UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

ENCLOSURE 1

SAFETY EVALUATION BY THE OFFICE OF SPECIAL PROJECTS

MICROBIOLOGICALLY INDUCED CORROSION (MIC) PROGRAM

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR POWER PLANT, UNITS 1 AND 2

DOCKET NOS. 50-327 AND 50-328

1.0 BACKGROUND

Sequoyah has experienced microbiologically induced corrosion (MIC) in the pipe walls of the carbon steel fire protection piping and in the butt welds of stainless (austenitic) steel in the essential raw cooling water (ERCW) system. The two known carbon steel MIC occurrences were in non-safety, stagnant portions of the fire protection system. TVA has not developed a program to address MIC for carbon steel piping in the fire system; however, leakage due to MIC in the system is not significant to date.

The stainless steel piping in the ERCW system had been in use for 9 years. During the 9 years of service, MIC had occurred at the butt welds in 6-inch diameter piping. The MIC attack initiated at the inside surface of the welds and degradation occurred in the form of voids that became larger, and deeper, and eventually developed into a throughwall leak. There can be several individual sites on a given weld. The leakage was small and was characterized as drips or moist areas around the butt welds.

TVA determined the extent of damage to the ERCW system by visual inspection for leaks and performed a sample radiographic inspection of 61 welds, which included the 28 leaks visually detected. TVA developed a MIC program for Sequoyah based upon the data developed through these inspections. The MIC program and the engineering which formed the basis for the program is described in TVA's letter dated January 20, 1987. An ongoing investigation is planned to monitor damage and verify the effectiveness of water treatment when the new water treatment program is implemented.

2.0 TVA'S MIC MITIGATION PROGRAM

The NRC contractor, Parameter, Inc., through its consultant NOVETECH Corporation, has reviewed the TVA MIC program. The program includes: (1) a surveillance and inspection program to identify leakage, (2) allowable degradation limits based on maintaining adequate margins against failure, (3) protection from leakage of nearby equipment important to safe shutdown, (4) repair of leaking welds, and (5) planned implementation of a water treatment program to retard MIC activity.

The contractor, in the attached Technical Evaluation Report (TER), has reached the following conclusions.

1. The screening criterion and associated analysis procedure developed to define allowable MIC degradation is acceptable.

2. The semiannual, weld-by-weld visual inspection program is adequate to identify leaking welds. The radiographic test (RT) examination to determine the extent of MIC degradation in the weld volume subsequent to leakage detection together with the screening criterion are adequate to assess the margin against failure for upset and postulated failed conditions.

3. Based on the review and evaluation of the licensee inspection, evaluation, and repair program, it is concluded that program implementation provides assurance that adequate safety margins will be maintained provided the program includes the following additional items: (1) at the same time leakage is detected, an assessment is made to ensure the acceptance criterion is not exceeded prior to the scheduled outage or repair, (2) the frequency of direct visual inspection of weld specific leaks is increased to monthly, and (3) the leakage from a leaking weld does not exceed 0.5 gpm and the total leakage from all welds does not exceed 1 gpm.

4. Although the proposed program does not comply exactly with the licensing application of Section XI of the ASME Code , it forms the basis for an adequate alternative to Code requirements, and, when combined with the previously recommended additions, provides an acceptable technical justification for implementation and relief from the exact Code requirements according to 10 CFR 50.55a.

The staff has reviewed the TER and concurs with the essential findings in the TER. The staff emphasizes that a relief request from the repair requirements of the ASME Code, Section XI is necessary if TVA implements the proposed program in the event that leakage occurs in the ERCW piping. In the relief request, TVA should include the time frame for deviation from the permanent Section XI repair, for example, an outage of sufficient duration to accomplish the repair but no later than the next refueling outage. The request should describe the hardship involved with performing an immediate repair.

In the TER, the contractor states, "Based on a review of the Code, we agree with the licensee that Section XI does not specifically address evaluation and repair of defects that are detected at a time other than a regularly scheduled Section XI inservice inspection." When actual flaws are detected in an ASME Code class component in an operating reactor, the staff expects the licensee to implement the requirements of ASME Section XI. When a throughwall flaw in ASME Class 1, 2, or 3 pressure retaining boundary is discovered by plant personnel during maintenance, the Technical Specifications shall be followed and the rules of ASME Section XI should be used for repairs.

TVA has stated it is developing some temporary repair methods for the ERCW stainless steel piping. The use of other than ASME Code repair methods requires NRC review and approval prior to their implementation.

3.0 CONCLUSION

The staff concludes that TVA's inspection, evaluation and repair program for MIC for the ERCW austenitic stainless steel piping, if properly implemented, provides reasonable assurance that the ERCW system is capable of performing its intended safety function. However, the staff position is that if leakage should occur in the ERCW piping, the requirements of ASME Code, Section XI apply and relief is required for the interim period in accordance with 10 CFR 50.55a.

Principal Contributor: R. Hermann

Dated:

EVALUATION OF STRUCTURAL INTEGRITY ANALYSIS FOR AUSTENITIC STEEL WELDS WITH MICROBIOLOGICALLY INDUCED CORROSION

1.0 BACKGROUND

Degradation from microbiologically induced corrosion (MIC) has been detected in austenitic steel girth butt welds in 6-inch piping of the essential raw cooling water (ERCW) system at Sequoyah Nuclear Plant (SQN). The MIC degradation initiates at the pipe inner surface and extends with time into the pipe wall. The degradation occurs in the form of voids at selected regions in the weld and produces a porous structure that eventually may leak.

Visual inspection of 385 of the 405 welds in the ERCW system revealed 28 leaking welds that were subsequently repaired. The leakages from the welds were relatively small and were characterized as dripping water or dampness around the MIC penetration. Radiographic examinations also were performed on a sample of 67 welds (including the 28 leaking welds) to better assess the extent of MIC degradation in the pipe wall. The volumetric examinations revealed varying degrees of MIC degradation in 61 of the 67 welds.

The licensee, Tennessee Valley Authority (TVA), has evaluated the MIC degradation in the ERCW piping, and has developed a program to ensure the degradation is monitored and controlled and that adequate margins against failure are maintained. This program was described in a January 20, 1988 letter (see Reference 1) and includes: (1) a surveillance and inspection program to identify leakage, (2) allowable degradation limits based on maintaining adequate margins against failure, (3) protection from leakage of nearby equipment important to safe shutdown, (4) repair of leaking welds, and (5) planned implementation of a water treatment program to retard MIC activity.

A description of the TVA program and a technical evaluation of that program are presented in Sections 2 and 3, respectively.

2.0 PROGRAM SUMMARY

2.1 Structural Analysis

The ERCW piping is ASME Code Class 3 piping. A structural analysis was performed to define the allowable MIC degradation and was based on maintaining the applied stress less than the Code allowable for Class 3 piping, or

$$\sigma_{app} \leq FS \cdot S_h \tag{1}$$

where

σ_{app} is the applied stress,

S_h is the Code allowable stress, and

FS is the margin and is equal to 1.2 or 2.4 for upset or faulted conditions, respectively.

The applied stress is determined for the weld specific bending moments, axial load, and level of degradation. The degree of degradation is used to reduce the pipe cross sectional area and section modulus, and consequently, to increase the computed applied stress, or

$$\sigma_{app} = (M/Z_r) + (p \cdot A_i)/A_r \tag{2}$$

where

σ_{app} is the applied stress,

M is the resultant bending moment at any specified weld location,

Z_r is the reduced section modulus determined for any specified degraded weld,

p is the pressure,

A_i is the pipe flow area,

$(p \cdot A_i)$ is the axial force due to pressure, and

A_r is the cross sectional area of the pipe determined for the degraded weld.

The bending moment in Eq. 2 includes deadweight and primary bending for upset conditions; seismic bending is added for postulated faulted conditions. Because system temperatures are low, thermal stresses were considered negligible. Axial seismic loads also are negligible and were not included in the applied stress computation.

The reduced section properties, Z_r and A_r, are determined by projecting all the degradation regions in the weld onto a plane passing through the centerline of the circumferential weld.

2.2 Allowable Degradation Screening Criterion

Eq. 2 and the results from the RT examination were used to establish a screening criterion to define allowable levels of MIC degradation. The criterion was developed by first computing the ratio $SF \cdot S_h/\sigma_{app}$ from Eq. 1 using the stress computed from Eq. 2. The stresses were computed using the reduced section properties and area for each of the 61 welds with MIC degradation and the loads associated with the location of maximum nominal stress in the ERCW system. This ratio was designated as the reserve factor and was plotted against the total circumferential length of MIC degradation for each associated weld. Allowable flaw lengths are those where the reserve factor is computed to be equal to or greater than 1.0.

The results indicate a linear relationship within a scatter band between reserve factor and total circumferential length of MIC degradation. This relationship indicates an allowable total circumferential flaw length for a reserve factor of 1.0 at the lower bound of the scatter band of about 8.5 to 9.0 inches for upset and faulted conditions, respectively.

2.3 Fracture Mechanics Analysis

A finite element fracture mechanics analysis also was performed to demonstrate that adequate margin against failure from MIC degradation exists in the ERCW piping (Ref. 3). The analysis was based on a comparison of the elastic plastic fracture mechanics crack driving force parameter, J-Integral, with the material resistance to crack extension, J at initiation.

The analysis results indicate that a large postulate flaw would not extend at postulated faulted loads.

2.4 MIC Detection During Service

Inspection for MIC is based on visual leakage detection and consists of daily walkdowns of accessible areas to assess general plant conditions, and semi-annual, weld-by-weld inspections of the ERCW piping.

2.5 Plant Response to Leakage

Section XI of the ASME Code requires a pressure test at operating pressure to detect defects in Class 3 piping; leaks found during the inspection are to be repaired. The licensee has stated that Section XI of the Code does not address evaluation and repair of defects that are detected at a time other than a regularly scheduled Section XI inservice inspection (ISI), and has developed a repair program that may or may not require repair when leakage is detected.

The response to leakage detection proposed by TVA includes the following. If leakage from the ERCW pipe welds is detected during Modes 5 and 6, repair will be made prior to restart. If the leakage is detected during Modes 1,2,3, or 4, the following action is planned: (1) perform radiographic (RT) examination of the leaking weld(s) within seven days of leakage detection, (2) if the examination exceeds the screening criterion, additional location specific analyses are to be performed and the integrity of the weld is to be reevaluated within seven days to determine adequate margin against failure, (3) if the reevaluation indicates the margins are not acceptable the appropriate action will taken according to the Technical Specifications, (4) if the reevaluation shows acceptable margins and the leakage does not present a personnel hazard or will not impact on safe shutdown equipment, the leak will be repaired at the next scheduled refueling.

2.6 Repair Method

Currently, the planned repair is to replace the leaking weld with a spool piece. Other options may be evaluated and implemented at a later time.

2.7 MIC Retardation

A water treatment program is planned to retard the MIC activity. Subsequent to program implementation, MIC degradation will be monitored to determine the effectiveness of the water treatment in MIC retardation.

3.0 EVALUATION

A review and evaluation of the information provided by TVA in References 1,2, and 3, and summarized in Section 2.0 has been performed; the results of this evaluation are presented in the remaining paragraphs of this section.

3.1 Analysis and Screening Criterion

The analysis procedure and assumptions used to develop the screening criterion generally were found to be acceptable. The evaluation determined that use of the reduced section properties properly account for the increase in applied stress that may result from the MIC degradation. Although the assumed MIC spacing in Reference 2 was slightly less conservative than that implied by the fracture mechanics analysis in Reference 3, the flaw depth assumption in Reference 2 compensates for the flaw spacing, and, overall, the applied stress computational method is acceptably conservative.

Application of the screening criterion generally will be conservative because it is based on the maximum stress location in the system and a degradation sample that is a reasonable representation of the weld population. Computation of the reserve margin for weld specific loads when leaks are detected also was determined to be acceptable for defining the limiting condition (upset or faulted) and allowable weld specific degradation level.

Because crack like defects may eventually form at MIC voids, a fracture mechanics analysis was performed as part of this review to determine the potential for unstable crack extension from MIC and verify the finite element results from Reference 3.

The analysis was based on a comparison of the elastic plastic fracture mechanics crack driving force parameter, J-Integral (J), with the material resistance to crack extension, J at initiation. The procedures used to compute J follow those described in Reference 4.

The evaluation was performed assuming a 9-inch long circumferential throughwall flaw and the faulted loads associated with the maximum stress location. The crack length corresponds to a reserve margin of 1.0 determined from the screening criterion. This crack is larger than any likely to exist and was postulated as a very conservative bound (i.e. half of the pipe circumference). Conservative assumptions for material tensile and toughness properties were used to model the base/weld metal configuration.

The results from the analysis indicate an applied J of approximately 325 in-lb./in^2. This compares to material resistance to crack extension of about 500 in-lb./in^2, which is limiting for austenitic steel welds generally (see Ref. 5). These results and the analysis assumptions demonstrate that large flaws will not extend under postulated faulted loading and that the screening criterion developed by the licensee is conservative.

3.2 Leakage Detection and Response

The planned semi-annual, weld-by-weld visual inspection has been evaluated and is judged acceptable based on the inspection frequency and inspection of individual welds where the insulation around the welds is removed and the welds will be visible during the inspection. Because the nature of the degradation is such that rapidly developing, significant leakage likely will not occur, and prior experience at SQN indicates small leaks can be detected, more frequent or additional inspection methods are not required to determine piping integrity prior to leakage being observed. Following leakage detection, the RT examination should be adequate to assess the degree of degradation in the weld volume.

Based on a review of the Code we agree with the licensee that Section XI does not specifically address evaluation and repair of defects that are detected at a time other than a regularly scheduled Section XI inservice inspection. However, licensing application of the Code in the Technical Specifications assumes that any inspection where degradation is detected is part of the approved ISI program and that Section XI evaluation and repair requirements are applicable. This application procedure indicates that leakage from MIC degradation in the ERCW piping must be repaired to comply with the Code requirements.

However, our review indicates that the inspection, evaluation, and repair program developed by the licensee forms the basis for an adequate alternative to Code requirements, and that a leaking weld can remain in service subsequent to reevaluation provided the following additional items are contained in the licensee's program: (1) at the time leakage is detected an assessment is made to ensure the acceptance criterion is not exceeded prior to the scheduled outage or repair, (2) the frequency of the direct visual inspection of weld specific leaks is increased to monthly, and (3) the leakage from a leaking weld does not exceed 0.5 gpm and the total leakage from all welds does not exceed 1.0 gpm. This alternate program provides an acceptable technical basis for relief from exact Code requirements according to 10CFR50.55(a).

3.3 Repair Method

Replacement of leaking welds using spool pieces is generally accepted practice and is preferred for this application, provided acceptable procedures for welding austenitic steel are followed. Other type repairs that may be considered in the future should be reviewed to ensure significant numbers of repairs do not impact on the overall integrity of the ERCW system.

4.0 CONCLUSIONS

1. The screening criterion and associated analysis procedure developed to define allowable MIC degradation are acceptable.

2. The semi-annual, weld-by-weld visual inspection program is adequate to identify leaking welds. The RT examination to determine the extent of MIC degradation in the weld volume subsequent to leakage detection together with the screening criterion are adequate to assess the margin against failure for upset and postulated faulted conditions.

3. Based on the review and evaluation of the licensee inspection, evaluation, and repair program, it is concluded that program implementation provides assurance that adequate safety margins will be maintained provided the program includes the following additional items: (1) at the time leakage is detected an assessment is made to ensure the acceptance criterion is not exceeded prior to the scheduled outage or repair, (2) the frequency of direct visual inspection of weld specific leaks is increased to monthly, and (3) the leakage from a leaking weld does not exceed 0.5 gpm and the total leakage from all welds does not exceed 1.0 gpm.

4. Although the proposed program does not comply exactly with the licensing application of Section XI, it forms the basis for an adequate alternative to Code requirements, and, when combined with the previously recommended additions, provides an acceptable technical justification for implementation and relief from the exact Code requirements according to 10CFR50.55(a).

5.0 REFERENCES

1. R. Gridley, Tennessee Valley Authority, "Sequoyah Nuclear Plant (SQN) Units 1 and 2 - Microbologically Induced Corrosion (MIC) Program," January 20, 1988, Docket Nos. 50-327 & 328

2. TVA-DNE Calculation CEB-CQS-355, RO, "Stress Evaluation of MIC Damage in ERCW 6-Inch Stainless Steel Girth Butt-Welds," December 15, 1987 (B41 871215 006).

3. TVA/Westinghouse Presentation, "Fracture Mechanics Evaluation of MIC Degraded Austenitic Steel Welds", Bethesda MD, January 4, 1988.

4. A. Zahoor, "Evaluation of J-Integral Estimation Scheme for Throughwall Flawed Pipes," Nuclear Engineering and Design 100 (1987) pp 1-9, North Holland Publishing.

5. Section XI Task Group for Piping Flaw Evaluation, "Evaluation of Flaws in Austenitic Steel Piping, Report NP-4690-SR, Electric Power Research Institute, Palo Alto, CA, July 1986.

Docket Nos. 50-327/328

March 31, 1988

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Mr. S. A. White
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Dear Mr. White:

SUBJECT: SAFETY EVALUATION OF MICROBIOLOGICALLY INDUCED CORROSION (MIC) PROGRAM

Re: Sequoyah Nuclear Plant, Units 1 and 2

Sequoyah Nuclear Plant has experienced MIC in pipe walls of carbon steel fire protection piping and in the butt welds of austenitic stainless steel in the essential raw cooling water (ERCW) system. By letter dated January 20, 1987, TVA submitted to the staff a program for MIC control in the ERCW system.

The NRC staff and its contractor, Parameter, Inc., have reviewed the TVA MIC program. The staff concludes that TVA's inspection, evaluation and repair program for MIC of the ERCW system is capable of performing its intended safety function. TVA should note that, if leakage should occur in the ERCW piping, the requirements of ASME Code, Section XI shall apply and relief will be required for the interim period in accordance with 10 CFR 50.55a.

A copy of the staff Safety Evaluation and the contractor Technical Evaluation Report is enclosed.

Sincerely,

Original signed by Rajender Auluck for
Gary G. Zech, Assistant Director
for Projects
TVA Projects Division
Office of Special Projects

Enclosures:
1. Safety Evaluation
2. Technical Evaluation Report

cc w/enclosures:
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