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Gentlemen:

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CALLAWAY PLANT UNIT 1
FACILITY OPERATING LICENSE NPF-30
SPECIAL REPORT 94-02
TENTH YEAR INSERVICE CONTAINMENT
VESSEL TENDON SURVEILLANCE FAILURE

The enclosed Special Report is an engineering evaluation submitted to satisfy Technical Specification (T/S) 3.6.1.6 action b and T/S 6.9.2. During the tenth year surveillance, on 8/3/94, the acceptance criteria of T/S 4.6.1.6.1.b.1 was exceeded due to corrosion on vertical tendon V68. In addition, on 8/5/94, T/S 4.6.1.6.1.b.2 acceptance criteria was not met on a tensile test on tendon V68. T/S 4.6.1.6.1.d.2 acceptance criteria was not met when, on 8/18/94, it was discovered that the net refill volume of the sheathing filler grease exceeded 5% of the net duct volume for five tendons.

Based on the enclosed engineering evaluation, the observed tendon conditions and voids in the sheathing filler grease do not indicate significant degradation of the post-tensioning system. The structural integrity of the containment building structure is assured.

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SPECIAL REPORT 94-02
EVALUATION OF THE TENTH YEAR INSERVICE TENDON SURVEILLANCE FOR THE CALLAWAY NUCLEAR PLANT

PART I of II

WIRE REMOVED FROM TENDON V68
CORROSION EXAMINATION AND TENSILE TESTS
REFERENCE TECHNICAL SPECIFICATION 4.6.1.6.1.b.1. and 2.

The Callaway Plant Technical Specification 4.6.1.6.1 requires the demonstration of containment building structural integrity through a surveillance of the containment post-tensioning system at the end of 1.5, 3.5 and 5.5 years following the initial structural integrity test, and at 5 year intervals thereafter. The 10th year surveillance of the system began on July 11, 1994. The 10th year surveillance is being performed by Precision Surveillance Corporation (PSC), East Chicago, Indiana, under contract to Union Electric.

On August 3, 1994 inspection of a wire removed from vertical tendon V68 had indications of corrosion level exceeding the acceptance criteria specified in Technical Specification 4.6.1.6.1.b.1.

On August 5, 1994 one of the three required tensile tests on the wire removed from vertical tendon V68 did not meet the acceptance criteria specified in Technical Specification 4.6.1.6.1.b.2.

The Callaway containment building is a post-tensioned, reinforced concrete structure comprised of a vertical cylinder with a hemispherical dome roof and is supported by a reinforced concrete slab. A continuous access gallery is provided beneath the foundation slab for inspection of the vertical tendons. Three concrete buttresses are provided for anchorage of the horizontal tendons. Anchorages are designed such that the tendons can be detensioned, inspected and retensioned readily during the life of the plant. The vertical cylinder wall is provided with a system of vertical and horizontal (hoop) tendons. Vertical tendons are continuous to form inverted U's that extend over the dome. The configuration of the tendons in the dome is based on a three-way system consisting of two groups of vertical tendons oriented at 90 degrees with respect to each other and a horizontal (hoop) group extending from the spring line to approximately 45 degrees from the horizontal. Hoop tendons in both the wall and the dome are placed in a 240 degree system in which three tendons form two completed rings using three buttresses for anchoring the tendons. Each tendon is comprised of 170 - 1/4 inch wires, terminating at each end with a cold formed buttonhead at the anchorage fixture.

The essential criterion for operability of the tendon system is to maintain the required prestressing force over the life of the plant. This prestressing force for an individual tendon is commonly referred to as the "lift-off" force. Additional characteristics of a tendon are determined by visual examination of a tendon wire and performing tensile testing of a wire. An individual tendon has a maximum of 170, 1/4 inch diameter wires. This amount of wires provides a redundant system so that a defect in an individual wire will not compromise the strength of the entire tendon.

WIRE CORROSION

On August 3, 1994 it was discovered that the wire pulled from tendon V68 exhibited corrosion levels that exceeded acceptable limits. Union Electric Specification C-1003(Q), Section 4.3.5.5.b describes corrosion levels 3, 4, and 5 to be unacceptable. The wire has four areas that are corrosion level 3. Level 3 is pitting greater than 0.000 inches but less than or equal to 0.003 inches. This condition was documented in the surveillance contractor's Nonconformance Report FN513-001 and Union Electric's SOS/NMR (Nonconforming Material Report) 94-1150.

In accordance with Specification C-1003(Q) and PSC's procedures, a second wire from tendon V68 was pulled on August 4, 1994. This wire did not exhibit any unacceptable corrosion levels.

This corrosion condition failed to meet Technical Specification 4.6.1.6.1.b.1. The corresponding Action Statement for this condition is 3.6.1.6.b which requires restoration of the "containment vessel to the required level of integrity or verify that containment integrity is maintained within 15 days and perform an engineering evaluation of the containment and provide a Special Report to the Commission within 30 days.......".

The corroded areas were carefully examined. The areas had a light bloom of oxidized metal. Active corrosion in tendon wire appears as a black, tar-like material. This was not present on the wire. It appears that during initial installation of V68 a portion of the original Amber 1601 shop coating was "wiped" off when the tendon was pulled through the sheath. Both wires were removed from the outside of the tendon. The corrosion most likely occurred during the time period between initial installation and initial greasing. This initial corrosion was arrested when the tendon sheath was filled with grease. There is no evidence of active corrosion on the wire.

This is an indication that the tendon grease (Visconorust 2090-P4) is performing its corrosion inhibiting function. The grease is a petrolatum or microcrystalline wax-base material, containing additives to enhance the corrosion-inhibiting and wetting properties, as well as to form a bond with the tendon steel. The grease also has the following properties for the lifetime of the containment for the anticipated range of temperature: 1) freedom from cracking and brittleness 2)continuous self-healing film over the coated surfaces 3) chemical and physical stability 4) nonreactivity with the surrounding and adjacent materials, and 5) moisture displacing characteristics. Each batch of original grease was analyzed for the presence of water soluble chlorides, nitrates, and sulfides.

WIRE TENSILE TESTS

Technical Specification 4.6.1.6.1.b.2 requires the minimum wire ultimate tensile strength to be 240.0 ksi. Three tests are required. The tendons are fabricated from ASTM A 421, Type BA wire.

Tensile tests on three samples of the first wire were performed on August 5, 1994. The results of these tests were as follows:

Sample V68-1A - 243.342 ksi
Sample V68-1B - 242.727 ksi
Sample V68-1C - 239.650 ksi

The test result from sample 1C is lower than the required ultimate tensile strength of 240.0 ksi. This was documented in the surveillance contractor's Nonconformance Report FN513-003 and Union Electric's SOS/NMR (Nonconforming Material Report) 94-1150.

The break location for sample 1A was at a point where corrosion was identified. The break location for sample 1C was not from an area of corrosion. The results from the sample is an indication that the corrosion did not adversely affect the strength of the wire.

The strength of sample 1C is within 99.85% of the acceptable limit. The average of the above three tests is 241.906 ksi. Due to the lower than expected result from sample 1C, additional testing was performed using the second wire pulled for corrosion examination for the test samples. The results of these tests were as follows:

Sample V68-2A - 244.573 ksi
Sample V68-2B - 244.573 ksi
Sample V68-2C - 243.958 ksi

The average strength of all six tests is 243.137 ksi. This is a positive indication that the tendon wire has acceptable strength.

The minimum tested yield for the three samples was 214.4 ksi. This is 12% greater than the design basis yield stress of 192 ksi. The ultimate strength of the wire is not used as a design basis for the containment building tendons.

Mill test reports for the two steel heats used to fabricate the wire in tendon V68 show ultimate stresses of 241.4 ksi and 240.4 ksi. The tested value for sample 1C is only 0.7% and 0.3% respectively below the mill test values. This is not an indication of abnormal degradation of the wire.

A review was performed of past surveillances and wire tests performed on the vertical tendons which were surveyed. The average tensile strength of tendons V1, V74, and V84 is 246.803 ksi.

Lift-off forces for the three surveyed vertical tendons are as follows:

V68 - 1428 kips or 171.2 ksi, expected range 154 to 170 ksi
V15 - 1432.5 kips or 171.7 ksi, expected range 152 to 168 ksi
V65 - 1438.5 kips or 172.4 ksi, expected range 153 to 174 ksi

All of the above lift-off forces are either well within or above the tolerance bands for the 10th Year Surveillance.

CONTAINMENT DESIGN BASIS

The containment building functions as a pressure vessel under accident conditions. It is the third barrier to possible radioactive releases from the reactor core. This function is performed by the ability of the containment to resist an internal design pressure of 60 psig (reference Bechtel Design Criteria C-0) without failure.

The Callaway Plant's post tensioning system was designed by Inryco and Bechtel Power Corporation. Inryco designed the vertical tendons using a wire stress equal to 156.9 ksi as shown in calculation C-155-205. The 156.9 ksi value is based on a maximum initial stress of 168 ksi, normal time dependent prestress loss, and a minimum prestress of 125.2 ksi at the end of design life. In Bechtel calculation C-01-107 an actual wire minimum prestress of 127.16 ksi was calculated based on the final number of tendons calculated by Inryco. Further, Bechtel calculation C-01-107 calculated a pressure capacity of the containment equal to 152 psig based on a tendon wire yield stress of 192 ksi. The minimum tested yield stress during this surveillance was 214.4 ksi.

In addition to the above design calculation, Bechtel Power Corporation prepared a study and report *Probabilistic Evaluation of Callaway Containment Structural Response to a Postulated Severe Accident* in February of 1992. This report includes Bechtel calculations 240-001 through 12. The summary of this report states that the "median ultimate pressure capacity....at 50% confidence....is 135.1 psig." The "lower bound capacity...at 95% reliability with 95% confidence....is 127.6 psig." At this point hoop tendons had reached yield strength (192 ksi). As evidenced by wire specimen testing during this surveillance there is even additional margin in the containment design due to even higher yields than specified (215.65, average). The pressures noted above are greater than two times the design basis accident pressure of 60 psig.

CONCLUSIONS

The corrosion observed on V68, wire #1 is postulated to have occurred between the time of initial installation and initial greasing. This corrosion does not exhibit the characteristics of active corrosion. The original mill test reports on wire used to fabricate tendon V68 were close to the acceptance value of

240 ksi. The break which occurred below 240 ksi was not in an area of corrosion. The break on sample 1A was above 240 ksi and was in an area with observed corrosion.

It is therefore concluded: 1) That the corrosion has not materially affected the strength of the tendon wire and 2) that the low break is an indication of statistical variations in strength tests which are very close to the documented mill tests of the original wire. That is, 239.65 ksi, surveillance tested vs. 240.4 ksi, original mill test report. The average of the three tests was above the 240 ksi acceptance value.

In addition to the above, reviews of the original containment design parameters, the containment tendon system design basis, and the containment response to a postulated severe accident has demonstrated that there is significant margin in the original design. The original specification for the tendon wire required a yield stress value of 192 ksi. The average yield for the wire samples tested in this surveillance was 215.65 ksi. Inryco designed the tendon system using a wire stress of 156.9 ksi. Based on the final number of tendons installed, Bechtel calculated an actual wire minimum prestress of 127.16 ksi at design pressure. Bechtel also calculated a maximum containment pressure capacity of 152 psig vs. a design pressure of 60 psig.

The lift-off forces for all surveyed tendons were within or above the projected acceptance band at the 10th Year Surveillance point. The verifies that each of the tendons is operable by meeting its overall design function.

Based on this evaluation the observed wire conditions do not indicate significant degradation of the post-tensioning system and containment integrity is maintained.

PART II of II

TENDON SHEATHING FILLER GREASE VOIDS
GREATER THAN 5% OF NET SHEATHING DUCT VOLUME
REFERENCE TECHNICAL SPECIFICATION 4.6.1.6.1.d.2

GREASE VOID FINDINGS

On August 18, 1994, it was discovered that the net refill volume of the sheathing filler grease exceeded 5% of the net duct volume for five tendons. This void condition did not meet the acceptance criteria in Technical Specification 4.6.1.6.1.d.2.

The Technical Specification requires verification of operability of the sheathing filler material, by assuring the "amount of grease replaced does not exceed 5% of the net duct volume, when injected at ±10% of the specified installation pressure." Since a void greater than 5% was discovered after filling, restoration of the tendon sheathing filler grease, specification action statement 3.6.1.6.b, was immediately satisfied with the exception of the Special Report. The NRC staff concurred with this position in a meeting on the same subject for the first year tendon surveillance on July 19, 1985.

This condition was documented in the surveillance contractors non-conformance report, FN513-004 and Union Electric's SOS/NMR 94-1200.

The measured voids are:

Tendon Surveillance Greasing Summary

Tendon	Percent Void
V15	12.1
V68	10.9
V65	6.7
12CB	13.0
45AC	13.0

DISCUSSION OF FILLER MATERIAL

The essential criterion for the operability of the sheathing filler material is to prevent corrosion of both the tendon wires and the anchorage components. The material used in the Callaway Plant post-tensioning system, Visconorust 2090P-4, accomplishes this by a characteristic which gives the filler grease an affinity to adhere to steel surfaces, an ability to emulsify any moisture in the system which nullifies its rusting tendency, and resistance to moisture, mild acids and alkalis. In addition, protection is afforded by each tendon wire being individually pre-coated with a grease, Amber 1601, prior to initial installation.

Results from the first, third, and fifth year tendon surveillances revealed voids in excess of 5% for most tendons surveyed, without a loss of integrity to the system. From lab tests on the removed wires and grease, and from visual inspections of the tendon components, the filler grease is performing its intended function of prohibiting or arresting corrosion of the tendon

The void in the tendon sheathing, as indicated by the refill volume varied from 6.7% to 13.0%, and may be attributed to a number of factors:

1) Visconorust 2090P-4 has a coefficient of expansion which yields an expansion of about 1% per every 20°F. Initial filling temperatures of the filler grease averaged 160°F. Cold weather conditions can cool the filler material to 40°F, giving a contraction of 6% of the net duct volume. During the tenth year inservice surveillance of the tendons, the temperature of insitu filler grease average 90°F, giving a contraction of 3 to 4% from initial fill.

2) Characteristics of the initial filling method may induce air entrapment into the filler grease. pumping operations can introduce air into filler material and may add up to as much as 2% of the net duct volume. The tendons at Callaway Plant were initially greased between April and October, 1981 by Inryco using current industry standard filling procedures.

3) Calculated voids between the wires which compromise the tendon bundle are approximately 7% of the net duct volume. During the initial filling operations, the tendon bundle was cold (ambient temperature of 65°F) and as the heated filler grease (exit temperature of 140°F) was pumped into the sheathing void, it solidified on the surface of the tendon bundle, leaving small voids between the wires. As the filler grease gradually heated the tendon bundle, it is likely that the voids between the wires allowed migration of the filler grease into the tendon bundle. Because this process is slow and gradual, it is reasonable to expect that it took place substantially after the filling operation was complete and possibly during the surveillance refill operation. In addition, this type of migration could also occur at other areas such as where tendons are in contact with the sheathing.

In addition, visual inspection of the exterior concrete of the containment building after the initial greasing and during the surveillance revealed no signs of grease seepage from the tendon duct. Therefore, refill volumes in excess of the lost grease during the surveillance indicates that the void existed within the tendon duct boundary.

The Callaway Plant tendons, requiring net refill volume of the filler material in excess of the 5% criteria, have not shown any abnormal visual deterioration, except as described and evaluated for tendon V68 in Part I of this report. The lift-off force for those tendons was found to fall within or above the predicted limits. Laboratory examination of the fill grease has been performed as of this date and found to be within the tolerance limits as specified in the Technical Specification. Visual inspection of the different components of the anchorage system revealed proper coverage by the filler material with no signs of corrosion or presence of water.

CONCLUSIONS

As indicated above, the function of the filler grease protecting the post-tensioning system was maintained. As long as sufficient filler grease has been introduced into the system to completely coat the wires and anchorage system, corrosion protection is assured. Voids can be expected due to the characteristics of the filler grease and initial filling operations as noted above. Since each wire is individually pre-coated with Amber 1601, the degree of filling interstitial spaces, which comprise the net duct volume, is not directly related to the degree of coating which occurs, and therefore, is not a major indicator of the operability of the post-tensioning system. Based on the lift-off results, visual inspection and results from the first, third, and fifth year surveillances, we have concluded that the structural integrity of the tendon and anchorage system has not been adversely affected by the measured void.

It is concluded that "voids in excess of 5% of the net duct volume" have not resulted in any degradation of the post-tensioning system, assuring the structural integrity of the containment building structure.

SUMMARY OF PARTS I AND II

The Part I evaluation of the wire corrosion and the one wire tensile test that was slightly lower than 240 ksi demonstrates that these two items had negligible effect on the containment system performance.

The Part II evaluation of measured grease voids in the tendon sheath demonstrates that the voids have not caused degradation of the post-tensioning system. The filler grease actually arrested corrosion that occurred during initial installation of tendon V68.

In addition, future scheduled surveillances of the post-tensioning system and full pressure integrated leak rate tests will monitor the structural parameters of the containment to detect any potential abnormal degradation, assure continued operability of the system, and verify containment building structural integrity on a continuing basis.

This report has been filed to meet the 30-day Action Statement as specified in Technical Specification 3.6.1.6.b.