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DUKE POWER

September 2, 1992

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

Subject: Catawba Nuclear Station, Unit 1
Docket No. 50-413
Technical Specification Amendment Supplement
Steam Generator Repair Criteria

On August 24, 1992, Catawba Nuclear Station submitted a proposed Technical Specification amendment to the NRC. The proposed revisions change the Steam Generator repair criteria for Catawba Unit 1 Cycle 7 operation. This amendment is intended to apply to Cycle 7 operation only. In the August 24, 1992 letter, Catawba committed to submit further technical justification for the proposed amendment at a later date. Please find enclosed the additional technical justification that supports the proposed amendment request.

Very truly yours,

M. S. Tuckman

M. S. Tuckman

MHH/TECHSPEC.SUP

Attachments

A001 1/1

xc: (w/Attachments)

Mr. S. D. Ebneter
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Mr. Heywood Shealy, Chief
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M. S. Tuckman, being duly sworn, states that he is Vice President of Duke Power Company, Catawba Nuclear Site; that he is authorized on the part of said Company to sign and file with the Nuclear Regulatory Commission this revision to the Catawba Nuclear Station License No. NPF-35, and that all the statements and matters set forth therein are true and correct to the best of his knowledge.

M. S. Tuckman

M. S. Tuckman, Vice President
Catawba Nuclear Site

Subscribed and sworn to before me the 2nd day of Sept, 1992.

Yvonne H. Jackson

Notary Public

My Commission expires:

Nov 21, 2000

CHANGES TO TECHNICAL SPECIFICATIONS

1. The proposed amendment modifies TS 3/4.4.5 to allow a tube to remain in service if the flaw indication signal amplitude is less than or equal to 1.0 volt, regardless of the depth of wall penetration. For flaw indications in excess of indicated 1.0 volt, but less than 2.5 volts, the tube can remain in service provided an RPC inspection of the indication does not detect ODSCC or any other degradation mode exceeding technical specification repair limits. Crack indications above 2.5 volts will be repaired by sleeving or plugging, and do not require RPC confirmation. Based upon an end of cycle voltage distribution for cracklike indications, additional tubes may be removed from service based on a conservative estimation of potential primary to secondary leakage in the event of a steam line break event, such that the leak rate will be limited to 1.0 gpm (maximum) in the faulted loop.

2. Application of a More Restrictive Leak Rate Limit

   TS 3/4.4.6 is modified to allow a primary to secondary leak rate of 150 gpd (0.1 gpm) per steam generator, 0.4 gpm (576 gpd) total for all steam generator. Implementation of this leak rate limit will reduce the potential for excessive leakage during both normal operating conditions and a postulated steam line break event in the Catawba steam generators.

BACKGROUND

INDUSTRY EXPERIENCE

In general, the degradation morphology occurring at the tube support plate intersections at plants in the U.S. can be described as axial ODSCC. Axially oriented macrocracks can occur at one of more azimuthal locations around the circumference of the tube. The macrocracks are comprised of short, nearly collinear microcracks separated by ligaments of material. Typical microcrack length is less than 0.2 inches. The corresponding macrocrack can be as long as the support plate thickness

Minor to moderate intergranular attack (IGA) can occur in addition to axial ODSCC.

CNS EXPERIENCE

Duke Power Company first found indications of Tube Support Plate (TSP) Outer Diameter Stress Corrosion Cracking (ODSCC) during the

End of Cycle (EOC) 4 refueling outage at Catawba Unit 1. During that refueling outage, 17 tubes were plugged due to ODSCC at the support plates. In April of 1991, during the EOC5 refueling outage, 158 tubes were plugged due to tube support plate ODSCC. Based on both Catawba-specific data and industry data, Weibull distributions were developed to predict the occurrence of future indications. The results of that study indicated that, during Unit 1's next scheduled outage (the EOC6 outage), approximately 300 to 400 tubes would require repair because of tube support plate ODSCC.

In the current outage (1EOC6) bobbin coil inspections of the steam generator tubes were completed by August 8, 1992. The inspection found approximately 7000 indications which affected approximately 4500 tubes. When an indication is found using the bobbin coil technique, the Motorized Rotating Pancake Coil (MRPC) is used to confirm the existence of the indication. Use of the MRPC on a sample population of Catawba Unit 1 tubes confirmed the presence of indications in approximately 23% of those tubes sampled. This effort was completed, and the data was available, on August 10, 1992. Using this conformation data and the current criteria required by the Catawba Technical Specifications, Catawba has projected that approximately 1020 tubes would require repair.

With this data available, Catawba management decided on August 11, 1992, to pursue the possibility of amending Unit 1's Tech Specs to permit the use of an interim plugging criterion. On August 11, 1992, Duke requested Westinghouse to begin its analyses to support such a change. That same day, Duke also contacted the NRC Staff to inform them of the results of the steam generator inspection and analyses. A TS change submittal was submitted on August 24, 1992 which included marked up TS pages and a No Significant Hazards Analysis.

LICENSING BASIS

In establishing the interim tube plugging criterion, the general approach is to verify the existence of acceptable margins to tube burst and to excessive steam generator tube leakage during all plant conditions.

The NRC Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," issued for comment, addresses tubes with through-wall cracking. The Regulatory Guide utilizes safety factors on loads for tube burst and collapse that are consistent with Section III of the ASME Code. Per paragraph C.3.d(1) of RG 1.121, the applicable analytical and loading criteria in thinned or unthinned tubes with through-wall cracks are:

1. Through-wall cracks in tubes should not propagate and result in tube rupture under accident condition loadings.

2. The maximum permissible crack length of the largest single crack should be such that the associated burst pressure is at least 3 times the normal operating pressure differential.

3. The leakage rate limit under normal operation set forth in the plant technical specifications should be less than the leakage limit determined for the largest permissible crack.

ANALYSIS SUMMARY

In developing the interim tube plugging criterion (IPC), the general approach, as outlined in Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," is to verify tube integrity under various postulated accident load combinations, the existence of acceptable margins to tube burst, no excessive steam generator tube leakage during all plant conditions and establishing an operating leakage limit such that the leakage associated with the longest permissible single crack is not exceeded.

Tube integrity under postulated LOCA + SSE (Safe Shutdown Earthquake) and Main Steam Line Break (MSLB) + SSE has been evaluated and is assured with the IPC. Specifically, some tube intersections near Tube Support Plate Wedges have been excluded from the application of the IPC (due to the potential for SG tube deformation during LOCA + SSE load calculation).

Based on data gathered from Model Boiler Tests, and pulled tube data, a correlation of bobbin coil voltage to burst pressure has been developed. The end of cycle limit is based on the capability of providing a factor of safety of 3 times normal operating differential pressure to tube burst. This burst pressure, which corresponds to 3750 psid, is equivalent to 4.1 volts. This voltage is then reduced to allow for defect growth during the cycle and uncertainties in the growth rate as well as eddy current uncertainties. Thus a 2.5 volt limit is established for required repair regardless of RPC confirmation. This is equivalent to the full APC limit.

Because of the complex data distributions, a Monte Carlo Analysis was performed to determine the post MSLB primary to secondary leakage, which took into account the beginning-of-cycle indication distribution based on bobbin coil voltages, the projected growth rates during the cycle based on the 541 largest defect indications identified initially during the 1EOC6 refueling outage, eddy current analyst variability, probe wear uncertainty and postulated leakage at steam line break conditions as a function of bobbin coil voltage. The results of this analysis conservatively indicate that the maximum expected primary to secondary leakage after a Main Steam Line Break would be approximately 0.54 gpm. This leakage, in addition to the primary to secondary leakage allowed for continued operation in the proposed Technical Specification yields a total of 0.94 gpm which is bounded by the 1 gpm total primary to secondary

leakage assumed in the Catawba FSAR

A reduced allowance for primary to secondary leakage to 0.1 gpm (150 gpd) will be established with this proposed IPC to allow detection of the largest single permissible crack.

CONCLUSIONS

The analysis performed for Catawba Unit 1 demonstrates that the requirements of Regulatory Guide 1.121 are fully satisfied by the proposed IPC at both beginning and end of cycle for Catawba Unit 1 Cycle 7. Additionally, no leakage is expected to occur during normal operating conditions upon application of this IPC. The results of a dose analysis, performed for a postulated main steam line break out ide of containment remain within the limiting dose consequence (Exclusion Area Boundary - Thyroid Dose) presented in the Catawba FSAR.

MARGIN COMPARISONS

The burst pressure capability for a 1.0 volt IPC can be favorably compared with that for a 40% depth plugging criterion. Because the uncertainty on the 40% depth burst pressure is not well defined, the comparison will be based on nominal data only. The nominal correlation burst pressures at 1.0 volt is 6920 psi. The nominal burst pressure at 40% depth for a 1.5 inch long uniformly thinned tube (general basis for 40% limit) is 6110 psi. Thus at nominal values, the 1.0 volt burst capability exceeds that associated with the 40% thinned repair basis.

Because Catawba Nuclear Station is the first plant with 3/4 inch SG tubes to request consideration of a voltage based IPC it is expected that comparisons will be made to IPC's granted for plants with 7/8 inch tubes. Specifically, the Beginning of Cycle Margin for a 3/4 inch tube with a one volt threshold for RPC confirmation provides a margin of 1.4 to tube burst from the 3 times normal Δp. This is the same BOC margin to tube burst provided by the 1 volt threshold for the 7/8 inch tube IPC's which operate at a slightly higher normal operating differential pressure across the SG tubes.

A similar analysis to that described above, has been performed to determine end of cycle margins. The end of cycle margin is calculated taking projected defect growth rates (plant specific) and eddy current uncertainties into account. The results of this analysis are tabulated in Attachment 2. Because the 3 times normal Δp provides the largest challenge to tube integrity the EOC margin comparison will be based on this value. As can be seen by the data presented in Attachment 2, both Catawba and the 7/8 inch tube data provide equivalent margins to tube burst at end of cycle.

TECHNICAL JUSTIFICATION

To preclude unnecessary repairs of tubes in the Catawba steam generators an interim tube plugging criterion has been developed. The plugging criterion involves a correlation between eddy current bobbin probe signal amplitude (voltage) and tube burst capability. Leakage during normal operating conditions is not expected to occur upon implementation of the interim plugging criterion. Any potential for primary to secondary leakage during a postulated SLB event is assessed relative to conservative leakage thresholds at various bobbin coil voltages. RG 1.121, "Bases for Plugging Degraded Steam Generator Tubes," describes a method acceptable to the NRC Staff to meet General Design Criteria 14, 15, 31, and 32 by reducing the probability and consequences of a steam generator tube rupture through determining the limiting safe conditions of degradation of steam generator tubes, beyond which they must be repaired removed from service.

The interim tube plugging criterion is based upon the conservative assumptions that the tube to tube support plate crevices are open (negligible crevice deposits or TSP corrosion exists), and that the tube support plates are displaced under SLB condition loadings. The OD SCC is thus considered to be free span degradation under normal and SLB accident conditions and the principal requirement for tube plugging considerations is to provide margin against tube burst per RG 1.121. The open crevice assumption leads to maximum leak rates compared to packed crevices and also maximizes the potential for TSP displacements (which can uncover cracks) under accident condition loadings.

TUBE INTEGRITY ASSESSMENT

For the faulted plant condition evaluation, the postulated events considered are Loss of Coolant Accident (LOCA), Steam Line Break (SLB), and Feedline Break (FLB) in combination with Safe Shutdown Earthquake (SSE). It is shown that potential through-wall cracks which may exist as a result of implementation of the interim tube plugging criterion are not expected to propagate and result in tube rupture under accident condition loadings. The potential effects of a postulated LOCA + SSE event on the continued maintenance of tube integrity and the ability of the Catawba steam generators to perform their intended safety function are addressed below and are found to be acceptable. The potential effects of a postulated SLB + SSE or FLB + SSE event on the continued maintenance of steam generator tube integrity are enveloped by the R.G. 1.121 criterion requiring the maintenance of a factor of safety of 3 times normal operating pressure differential to tube burst with the presence of a through-wall crack. This is the case as the combined maximum tube bending stress at any elevation during a SSE event is less than the tube material yield strength (using lower tolerance limit

properties). Outer diameter stress on the order of the yield strength of the tube material is required before any significant effect on tube burst strength is realized (WCAP-7832A). Tube burst capability following a combined SLB + SSE or FLB + SSE event upon implementation of the interim plugging criterion is evaluated below and is found to be acceptable.

Combined SLB + SSE/FLB + SSE Loadings

During a postulated accident, lateral support provided to the tube by the TSP can induce bending stresses at the TSP intersection, which vary from tension to compression around the tube circumference. Compressive stresses have the potential to reduce the tube burst capability due to crack opening.

Test results show that bending stresses on the order of the tube material yield strength at operating temperature are required to significantly affect tube burst capability. Per RG 1.121, burst capability during accident conditions is required to be at least 2650 psi. Also per R.G. 1.121, the bending stress due to SSE must be coupled with the pressure induced primary membrane stress when evaluating the effects of a combined SLB + SSE or FLB + SSE event. Based on the results of the seismic analyses, the maximum bending stresses at the top TSP have been shown to be less than the tube yield strength at temperature. As noted above, bending stresses approaching the material yield are required to affect burst. Therefore, the postulated effects of a combined SLB + SSE do not adversely affect the burst capability of the Catawba tubing.

Combined LOCA + SSE Loadings

In addressing the combined effects of LOCA + SSE on the steam generator component (as required by GDC 2, and RG 1.121), it has been postulated that local tube collapse may occur in the steam generators at some plants. The tube support plates may become deformed as a result of radial loads at the wedge supports at the periphery of the plate due to combined LOCA and SSE loadings.

There are two issues associated with local steam generator tube collapse. First, the potential collapse of steam generator tubing adjacent to wedge groups reduces the RCS flow area through the tubes, which may increase LOCA peak clad temperature (PCT). Second, there is a potential that partial through-wall cracks in tubes could progress to through-wall cracks, or that existing through-wall cracks might open up, during tube deformation resulting in secondary to primary in-leakage, which similarly may cause an increase in peak clad temperature (PCT).

In order to estimate the level of tube deformation resulting from the combined LOCA + SSE loadings, results from a crush test program for Model D steam generators are utilized. The force/deflection

results represent inelastic behavior of the plate and tubes. In order to make use of this data, an approximation was made between the elastic analyses that determine the plate loads and the inelastic crush test. This approximation is based on the area under the force deflection curve for the crush test versus the area corresponding to elastic plate response.

Since the leak-before-break criterion has been approved for the Catawba Unit 1 reactor coolant loop piping, large break LOCA forces can be excluded, and only small break forces require evaluation. Conservatively, large break forces were used for the LOCA + SSE evaluation. The results of the analyses indicate that for the flow distribution baffle elevation, no tubes would be excluded from IPC implementation. However, a limited number of tubes adjacent to the wedge groups for the remainder of the plate locations, may deform or collapse and secondary to primary in-leakage may occur. The IPC cannot be applied to these locations, and they will be plugged or repaired by sleeving if TSP degradation is detected at elevations other than the FDB in these tubes.

For all other steam generator tubes (tubes not located in wedge areas), the possibility of secondary to primary leakage in the event of a LOCA + SSE event is not significant. Any secondary to primary leakage is expected to be less than the current primary to secondary operating leakage limit. Steam generator tube integrity and operability are enhanced with the reduction of leakage allowed from 500 gpd to 150 gpd per steam generator. Furthermore, secondary to primary leakage would be less than primary to secondary leakage for the same differential pressure since the cracks tend to tighten under secondary to primary differential pressure. Additionally, the presence of the tube support plate is expected to reduce the amount of in-leakage as the annulus between the TSP hole and tube functions as a leak limiting orifice.

TUBE BURST CAPABILITY DISCUSSION

The criterion of RG 1.121 to maintain a factor of 3 times normal operating pressure differential on tube burst is inherently satisfied during normal operating conditions. Based on Catawba eddy current data, the tube support plate elevation ODSCC is situated within the thickness of the tube support plates. Steam generator tube denting (due to TSP corrosion) and cracking potentially initiate and progress at high temperature within the TSP. Since the tubes and support plates are in an equilibrium situation during normal operation, and since the causes of the cracking occur at the tube/support plate intersections, it is clear that the cracking would be situated within the plates during normal operating conditions and that tube burst cannot occur due to degradation within the TSP.

Catawba Pulled Tube Burst Test Results

In general, the burst testing of the Catawba tubes is judged to have been concluded prior to true bursting of the tube. Little or no crack tearing (representing ductile failure of the tube material) was observed for many of the burst tests, and therefore, adjustments must be applied to the burst test results in order to yield burst pressures indicative of the point of ductile failure in the tube. Where burst test data is discussed, adjusted burst pressures will be given in parenthesis. Table 2 outlines the Catawba burst test results.

Table 2

Catawba Unit 1 Tube Burst Test Data

Tube	TSP	Field Bobbin Volts	Post Pull Bobbin Volts	Burst Pressure	Maximum Crack Depth
R5C112	2 hot leg	0.48	0.25	9700 (10800)	N/A
R5C112	3 hot leg	1.82**	5.06	4150 (N/A)*	93%
R10C6	2 hot leg	1.46	2.07	6000 (7100)	72%
R10C6	3 hot leg	1.31	5.34	4850 (5740)	N/A
R7C47	3 hot leg	1.57	1.13	N/A*	84%
R20C46	2 hot leg	0.42	0.82	8600 (N/A)*	N/A
R20C46	3 hot leg	0.79	1.04	7200 (N/A)*	N/A
R10C69	2 hot leg	NDD	NDD	9400 (10340)	N/A
R10C69	3 hot leg	1.48	3.31	5000 (N/A)*	N/A

* Burst adjustment expected to be greater than 1.25, therefore these tubes not included in burst data base.

** Based on the large discrepancy between the pre and post pull data it appear that this sustained additional damage during the tube pulling process. Therefore basing a leakage threshold on the data provided by this tube is conservative.

3/4" Model Boiler Burst Data

A set of 15 laboratory induced stress corrosion cracking tube specimens are used in the 3/4" tubing data base in the development of the interim plugging criterion.

CATAWBA TUBE WALL DEGRADATION CHARACTERIZATION

To date, 5 tubes have been removed from the Catawba Unit 1 steam generators and destructively examined. The corrosion morphology of the Catawba pulled tube is consistent with the evidenced TSP degradation morphology. The maximum length of intergranular corrosion evidenced from Catawba pulled tubes is 0.5 inch, centered about the midpoint of the tube support plate.

Testing of model boiler specimens for free standing tubes at room temperature conditions show burst pressures in excess of 5475 psi for indications of outer diameter stress corrosion cracking with voltage measurements as high as 11 volts. Burst testing of Catawba pulled tubes indicate burst pressure of up to 7100 psi for 1.46 volt indications.

Based on the existing 3/4" data base for free span tubing, and correcting for the influence of Catawba operating temperature on material properties, and for the minimum strength levels, the safety requirements for tube burst margins during both normal and accident condition loadings for Catawba can be satisfied with bobbin coil indications with voltage levels less than 4.1 volts, independent of the depth measurement. Alternate crack morphologies could correspond to 4.1 volts so that a unique crack length is not defined by the burst pressure to voltage correlation. To address such uncertainties in burst capability, the structural limit is based on the lower 95% confidence level on the burst correlation. Again, conservatism is added by assuming the crevice area will behave as free span degradation.

CATAWBA GROWTH RATES

Voltage growth rates for the Catawba steam generators have been defined in terms of percent growth per cycle and are applied at the voltage amplitude requiring tube plugging.

To address the potential for variations in future cycle length, an average voltage growth allowance of 45% is applied to establish the plugging or repair limit. The average growth allowance is determined from the eddy current results (the 541 largest indications) of Unit 1 Cycle 6. These results for Catawba Unit 1 show a 25% average growth (0.18 volt absolute growth) over the entire range of voltages and about 10% average growth (0.14 volt absolute growth) for indications above 0.75 volts at the beginning of the last cycle.

The Cycle 5 growth data were developed for 126 indications at TSPs plugged in 1991 at EOC5. For BOC indications < 0.75 and <1.0 volts, Cycle 5 and 6 show essentially the same average growth rate (about 40% and 29% respectively). This difference is most likely due to the larger number of indications used for the growth rates in Cycle 6 than for 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 as used for the Catawba Unit 1, IPC tube integrity assessments.

The voltage based structural limit must be reduced by the allowances for crack growth during the next cycle plus eddy current uncertainties to obtain a voltage based tube plugging limit which supports the margins to tube burst outlined in RG 1.121. For a EOC voltage structural limit of 4.1 volts, with values for average growth per cycle, and assumed eddy current uncertainty of 45% and 20% respectively, the plugging limit is determined to be 2.5 volts. For the interim, the voltage based plugging limit is set at 1.0 volts, thus, a 1.5 volt margin is realized upon application of the interim plugging limit of 1.0 volts. Applying the growth value of 0.62 Volts and an NDE uncertainty of 16% to the interim plugging limit results in a nominal expected EOC 7 voltage of 1.8 volts. A 2.3 volt nominal margin to burst capability of 3 times the normal operating pressure differential is provided for EOC 7 conditions.

EDDY CURRENT INSPECTION CAPABILITY

Detection of Indications Discussed

The probability of detection of indications at tube support plate elevations has been previously evaluated for both bobbin coil and RPC probes at another plant. This evaluation combined field inspection results with pulled tube examination results for TSP indications.

Available data for the IGA/SCC mode of tube degradation has been evaluated for detectability. The overall pulled tube data base for IGA/SCC indications shows voltage levels as high or higher than obtained for ODSCC at comparable depths of indications. Degradation of this type is considered to be readily detectable. Pulled tubes from European plants with more significant levels of IGA exhibited bobbin voltages as high as 11 volts. The burst characteristics of this tube are calculated to exceed the Reg Guide 1.121 minimum limit of 3 times the normal operating pressure differential.

Based on the previous evaluation, the probability of detection of stress corrosion cracking > 40% average (actual) depth is approximately 100%. Very short (approximately 0.2") cracks could have greater than 40% depth for detectability. It should be noted that the Technical Specification 40% plugging limit represents an NDE determined depth, dependent on tube wall degradation type, which may represent actual tube degradation in the range of 55%, based on an assumed uncertainty of 15% for phase angle based depth calls.

100% Eddy Current Inspection

Addressing RG 1.83 considerations, upon implementation of the criterion, all future refueling outages implementing IPC or APC

will involve a 100% inspection of all hot leg tubes down to the lowest cold leg intersection with identified ODSCC in order to monitor the progression of ODSCC.

A RPC inspection will be conducted for all flaw like bobbin probe indications exceeding a signal amplitude of 1.0 volt but less than 2.5 volts. The RPC results are to be evaluated to establish that the principal indications can be characterized as ODSCC. If indications other than ODSCC are identified, these indications will be evaluated against a 40% depth requirement for tube plugging. The RPC inspection recommendation is consistent with a threshold value below which SLB leakage is expected to be negligible and other types of degradation (wear, cold leg thinning, etc.) are not expected to have a significant effect on steam generator tube integrity.

Catawba Eddy Current Methodology

The Catawba Unit 1 EOC 6 bobbin coil data was analyzed in accordance with the Eddy Current Analysis Guidelines, Catawba Nuclear Station Unit 1, Rev. 2 dated July 9, 1992. All signals indicative of degradation were reported regardless of depth and with no minimum voltage threshold. All data were analyzed with 2 independent reviews (primary and secondary analysts). The results of the primary and secondary analysts were compared and resolved by a team of 2 resolution analysts.

Every HL call was then remeasured to obtain a voltage value consistent with Westinghouse recommendation for measuring bobbin voltages for ODSCC degradation at HL TSPs. This process was simply a measurement exercise, to obtain a voltage value related to a specific normalization, channel (550/130 Khz MIX 5), and signal isolation. This was not a reanalysis as the presence of the degradation at each reported TSP had already been determined and was not changed. The remeasurement was performed in accordance with the Hotleg Tube Support Re-Sizing Analysis Guidelines, Rev. 0, dated August 12, 1992. An analyst remeasured each HL TSP call and generated bobbin coil graphics depicting the call. Each call was reviewed by a team of 2 resolution analysts who concurred with the accuracy of the measurement, and assured all HL TSP calls were resized.

Every HL TSP call was then remeasured two more times:
Once again on the current EOC 6 bobbin data with a 400/130 Khz mix and also from the EOC5 1991 data with a 400/100 Khz mix. These remeasurements were performed to obtain ODSCC growth trending information. The remeasurements were performed in accordance with the Hotleg Tube Support Re-Sizing Analysis Guidelines for Growth Trending, Rev. 0 dated August 12, 1992. These measurements were also performed by an analyst with two resolution analysts reviewing them for accuracy.

To obtain growth trending information over 2 cycles, a set of HL TSP calls plugged after the EOC 5 analysis in 1991 were remeasured using the EOC 5 1991 data using a 400/100 Khz mix. Resizing and resolution were performed in identical fashion to the growth trending described in the paragraph above.

Assumed Eddy Current Uncertainties

The NDE uncertainties on bobbin probe voltage include such factors as probe wear, calibration standard, and measurement repeatability. The eddy current uncertainty allowance in measuring voltage is conservatively set at 20% for the full APC. This large NDE uncertainty allowance factors in both the contribution from analyst variability and probe wear. A 16% NDE uncertainty is utilized for the development of the IPC.

TUBE LEAKAGE CONSIDERATIONS

Although, following the implementation of the bobbin probe signal amplitude plugging criterion, tubes are not expected to burst under normal or accident conditions, and are expected to retain sufficient margin, it cannot be assured that the cracks will not leak during all plant conditions.

Operating Plant Leakage Experience

Pulled tube examination results from other plants indicate that through-wall cracks can potentially occur below 10 volts but that the associated crack lengths are short with no measurable leakage at operating conditions. Leakage at operating conditions has not been identified for bobbin coil voltages less than 6.2 volts in a 3/4" tube in the field.

A total of three suspected tube leaks are attributable to OD SCC at the TSPs in operating European steam generators. Two leakers (crack indication signal amplitudes of about 6.2 and 20 volts occurred at one plant in the same operating cycle. In this case, a total of 5 tubes were suspected to be contributing to the leakage of less than 140 gpd. The other crack indication which leaked had a signal amplitude of 7.7 volts and an indicated depth of 92% through-wall; the leakage also included leakage at roll transitions from other tubes and was 63 gpd. No field leakage has been reported below 6.2 volts and no measurable field leakage was observed for the pulled tube from Catawba at 1.82 volts with through wall degradation. A reasonable judgement for the leakage threshold at SLB conditions is approximately 1.82 volts with a significant likelihood of exceeding 6.0 volts for operating plant leakage detectability.

Accident Condition Loadings Leakage

For Catawba steam generator interim tube plugging criterion for TSP elevation ODSCC, the total SLB leakage limit of 1.0 gpm is met by determining the end of cycle SLB leak rate for tubes left in service with crack indications. As noted above, a reasonable judgement for the zero leakage threshold at steam line break conditions is approximately 1.82 volts. This tube, removed from the Catawba plant, leaked at approximately 0.0025 gpm at SLB conditions. Based on the 3/4" pulled tube data base, a 3.5 volt indication conservatively would be bounded by leakage a 0.0044 gpm (1 liter/hr) at SLB pressures. Expected SLB leakage for indications exceeding 3.5 volts EOC, is conservatively assumed to be 0.041 gpm (10 liters/hr). Any interim criterion utilizing a lower bobbin voltage based plugging limit which would predict EOC voltages under 1.8 volts would result in no primary to secondary leakage at SLB conditions.

Determination of Expected Leakage During SLB Conditions

As noted above, a number of tube intersections with voltage signals that satisfy the interim tube plugging criterion will remain in service until inspected and reevaluated during subsequent refueling outages. It is conservatively assumed that some of this number will have the potential for leakage during a postulated steam line break - although leak rate testing of pulled tubes has not demonstrated potential for leakage from crack indications with voltages under 1.8 volts. Therefore, leakage rate during steam line break conditions is to be evaluated for the tubes remaining in service at each outage. Uncertainties in voltage signal, growth allowance, and leakage rate versus voltage are accounted for using Monte Carlo techniques. An end of cycle voltage population is assessed (accounting for uncertainties) for the potential for leakage during a postulated steam line break event.

The current distribution of number of indications versus voltage has been obtained for the Catawba steam generators. Also, the most recent change in voltage was obtained on an effective full power year (EFPY) basis. The current voltage distribution is then combined with the voltage growth rate measurement, using Monte Carlo techniques, to establish an end of cycle voltage distribution. Uncertainty in the voltage signals for the current inspection is accounted for in a statistical manner via Monte Carlo simulations utilizing distributions for the NDE uncertainties.

An interim criterion which uses a bobbin probe voltage based plugging limit which would predict EOC voltages less than 1.8 volts for flaw like indications would not result in leakage at SLB conditions. Based upon the probabilistic determination of EOC voltages using Monte Carlo, and applying the leak rate values listed above for the three voltage thresholds, an EOC SLB leak rate of 0.54 gpm has been calculated which does not adversely affect radiological consequences. The deterministic leakage has been determined to be .15 gpm.

LIMITING CRACK LEAKAGE DEVELOPMENT

The RG 1.121 acceptance criterion for establishing an operating leakage limit requires that plant shutdown be initiated if the leakage associated with the longest permissible single crack is exceeded and, thus, provides for leak-before-break. The longest permissible crack is the length that provides a factor of safety of 3 against bursting at normal operating pressure differential. For 3/4" tubing, a voltage amplitude of 4.1 volts for typical ODSCC corresponds to meeting this tube burst requirement at the lower 95% confidence level on the burst correlation. Alternate crack morphologies can correspond to 4.1 volts so that a unique crack length is not defined by the burst pressure versus voltage correlation. Consequently, typical burst pressure versus through-wall crack length correlations are used below to define the "longest permissible crack" for evaluating operating leakage limits.

The single through-wall crack lengths that result in tube burst at 3 times normal operating pressure differential and SLB conditions are about 0.48 inch and 0.76 inch, respectively. A maximum operating leak rate of 150 gpd will be implemented at the Catawba Unit 1 plant. Primary to secondary leakage up to 150 gpd provides for the detection of a 0.4 inch long through-wall crack, based on mean leak rates and a 0.6 inch long through-wall crack at the 95% confidence level leak rates. Thus, for cracking that may be occurring at location within the TSP elevation, the Catawba 150 gpd limit provides added conservatism for plant shutdown prior to reaching critical crack lengths for SLB conditions at leak rates less than a 95% confidence level and for three times normal operating pressure differential at less than nominal leak rates.

Therefore, leak-before-break is enhanced for tubes with ODSCC occurring within the TSP intersections with the 150 gpd leakage limit.

DOSE ANALYSIS

Of the accidents analyzed in Chapter 15 of the FSAR, only the Main Steam Line Break Analysis is affected by IPC. The Catawba Technical Specifications limit operating leakage to 0.4 gpm (576 gpd) from all steam generators, 150 gpd in any one steam generator. The calculated leakage during a postulated SLB event is approximately 1 gpm total leakage from all steam generators. Assuming 1.0 gpm total leakage (0.64 in the faulted loop, 0.3 in the non-faulted loops), the results of a dose evaluation for a main steam line rupture outside the containment structure indicate that the limiting dose, Exclusion Area Boundary Thyroid Dose, is within the value presented in the Catawba FSAR.

CONCLUSION

The steam generator tube plugging criterion for the tube support plate elevation degradation observed in the Catawba steam generators is summarized in Table 1.0. The recommended tube plugging criterion is based upon bobbin coil inspection voltage signal amplitude, which is correlated with tube burst capability. The criterion is developed to preclude free span tube burst if it is postulated that TSP displacement would occur under accident condition loadings. The interim tube plugging limit provides RG 1.121 tube burst margin. The interim criterion plugging limit (much more conservative than the structural plugging limit) is expected to result in the majority of the end of cycle (EOC) voltages being below the SLB leakage threshold. A small number of tubes can be expected to grow at faster than expected rates. However, the leakage potential from the crack indications in these tubes is expected to be less than the 1.0 gpm total leakage assumed in the FSAR accident analyses during a postulated SLB, thereby maintaining offsite doses to less than a small fraction of the 10CFR100 guidelines.

Table 1.0
INTERIM STEAM GENERATOR TUBE PLUGGING CRITERION
FOR
TUBE SUPPORT PLATE ELEVATION
ODSCC

BOBBIN SIGNAL VOLTAGE	ACTION
≤ 1.0	LIMITED *
> 1.0 but less than 2.5	RPC **
≥ 2.5	PLUG OR REPAIR

* If it is found that the potential for steam line break leakage at end of cycle conditions for tubes planned to be left in service exceeds 0.7 gpm in any steam generator, then additional tubes will be plugged to reduce steam line break leakage potential in that steam generator to below 0.7 gpm. If additional tubes are to be plugged or repaired in order to show compliance with the 1.0 gpm leakage limit, the largest bobbin coil voltage flaw indications would be plugged or repaired.

** Plug or repair if indication of ODSCC are detected.

The 4.1 volt signal amplitude, which comprises the structural requirement for a free span tube to have a burst capability equivalent to 3 times the normal operating pressure differential (3750 psi), must be reduced for NDE measurement uncertainties and

projected crack growth between inspections to establish the allowable structural limit for tube plugging. The development of the 4.1 volt structural limit is based upon a lower 95% prediction interval reduction of burst data, with burst pressures adjusted to lower tolerance limit strength properties at operating temperatures (650°F). The voltage limit with this same basis is 10.95 volts at the SLB pressure differential of 2650 psi.

In addition to meeting the structural criteria, use of the interim plugging criterion also limits normal operating and SLB leakage to acceptable levels during all plant conditions. For normal operating conditions, no leakage has been reported below 6.2 volts. The threshold voltage for detectable plant leakage is estimated at about 6.0 volts. For SLB conditions, pulled tube data indicate that a threshold voltage of about 1.8 volts could result in through-wall cracks long enough to leak at SLB conditions.

Attachment 2

Projected End of Cycle 7 Tube Burst Margins

ECC Volt	Lower 95% B.P.		Ratio to 3 x delta P			Ratio to SLB		
	3/4	7/8	3/4 (3750)	7/8 (4380)	Ratio	3/4	7/8	Ratio
90% Confidence Level Data								
1.8	4660	5640	1.24	1.29	.96	1.76	2.13	.83
99% Confidence Level Data								
3.37 (7/8)		5013		1.14			1.89	
2.81 (3/4)	4186		1.12		.98	1.58		.84
99% Confidence Level Data IPC = 0.84 volt								
2.58 (3/4)	4284	5013	1.14	1.14	1.0	1.62	1.89	.86
99% Confidence Level Data IPC = 0.70 volt								
2.39 (3/4)	4366	5013	1.16	1.14	1.02	1.65	1.89	.87
99% Confidence Level Data IPC = 0.50 volt								
2.11 (3/4)	4482	5013	1.2	1.14	1.05	1.69	1.89	.89