Westinghouse Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

September 16, 1992
CAW-92-356

Document Control Desk
US Nuclear Regulatory Commission
Washington, DC 20555

Attention: Dr. Thomas Murley, Director

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: WCAP-13494 "Catawba Unit 1 Technical Support for Steam Generator Interim Tube Plugging Criteria for Indications at Tube Support Plates" (Proprietary)

Dear Dr. Murley:

The proprietary information for which withholding is being requested in the above-referenced letter is further identified in Affidavit CAW-92-356 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 Duke Power Company.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-92-356, and should be addressed to the undersigned.

Please note that WCAP-13494 contains information for which withholding is being requested by the Electric Power Research Institute (i.e., all information bracketed and identified by a superscript (g) within the subject report). Please see the September 17, 1992 letter, A. Kenny, EPRI, to Mary Hazeltine (Duke Power Company). Correspondence with respect to the proprietary aspects of the Electric Power Research Institute (EPRI) information should be directed to Mr. Arthur Kenny of EPRI, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303).

Very truly yours,

Nicholas J. Liparulo, Manager
Nuclear Safety and Regulatory Issues

/cid
Enclosures

cc: M. P. Siemien, Esq.
Office of the General Counsel, NRC

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CAW-92-356

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

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

Peter J. Morris

Peter J. Morris, Manager
Strategic Safety and Regulatory Issues

Sworn to and subscribed
before me this 16th day
of September, 1992

Lorraine M. Piplica
Notary Public

Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 1995
Member, Pennsylvania Association of Notaries

0516C-DLC:1-091192

(1) I am Manager, Strategic Safety and Regulatory Issues, in the Nuclear and Advanced Technology 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.

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 "Catawba Unit 1 Technical Support for Steam Generator Interim Tube Plugging Criteria for Indications at Tube Support Plates", WCAP-13494 (Proprietary), September, 1992 for Catawba Unit 1, being transmitted by the Duke Power Company letter and Application for Withholding Proprietary Information from Public Disclosure, to Document Control Desk, Attention Dr. Thomas Murley. The proprietary information as submitted for use by Duke Power Company for Catawba Unit 1 is expected to be applicable in other licensee submittals in response to certain

NRC requirements for justification of steam generator tube alternate plugging criterion.

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

(a) Provide documentation for steam generator tube interim and alternate plugging criterion.

(b) Provide a basis for the form of the steamline break (SLB) leak rate correlation.

(c) Provide SLB leak rate analyses.

(d) Assist the customer in obtaining NRC approval.

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.

Proprietary Information Notice

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (g) contained within parentheses located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(g) of the affidavit accompanying this transmittal pursuant to 10 CF 790(b)(1).

Copyright Notice

The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which are necessary for its internal use in connection with generic and plant-specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.790 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection not withstanding. With respect to the non-proprietary versions of these reports, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. The NRC is not authorized to make copies for the personal use of members of the public who make use of the NRC public document rooms. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

CATAWBA SUMMARY OF WCAPS 13494 & 13496

INTRODUCTION

The proposed amendments would change TS Sections 3/4.4.5.3, 3/4.4.6.2, and the Bases 3/4.4.5, 3/4.4.6.2, and 3/4.4.8 to allow the implementation of interim steam generator tube repair criteria for the tube support plate elevations. The amendment also reduces the allowed primary-to-secondary operational leakage from any one steam generator from 500 gallons per day to 150 gallons per day. The total allowed primary-to-secondary operation leakage through all steam generators is reduced from one gallon per minute to 0.4 gallons per minute total primary to secondary. This amendment is only applicable for fuel Cycle 7.

BACKGROUND

Previous inservice inspections and examinations of the steam generator (SG) tubes at Catawba Unit 1 have identified intergranular stress corrosion cracking (IGSCC) on the outer diameter of the tubes at the tube support plate (TSP) intersections. Catawba refers to this particular form of IGSCC as outer diameter stress corrosion cracking (ODSCC).

Outer diameter stress corrosion cracking activity at TSP intersections is a common degradation phenomenon in SGs in nuclear power plants. Approximately 20 3/4" tubes including 42 tube-to-TSP intersections, have been removed from affected SGs across the industry for examination and testing. These include tubes from Catawba Unit 1 (including 9 TSP intersections). Each of these pulled tube TSP intersections was sectioned and metallographically examined. In general, these examinations have revealed multiple, segmented, and axial cracks with short lengths for the deepest penetrations. The outer diameter stress corrosion cracking is generally confined to within the thickness of the TSPs, consistent with the corrosion mechanism which involves the concentration of impurities, including caustics, in the tube-to-TSP crevices. There is some potential for shallow ODSCC for a short distance above or below the TSP. This has been observed for 7/8" tubes for 2 of the pulled TSP intersections from another plant.

To date the pulled tube specimens from Catawba Unit 1 have shown minimal intergranular attack (IGA) involvement with the ODSCC. However, more significant IGA involvement has been observed on some pulled tube specimens from other plants. These results suggest that the degradation develops as IGA plus stress corrosion cracking (SCC), particularly when maximum IGA depths greater than 25% are found. A large number (greater than 100) of axial cracks around the circumference are commonly found on these tubes. The maximum depth of IGA is typically one half to one third of the SCC depth. Patches of cellular IGA/ODSCC formed by combined axial and circumferential orientation of microcracks are frequently found in pulled tube examinations. Axial crack segments have been the dominant flaw feature affecting the structural integrity of the pulled tube specimens as evidenced by results of burst tests performed for 17 of the pulled TSP intersections prior to sectioning.

Technical Specification 4.4.5.4.a.6, Plugging or Repair Limit, requires that tubes with imperfections exceeding 40% of the nominal tube wall thickness be repaired by sleeving or removed from service by plugging. This repair criterion would result in unnecessary removal of significant numbers of SG tubes from service. The interim plugging criterion is proposed to preclude this.

Duke Power's August 24, 1992 letter requested interim modifications to the tube repair limit and primary-to-secondary leakage limit in the Technical Specifications for the 7th operating cycle only. The proposed modifications to the tube repair limits include a one volt repair criterion for flaws confined to the thickness of TSP in lieu of the currently applicable depth-based limit of 40%. This repair criterion is more restrictive than the present limit. This criterion would only apply to ODSCC degradation confined to within the thickness of the TSPs.

TECHNICAL SPECIFICATION CHANGES

Catawba Unit 1 Technical Specification 4.4.5.4.a.6, Plugging or Repair Limit, and Bases 3/4.4.5, Steam Generators, are revised to specify that the repair limit at the TSP intersections for the seventh operating cycle is based on the analysis in WCAP-13494 to maintain SG tube serviceability as described below:

a. An eddy current inspection using a bobbin of 100% of the hot leg TSP intersections and down to the lowest cold leg SG TSP intersections with known outside diameter stress corrosion cracking will be performed for tubes in service.

b. Degradation within the bounds of the TSP with a bobbin voltage less than or equal to 1.0 volt will be allowed to remain in service.

c. Degradation within the bounds of the TSP with a bobbin voltage greater than 1.0 volt will be repaired or plugged except as noted in d. below.

d. Indications of potential degradation within the bounds of the TSP with a bobbin voltage greater than 1.0 volt, but less than or equal to 2.5 volts, may remain in service if a rotating pancake coil probe (RPC) inspection does not detect degradation. Indications of degradation with a bobbin voltage greater than 2.5 volts will be plugged or repaired.

Catawba Unit 1 Technical Specification 3.4.6.2 and Bases 3/4.4.5 are revised to specify that, for the seventh operating cycle only, primary-to-secondary leakage through all SGs shall be limited to 0.4 gpm total reactor to secondary and 150 gpd through any one SG. Primary-to-secondary leakage during a steamline break (SLB) will not exceed one gpm.

Inspection Issues

With the exception of a probe wear standard, eddy current test guidelines were utilized which ensure that the field bobbin indication voltage measurements were obtained in a manner consistent with how the voltage limit was developed for the IPC. These guidelines define the bobbin specification, calibration requirements, specific acquisition and analyses criteria, and flaw recording guidelines to be used in the inspection of the steam generators. To supplement these guidelines, all voltage indications less than 1.0 volt were recorded. All flaw indications, regardless of voltage amplitude, have been recorded.

The proposed bobbin inspection program is consistent with the development of voltage-based repair limits; namely, the establishment of the relationship between burst pressure and bobbin voltage. In addition, an RPC sample inspection of tubes at TSP intersections was performed. Catawba inspected most dents, a sample of indications with unusual phase angles, and all artifacts. The RPC can provide improved resolution of flaw indication as compared to the bobbin probe in the presence of dents and artifacts, and is sensitive to both axial and circumferential flaws. In addition, tubes in the RPC sample program, which exceed the 1.0 volt bobbin IPC limit and had RPC confirmed indications were plugged or repaired.

Catawba 1 RPC inspected TSP intersections exhibiting bobbin indications exceeding 1.0 volt, but less than 2.5 volts. The RPC inspections permitted characterization of the indications found by the bobbin to confirm or deny the existence of any actual tube degradation. The proposed repair limit is based on axially oriented ODSCC as the dominate degradation mechanism with some IGA involvement. The proposed limit is also based on the premise that any significant degradation is confined to the TSP. There were no unforeseen RPC findings relative to the characteristics of the flaws at the TSPs. Unforseen findings would have included any detectable circumferential indication or detectable indications extending outside the thickness of the TSP.

Tube Integrity Issues

The purpose of the Technical Specification tube repair limits is to ensure that tubes accepted for continued service will retain adequate structural and leakage integrity during normal operating, transient, and postulated accident conditions, consistent with General Design Criteria 14, 15, 31, and 32 of 10 CFR Part 50, Appendix A. Structural integrity refers to maintaining adequate margins against gross failure, rupture, and collapse of the SG tubing. Leakage integrity refers to limiting primary-to-secondary leakage to within acceptable limits. The traditional strategy for accomplishing these objectives has been to establish a minimum wall thickness requirement in accordance with the structural criteria of Regulatory Guide 1.121, "Basis for Plugging Degraded PWR Steam Generator Tubes." Allowance for eddy current measurement error and flaw growth between inspections has been added to the minimum wall thickness requirements (consistent with the Regulatory Guide) to arrive at a depth-based repair limit. Enforcement of a minimum wall thickness requirement would implicitly serve to ensure leakage integrity (during normal operations and accidents), as well as structural integrity. It has been recognized, however, that defects, especially cracks, will occasionally grow entirely through-wall and develop small leaks. For this reason, tight limits on allowable primary-to-secondary leakage have been established in the Technical Specifications to ensure timely plant shutdown before adequate structural and leakage integrity of the affected tube is impaired.

The proposed tube repair limits for Catawba Unit 1 consist of voltage amplitude criteria rather than the traditional depth-based criteria. Thus, the proposed repair criteria represents a departure from the past practice of explicitly enforcing a minimum wall thickness requirement.

The pulled tube examinations show that for bobbin indications up to 1.82 volts the maximum crack can be up to 97% through-wall. The likelihood of through-wall or near through-wall crack penetration appears to increase with increasing voltage amplitude. Clearly, some of the tubes which will be found to contain "non-repairable" indications under the proposed interim criteria may develop through-wall and near through-wall crack penetrations during the upcoming cycle, thus creating the potential for leakage during postulated SLB accident. Therefore, these tubes are plugged or repaired by sleeving.

Structural Integrity

Burst Integrity

A burst strength/voltage correlation has been developed to demonstrate that bobbin indications satisfying the proposed 1.0 volt interim repair criterion will retain adequate structural margins during Cycle 7 operation, consistent with the criteria of Regulatory Guide 1.121. The burst strength/voltage correlation for 3/4" tubing includes the burst pressure versus field bobbin voltage data (pre-pull values for 8 pulled tubes (10 TSP intersections) including 3 TSPS from Catawba Unit 1. This pulled tube data is supplemented by 47 data points from laboratory tube specimens containing ODSCC flaws produced in model boiler tests under simulated field conditions. The bobbin voltage data used to construct the burst pressure/voltage correlation has been normalized to reflect calibration standard voltage set-ups and voltage measurement procedures consistent with the NDE Data Acquisition and Analysis Guidelines in WCAP-13494. This normalization ensures consistency among the voltage data in the burst pressure/voltage correlation and, in addition, ensures consistency between the voltage data in the correlation and field voltage measurements at Catawba Unit 1.

The most limiting burst pressure criterion of Regulatory Guide 1.121 is that degraded tubes shall retain a margin of three against burst at normal operating differential pressure across the tube. For Catawba Unit 1, this translates to a limiting burst pressure criterion of 3750 psi. From the burst pressure/voltage correlation, the maximum voltage which will satisfy this burst pressure criterion at a 95% confidence intervals is 4.1 volts. The 2.5 volt IPC limit, specified in WCAP-13494 includes a 22% allowance for NDE measurement uncertainty and for a 45% increase during the next operating cycle. The NDE measurement uncertainty estimates considered uncertainties stemming from bobbin design characteristics, bobbin wear (which affects centering), variability in American Society of Mechanical Engineers (ASME) calibration standards, and variability in the analysts' interpretation of the signal voltage. The NDE Data Acquisition and Analysis Guidelines were used to minimize the uncertainties as they apply to the interim criteria. Based on implementation of these guidelines, a cumulative probability distribution of the residual measurement uncertainty (applicable to each bobbin indication) has been developed. The assumed 22% uncertainty in the voltage measurements is conservative with respect to the upper 90% cumulative probability value as determined from the cumulative probability distribution.

Potential flaw growth between inspections has been evaluated based on observed voltage amplitude changes during Cycles 5 and

6 at Catawba Unit 1.

Growth rates for Catawba Unit 1, Cycle 6 were developed using the total population of flaw indications. The Cycle 5 growth data were developed for 126 indications at TSPs plugged in 1991 at EOC5. Most of the Cycle 5 growth rates for BOC indications greater than 1.0 volt were negative and therefore were not reliable for comparisons with Cycle 6 growth rates. For BOC indications less than 0.75 and less than 1.0 volts, Cycles 5 and 6 show essentially the same average growth rate (about 49% and 29% respectively). The maximum increase in voltage for Cycle 5 was 1.8 volts compared to 2.31 volts for Cycle 6. The maximum Cycle 6 growth rate includes adjustments for cross-calibration of the ASME standards used in both 1991 and 1992 inspections. The larger Cycle 6 growth is most likely due to the larger number of indications used for the growth rates in Cycle 6 as compared to Cycle 5. Based on the similarity between Cycles 5 and 6 growth, the Cycle 6 growth rate data can be expected to be representative of Cycle 7 anticipated growth.

For any specific individual tube, NDE measurement uncertainty and/or voltage growth may exceed the values assumed in the above deterministic basis for the 1.0 volt IPC repair limit, since the deterministic basis does not consider the tail of the voltage measurement and voltage growth distribution. In addition, burst pressure for some tubes may be less than the 95% confidence values in the burst pressure/voltage calculation. These uncertainties are directly accounted for by use of Monte Carlo methods to demonstrate that the probability of burst during SLB accidents is acceptably low for the distribution of voltage indications being left in service. Under this approach, the beginning-of-cycle (BOC) indications left in service are projected to the end-of-cycle (EOC) by randomly sampling the probability distributions for NDE uncertainties and voltage growth per cycle. For each EOC Monte Carlo sample of bobbin voltage, the burst pressure/voltage correlation is randomly sampled to obtain a burst pressure. The 100,000 Monte Carlo samples are performed for the BOC distribution. The probability of tube burst at SLB is obtained from the cumulative probability distribution of EOC burst pressures for burst pressures less than the SLB pressure differential of 2650 psi.

This kind of Monte Carlo analysis was performed for the distribution of indications found during the previous (i.e., 1991) inspection at Catawba Unit 1. This analysis indicated that implementation of a 1.0 volt repair criterion at that time would yield a conditional probability of burst, given SLB of 1.1×10^{-5}. This is an extremely low probability, approximately three orders of magnitude less than the value considered in a

Staff generic risk assessment for SGs (NUREG-0844). Over time, the number of indications found between 0 and 3.5 volts can be expected to increase.

Therefore, the IPC proposal (involving the 1.0 volt repair criterion) includes a provision for determining the probability of burst at SLB conditions following each outage for indications left in service to confirm the continued adequacy of the repair criterion.

WCAP-13494 demonstrates that the proposed 1.0 volt interim criterion will provide adequate assurance that tubes with indications which are accepted for continued service will meet the burst pressure criteria of Regulatory Guide 1.121 The bounding value of voltage growth/cycle at Catawba Unit 1 has not exceeded 2.77 volts including an adjusted increase over Cycle 6 for the longer operation planned for Cycle 7. This 2.77 volts represents a bounding value assuming no increase in corrosion rates over what has been observed previously at Catawba Unit 1. Assuming a 22% voltage measurement uncertainty (90% cumulative probability value) for a 1.0 volt indication left in service, the EOC voltage is expected to be bounded by 4.05 volts. This is below the 4.1 voltage limit evaluated as the lower 95% confidence limit for meeting the most limiting burst pressure criterion (i.e., three times normal operating pressure differential).

As part of the interim repair criteria, indications with bobbin voltages greater than 1.0 volt, but less than or equal to 2.5 volts will remain in service if RPC inspection does not confirm the indication. Short and/or relatively shallow cracks that are detectable by the bobbin may sometimes not be detectable by RPC, although the RPC is considered to be more sensitive to longer, deeper flaws which are of structural significance.

Burst strength is not a unique function of voltage, rather, for a given voltage, there is a statistical distribution of possible burst strengths as indicated in the burst pressure/voltage correlation. Burst pressures for bobbin indications which were not confirmed by RPC will tend to be at the upper end of the burst pressure distribution. The 2.5 volt cutoff, at which all bobbin indications would be plugged or repaired (with or without confirming RPC indications), provides additional assurance that all excessively degraded tubes will be removed from service.

<u>Combined Accident Loadings</u>

The effects of combined safe shutdown earthquake (SSE) and loss-of-coolant accident (LOCA) loads and SSE plus SLB loads on tube integrity, consistent with the General Design Criterion 2 (GDC-1) of 10 CFR Part 50, Appendix A have been evaluated. A combined LOCA plus SSE must be evaluated for potential yielding of the TSPs which could result in subsequent deformation of the tubes. If significant tube deformation should occur, primary flow area could be reduced and postulated cracks in tubes could open up which might create the potential for in-leakage (i.e, secondary-to-primary) under LOCA conditions. In-leakage during LOCA would pose a potential concern since it may cause an increase in the core peak clad temperature (PCT).

The most limiting accident conditions for tube deformation considerations result from the combination of SSE and LOCA loads. The seismic excitation defined for SGs is in the form of acceleration response spectra at the SG supports. In the seismic analysis, generic response spectra were used which envelop the Catawba-specific response spectra. A finite element model of the Model D SG was developed and the analysis was performed using the WECAN computer program. The mathematical model consisted of three dimensional lumped mass, beam and pipe elements as well as general matrix input to represent the piping and support stiffness. Interactions at the TSP shell and wrapper/shell connections were represented by concentric spring-gap dynamic elements. Impact damping was used to account for energy dissipation at these locations.

Prior qualification of the Catawba Unit 1 primary piping for leak-before-break requirements resulted in the limiting LOCA event being the break of a minor branch line. The loads for the primary piping break were used as a conservative approximation. The principal tube loading during a LOCA is caused by the rarefaction wave in the primary fluid. This wave initiates at the postulated break location and travels around the SG tube U-bends. A differential pressure is created across the two legs of the tube which causes an in-plant horizontal motion of the U-bends and induces significant lateral loads on the tubes. The pressure time histories needed for creating the differential pressure across the tube are obtained from transient thermal-hydraulic analyses using the MULTIFLEX computer code. For the rarefaction wave induced loadings, the predominant motion of the U-bends is in the plane of the U-bend. Thus the individual tube motions are not coupled by the anti-vibration bars and the structural analysis is performed using single tube models limited to the U-bend and the straight leg region over the top two TSPs.

In addition to the rarefaction wave loading discussed above, the tube bundle is subjected to bending loads during a LOCA. These loads are due to the shaking of the SG caused by the break hydraulics and reactor coolant loop motion. However, the resulting TSP loads from this motion are small compared to those due to the rarefaction wave induced motion.

To obtain the LOCA induced hydraulic forcing functions, a dynamic blowdown analysis is performed to obtain the system hydraulic forcing functions assuming an instantaneous (1.0 msec break opening time), double-ended guillotine break. The hydraulic forcing functions are, when applied along with the displacement time-history of the reactor pressure vessel (obtained from a separate reactor vessel blowdown analysis) to a system structural model that includes the SG, the reactor coolant pump, and the primary piping. This analysis yields the time-history displacements of the SG at its upper lateral and lower support nodes. These time-history displacements formulate the forcing functions for obtaining the tube stresses due to LOCA shaking of the SG.

In calculating a combined TSP load, the LOCA rarefaction and LOCA shaking loads were combined directly, while the LOCA and SSE loads were combined using the square root of the sum of the squares. The overall TSP load was transferred to the SG shell through wedge groups located at discrete locations around the plate circumference.

The radial loads due to combined LOCA and SSE could potentially result in yielding of the TSP at the wedge supports, causing some tubes in the vicinity of the wedge supports to be deformed. Utilizing results from recent tests and analysis programs, Catawba has shown that tubes will undergo permanent deformation if the change in diameter exceeds a minimum threshold value. This threshold for tube deformation is related to the concern for tubes with preexisting tight cracks that could potentially open during a combined LOCA plus SSE event. For Catawba Unit 1, the LOCA plus SSE loads (using large break forces) were determined to be of such magnitude that a limited number of the tubes (which are assumed to contain preexisting tight cracks) are predicted to exceed this deformation threshold value and, therefore, can lead to significant tube leakage. The IPC will not be applied to these tubes.

The effect of SSE bending stresses on the burst strength of tubes with axial cracks has been assessed. Tensile stress in the tube wall would tend to close the cracks while compressive stress would tend to open the cracks. On the basis of previously performed tests, it has been concluded that the burst strength of tubes with through-wall cracking is not affected by an SSE event.

Based on information provided it can be concluded that, at Catawba Unit 1, limited tube deformation can occur during an SSE plus LOCA event. However, the potential for in-leakage is nullified by not permitting the IPC to be applied to the subject tubes. In addition, burst strength of tubing with through-wall cracks is not affected by an SSE event.

Leakage Integrity

As discussed earlier, a number of the indications satisfying the proposed interim 1.0 volt repair limit can be expected to have or to develop through-wall and/or near through-wall crack penetrations during the next cycle, thus creating the potential for primary-to-secondary leakage during normal operation, transients, or postulated accidents. Adequate leakage integrity during normal operating conditions is assured by the proposed restrictive Technical Specification limits on allowable primary-to-secondary leakage. Adequate leakage integrity during transients and postulated accidents is demonstrated by showing that, for the most limiting accident, the resulting leakage will not exceed the total primary to secondary leak rate assumed in the FSAR.

The Catawba Nuclear Station Final Safety Analysis Report (FSAR), Chapter 15, identifies accidents which result in secondary steam release causing the consequences of these accidents to be affected by the amount of primary to secondary leakage. Of these accidents, the SLB was determined to be the most-limiting. In this case, since the SG in the faulted loop is subject to dryout, the active release path is conservatively assumed to be direct to the environment, without any mitigation resulting from mixing with secondary liquid coolant in the SG.

For the purpose of supporting the interim repair limit proposal, Catawba has proposed that the maximum allowable primary-to-secondary leak rate during SLB be 1.0 gpm. The offsite dose using the IPC is bounded by the current FSAR dose for SLB.

The SLB leakage calculation model uses a correlation between leakage test data obtained under simulated SLB conditions (at a given TSP location), and the corresponding normalized bobbin voltage (SLB leakage/voltage correlation). The 3/4" tubing SLB leakage data includes 32 data points from the model boiler specimens described earlier. Inclusion of the evaluated pulled tube data in the leakage correlation has been shown to result in negligible change to the correlation. The calculation method involves establishing the voltage distribution of the indications being accepted for continued service. Probability distributions of voltage measurement uncertainty voltage growth/cycle, and SLB leak rate versus voltage are accounted for by Monte Carlo techniques in predicting the distribution of EOC voltages. One hundred thousand Monte Carlo simulations of the EOC distribution of indication are performed. SLB leakage is evaluated at the 90% cumulative probability level utilizing a 2.0 volt threshold for SLB leakage. Under the extreme assumption of no leakage threshold, the potential SLB leakage would be 0.67 gpm.

Based on the voltage distributions found during previous inspection (1991) at Catawba Unit 1, and assuming implementation of the 1.0 volt repair criterion, the estimated leakage during a postulated SLB at EOC7 was 0.54 gpm at the 90% cumulative probability level.

In support of the one volt interim repair criterion, the above analysis will be updated to consider the distribution of voltages for indications satisfying the one volt criterion during the next refueling outage inspection if voltages deviate from the original simulation and, therefore, are not bounded by the original analysis. The analysis will also reflect the distribution of voltage changes observed during Cycle 7 (i.e., 1990 to 1992).

In addition to the above analysis, primary to secondary leakage at EOC for SLB was verified to be below 1.0 gpm assuming a deterministic calculation method. The method consisted of the following:

Determine the end-of-cycle (EOC) voltage distribution in terms of the number of indications falling into each of the following EOC voltage ranges:

<2.0 volts
>2.0 to 3.5 volts
>3.5 volts

Acceptable methods for determining the EOC voltage distribution include:

- The methodology described in WCAP-13494. This involves sampling of the cumulative probability distributions of NDE measurement error and of voltage growth during the most recent operating cycle using Monte Carlo techniques and applying the results to the beginning-of-cycle (BOC) voltage distribution.

A simplified approach may be used as an alternative (to the WCAP-13494 approach) provided it provides for a conservative treatment of the tails of the cumulative probability distributions of NDE measurement error and of voltage growth to the 100% cumulative probability values.

SLB leakage as a function of EOC voltage shall be determined as follows:

EOC Voltage	SLB Leakage
<2.0 volts	
>2.0 to 3.5 volts	1 liter/hour
>3.5 volts	10 liters/hour

The Monte Carlo method for determining the EOC voltage distribution was applied for the BOC 7 voltage distribution. The analysis using the above stepwise change in leak rate resulted in a potential SLB leak rate of about 0.01gpm.

Proposed Interim Leakage Limits

Description

An interim change to the reactor coolant primary to secondary system leakage limit criteria in Technical Specification 3.4.6.2 that is applicable to the seventh operating cycle only is also proposed. The current 500 gpd limit for primary-to-secondary leakage through any one SG is changed to 150 gpd. In addition, the limit on total leakage through all SGs would be reduced from 1.0 gpm to 0.4 gpm.

Discussion

The current 500 gpd limit per SG is intended to ensure that through-wall cracks which leak at rates up to this limit during normal operation will not propagate and result in tube rupture under postulated accident conditions consistent with the criteria of Regulatory Guide 1.121. The current 1.0 gpm limit for total primary-to-secondary leakage is consistent with the 1.0 gpm total leakage assumed for SLB analyses.

Development of the proposed 150 gpd limit per SG has utilized the extensive industry data base regarding burst pressure as a function of crack length and leakage during normal operation. Based on leakage evaluated at the lower 95% confidence interval for a given crack size, the proposed 150 gpd limit would be exceeded before the crack length reaches the critical crack length for SLB pressures. Based on nominal, best estimate leakage rates, the 150 gpd limit would be exceeded before the crack length reaches the critical length for three times normal operating pressure.

The proposed interim change is more restrictive than the existing limits and is intended to provide a greater margin of safety against rupture. The proposed interim limits are also intended to provide an additional margin to accommodate a rogue crack which might grow at much greater than expected rates, or unexpectedly extend outside the thickness of the TSP, and thus provide additional protection against exceeding SLB leakage limits.

Summary

Based on the above evaluation, it can be concluded that the proposed interim tube repair limits and leakage limits will ensure adequate structural and leakage integrity of the SG tubing at Catawba Unit 1, consistent with applicable regulatory requirements.