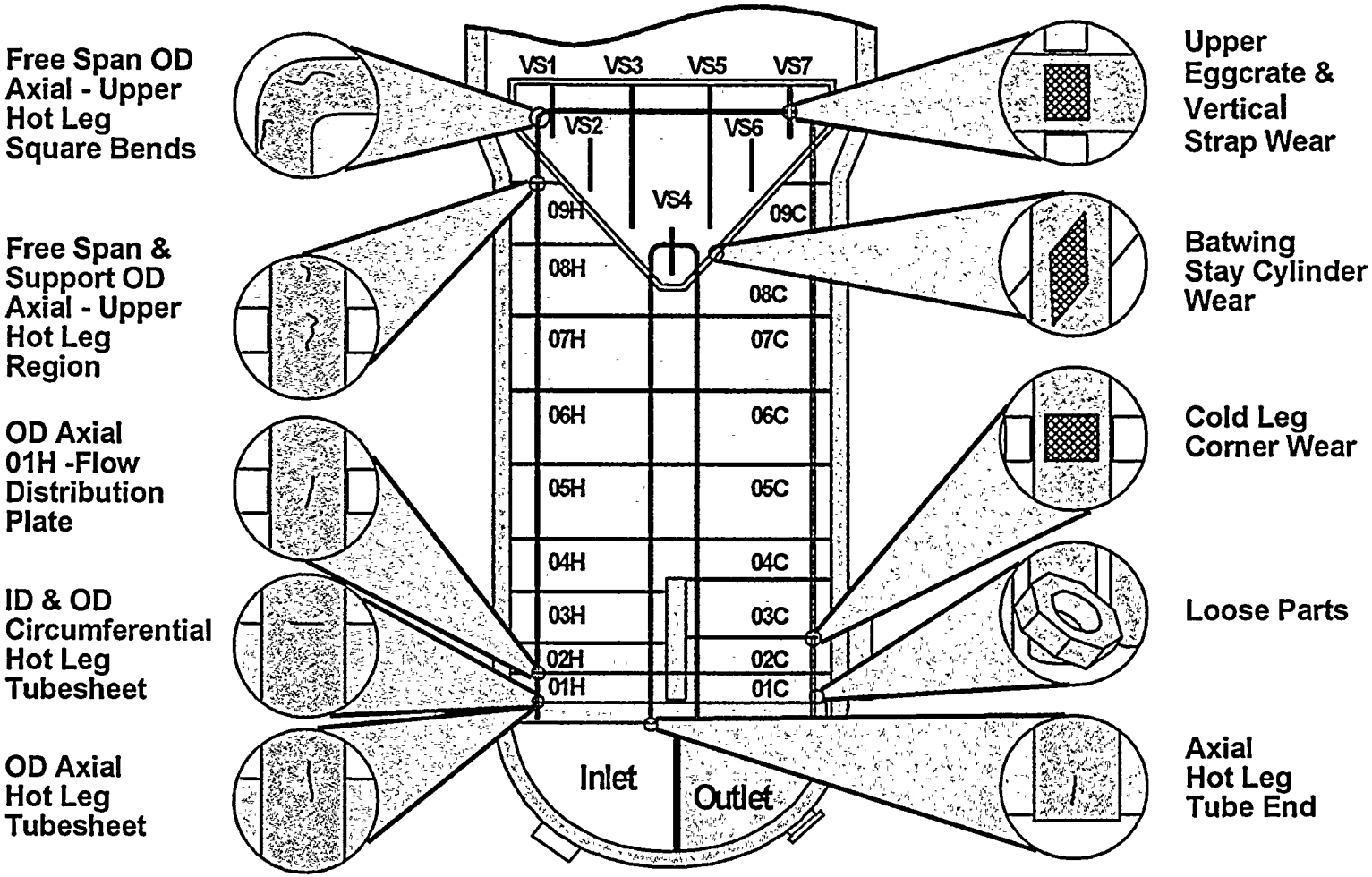

Figure 1

Sizing Techniques

Service-induced flaws may remain in service based on the non-destructive examination (NDE) techniques described below. These techniques are applied during steam generator tube examinations performed at PVNGS in accordance with the PVNGS Quality Assurance Program. The PVNGS Steam Generator Eddy Current Examination Procedure defines the conduct of examinations and ensures that the applicable requirements of ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components* – 1980 Edition including Addenda through Winter 1981, ASME Section V, *Nondestructive Examination* - 1980 Edition including Addenda through 1981 and Regulatory Guide 1.83, *Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes* are implemented. The qualification data sets of Appendix H to the EPRI *PWR Steam Generator Examination Guidelines* provide additional information that is used to assist in the sizing of flaws and characterizing degradation-specific mechanisms. A description of the type of indications found at PVNGS, steam generator tube examination methods used, and the technical basis for these methods are provided as follows:

Wear and Tube Fretting

Mechanism - *Support-Induced Wear*

As stated previously, APS applies repair criteria for service-induced wear in accordance with the PVNGS Technical Specifications or the more conservative mechanism-specific administrative plugging limits. For support-induced wear, flaw sizing is accomplished using the 500/100 kHz differential mix of a bobbin coil probe. A calibration curve for amplitude vertical maximum is determined based on the applicable test standards that replicate the damage mechanism type and quantity. The calibration curve must represent the full range of expected depths.

Technical Basis:

In accordance with Revision 4 of the EPRI PWR *Steam Generator Examination Guidelines*, the support wear sizing qualification is based on 64 sample data points. The samples ranged in depth from 4% to 78% through-wall. Therefore, the sizing data set requirements of Appendix H to the EPRI guidelines were satisfied. Site performance testing conducted by APS, described in References 4 and 7, indicated that the bobbin coil probe also has appropriate sizing capability for flaws having through-wall depths within the range of 10-50%. Use

of the bobbin coil probe as a detection technique for wear has also been qualified, and is included in the data set for Appendix G, *Qualification of Nondestructive Examination Personnel for Analysis of Eddy Current Data (QDA),* of the EPRI guideline. Additionally, APS performs a rotating coil (RC) probe (using a Plus Point coil probe) inspection of bobbin coil probe hot leg wear indications that are >20% through-wall to verify that SCC is not present. As stated previously, if SCC is detected the tube is removed from service, otherwise the wear indication is dispositioned in accordance with the applicable PVNGS repair criteria.

Mechanism – *Loose Part Induced Wear*

Wear due to a loose part is plugged upon detection regardless of size. The only exception to this criterion occurs when the part is physically removed from the steam generator. Removal of the loose part from the steam generator will arrest this damage mechanism. If the loose part is successfully removed from the steam generator, the indication may be sized using the techniques described above for support-induced wear and the appropriate plugging criteria will be applied to the indication. The affected tube may be left in service if the size of the indication is less than 40% through-wall.

Technical Basis:

Defects due to loose part wear are left in service only if the object causing the tube wall loss is removed from the steam generator and the indication is less than 40% through-wall. The techniques and technical basis described for support-induced wear are applicable for this repair criteria. In addition, APS has conducted a loose part study (Reference 8) documenting the NDE signal response of 16 objects of differing sizes and materials. The information from this study has been incorporated into the PVNGS Data Analysis Training program. This information provides the analyst with signal response information to relate the flaw signal with the causal factor. Therefore, it is very unlikely that wear indications due to loose parts will not be detected and resolved. As indicated previously, if a loose part is detected, every reasonable effort is made to remove the offending part from the steam generator. If the part cannot be removed, then the tube is removed from service.

Mechanism – *Tube-to-Tube Wear (TTW)*

As indicated in Reference 2, steam generator tube pulls conducted at PVNGS in Units 2 and 3 found unique volumetric indications occurring in the tube bend region of some of the tubes that were removed from the steam generators. The indications on the affected tubes did not show any evidence of IGA and are believed to be the result of tube wear due to tube-to-tube contact. Tubes with this type of indication are removed from service if the indication has been determined to exceed 35% through-wall depth, as measured by RC techniques. The RC exam also verifies that SCC is not present within the indication.

Technical Basis:

The examination results of the steam generator tubes that were pulled from the Unit 2 and 3 steam generators determined that several small indications, located on either the extrados or intrados of the square bend region of the affected tube, were most likely the result of tube-to-tube contact. NDE examination of these tubes demonstrated the ability to detect, size and characterize the defects with RC probe techniques. Since the RC probe techniques are qualified to detect SCC, these techniques may also be used to verify that SCC is not present in the indication. As indicated above, tubes with this type of indication are removed from service if the indication has been determined to exceed 35% through-wall depth, or if SCC is present within the indication.

The NDE examination and analysis information that was obtained as a result of the steam generator tube pulls has been incorporated into the PVNGS Data Analysis Training Manual. Motorized Rotating Pancake Coil (MRPC) and Plus Point coil probes are also EPRI Appendix H qualified detection techniques for SCC detection and are included in the data set for Appendix G, *Qualification of Nondestructive Examination Personnel for Analysis of Eddy Current Data (QDA),* of the EPRI guideline. As stated previously, if SCC is detected the tube is removed from service, otherwise the wear indication is dispositioned in accordance with the applicable PVNGS repair criteria.

Tube Corrosion

APS administratively removes all tubes with detected corrosion from service by plugging regardless of size and depth of the flaw. As described in References 2 and 9, APS performs extensive RC (Plus Point) probe examinations of all steam generator tube locations that may experience potential corrosion.

Non-Flaw/Non-Service Induced Indications

The large-scale use of RC examinations by PVNGS and industry has resulted in defining various three-letter codes to describe certain steam generator tube NDE inspection results. Examples of these codes are described in Appendix F of the EPRI *PWR Steam Generator Examination Guidelines*. Codes used to describe SCC such as Single Axial Indication (SAI) or Single Circumferential Indication (SCI) are codes that are used to designate a pluggable indication. Other codes are used to confirm non-flaw type indications or indications which are not service-induced such as manufacturing marks. The following information is provided for the three-letter codes utilized at PVNGS that identify non-flaw type indications or indications that are not service-induced. These codes require an engineering evaluation to be performed during the inspection process to confirm that neither the PVNGS Technical Specifications nor administrative repair criteria are exceeded.

APS conducted steam generator tube pulls that removed 31 tube sections from the Units 2 and 3 steam generators. The examination results of the pulled tubes, as well as visual inspections that have been performed in the steam generators, have confirmed the presence of certain tube conditions that are detectable by eddy current testing, but do not represent flaw-like indications. These include:

- Tube Bowing – three-letter code designation, BOW
- Linear Tube Deposits – three-letter code designation, PDP
- Loose Parts – three-letter code designation, PLP
- No Tubesheet Expansion – three-letter code designation, NTE
- Expansion Transition Location above or below top of tubesheet – three-letter code designation, ETL

These codes are used to identify these types of tube conditions so that this information may be archived and used for historical information or trending purposes.

Certain non-service induced tube indications or imperfections require additional lead analyst or historical reviews, or may require additional diagnostics and engineering evaluation to be performed. These tube indications include:

Imperfection - *Manufacturing Buff Marks*

RC probe inspections of manufacturing marks may be performed either as part of the PVNGS steam generator tube NDE sampling program, or as a consequence of planned inspections for other causes, such as freespan SCC. Manufacturing buff marks are volumetric imperfections and are identified with a RC three-letter code designation VOL. These imperfections are verified through historical review of eddy current testing data. The RC examinations also verify that SCC is not present in the indication. VOL indications are not removed from service unless there is evidence of SCC occurring or the eddy current testing signal for the imperfection has changed when compared with the historical data.

Technical Basis:

Neither the industry nor APS has developed a qualified sizing technique for RC examination of manufacturing buff marks. Therefore, it is essential that a review of historical eddy current testing data be performed when a VOL imperfection is identified. Eddy current testing data analysts performing work at PVNGS review the historical data for all confirmed VOL indications to ensure that the eddy current testing data signal has not changed. In addition, the current eddy current testing data for the VOL indication is reviewed to ensure that SCC is not associated with the indication. APS has performed an engineering review of Reference 10, which is the original manufacturer tubing specification, to provide further assurance that the VOL indications (manufacturing marks) did not exceed the requirements of the PVNGS Technical Specifications

Imperfection – *Geometry (Small radius U-bends)*

As stated in References 9 and 11, APS performs Plus Point coil probe eddy current inspections in all steam generator tubes that have small radius U-bends, i.e., steam generator tubes located in the first two to four rows of tubes in the steam generators. These additional inspections were implemented due to the presence of axial SCC occurring in tubes within the bend region on some steam generator tubes located in these rows. During an engineering evaluation of Unit 2 eddy current data, APS determined that small non-flaw-like indications in the U-bends may be initiation sites for SCC defects. Consequently, the three-letter code designation GEO (Geometry) was established for the Plus Point coil signal associated with these types of imperfections. The NDE examination and analysis information that was obtained as a result of this engineering evaluation has been incorporated in the PVNGS Data Analysis Training Manual.

Technical Basis:

As stated in Reference 11, APS removes from service any steam generator tubes located in rows one through four of the PVNGS steam generators that have GEO indications associated with them. The PVNGS steam generator tube inspection program and the data analysis training that is provided to the data analysts assures that any tube with this type of indication will be detected and removed from service.

Imperfection – *Volumetric Indications*

During the conduct of RC probe examinations, volumetric indications not associated with wear, manufacturing buff marks, or flaw-like bobbin coil probe signals may be detected and are classified as either single volumetric indications (SVI) or multiple volumetric indications (MVI). The examination results of the steam generator tubes that were pulled from the Unit 2 and 3 steam generators determined that these types of indications could be scratches, pitting, fabrication-related imperfections or IGA on the tube. Consequently, further review and engineering evaluation are required when these indications are detected.

When SVIs or MVIs are detected, the APS Level III Lead Analyst and APS engineering staff perform reviews of the historical eddy current testing data for the tube and the examination results of the steam generator tubes that were previously pulled from the Units 2 and 3 steam generators. These reviews are necessary such that an accurate determination may be made to confirm whether the signal is representative of IGA or pitting, or that a change in the eddy current testing signal has occurred when compared to previous inspection results. If this review determines that the indication has evidence of corrosion (SCC, IGA or pitting), the tube is removed from service regardless of the size of the indication.

Technical Basis:

The presence of volumetric imperfections that are non-progressive has been observed on steam generator tubes that have been removed from steam generators throughout the industry and at PVNGS. Since these types of imperfections may become SCC initiation sites, APS utilizes both bobbin and rotating coil techniques to verify that the imperfection remains non-progressive, i.e., the imperfection remains free of corrosion. Both of these techniques are qualified for the detection of SCC and IGA. If any corrosion is detected in the imperfection, or the review of the historical eddy current testing data indicates that a change in signal has occurred, the tube will be removed from service. If

these reviews indicate that the imperfection remains non-progressive, then the tube may remain in service.

PVNGS-specific tube pull information on the detection and characterization of these types of indications is provided in the PVNGS Data Analysis Training Manual. Therefore, there is a high degree of assurance that these types of imperfections will be detected and accurately assessed.

Summary

APS has employed the appropriate ASME Code, and Regulatory Guide 1.83 requirements, as well as the supplementary guidance of the *EPRI PWR Steam Generator Examination Guidelines* to define a defect management program for the PVNGS steam generators. Also incorporated into this program are PVNGS plant specific performance demonstrations and the examination results of the steam generator tubes that were pulled from the Units 2 and 3 steam generators. The PVNGS program removes all steam generator tubes with detected corrosion defects from service, and conservatively plugs tubes with other service-induced degradation, such as wear.

APS will implement Nuclear Energy Institute (NEI) 97-06, *Steam Generator Program Guidelines*, for steam generator inspections that are performed after January 1, 1999. As specified in NEI 97-06, each utility is required to follow the inspection guidelines contained in the latest revision of the EPRI *PWR Steam Generator Examination Guidelines*. Revision 5 of the EPRI *PWR Steam Generator Examination Guidelines* requires site validation of Appendix H data sets to assure applicability to PVNGS. The process of site validation includes a documented review of the technique's tubing essential variables (e.g., deposits, tube geometry changes, signal characteristics) to ensure the application is consistent with the PVNGS-specific steam generator conditions. This process will provide further assurance of technique capability and applicability. APS has initiated this process, and the program will be fully implemented by January 1, 1999, as required by the NEI initiative.

ATTACHMENT 1

List of References

References:

1. NEI 97-06, *Steam Generator Program Guidelines*, December 1997.

2. K. M. Sweeney, *Palo Verde Nuclear Generating Station Unit 2 Cycle 7 Steam Generator Evaluation*, Arizona Public Service Report, submitted to USNRC via letter 102-03849-JML/AKK/JRP dated January 19, 1997.

3. K. M. Sweeney, *Palo Verde Nuclear Generating Station Unit 3 Cycle 6 Steam Generator Evaluation*, Arizona Public Service Report, submitted to USNRC via letter 102-03748-WLS/AKK/JRP dated August 6, 1996.

4. K. M. Sweeney et al, *Batwing Support Induced Wear Degradation of Steam Generator Tubing during Cycle 7*, Arizona Public Service Report, submitted to the USNRC via letter 102-03931-JML/AKK/JRP dated May 9, 1997.

5. Combustion Engineering Report, *Flow Distribution and Tube Vibration Evaluation of System 80 Steam Generator Tube Lane/Economizer Corner Region*, submitted to the USNRC via letter LD-88-049 dated July 1, 1988.

6. Combustion Engineering Report, *Examination of Palo Verde-3 Steam Generator Tubes Removed During the 1994 Outage, Final Report*, V-PENG-TR-004, dated July 1994.

7. J. M. Russell, *Alternate Method to Quantify Wall Loss at Batwing and Vertical Strap Intersections – Palo Verde Unit 2,* Combustion Engineering Report, January 31, 1989.

8. M. Chambers, *Palo Verde Loose Parts Study*, Conam Nuclear Inc Report, February 1992.

9. APS Letter 102-03401-WLS/AKK/JRP, *Response to Generic Letter 95-03, Circumferential Cracking of Steam Generator Tubes*, dated June 27, 1995.

10. Combustion Engineering Specification N-P43B2 (h), *Purchase Specification for Nickel-Chromium-Iron Alloy Tubular Products, ASME Section III*, dated October 30, 1973.

11. APS Letter 102-04040-JML/AKK/JRP, *Response to Request for Additional Information Regarding Monitoring and Operational Assessment of Steam Generators for Palo Verde Unit 2 and Continued Operability of Steam Generators for Palo Verde Units 1 and 3*, dated November 18, 1997.