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

June 15, 1992

Docket No. 50-255

Mr. Gerald B. Slade
Plant General Manager
Palisades Plant
Consumers Power Company
27780 Blue Star Memorial Highway
Covert, Michigan 49043

Dear Mr. Slade:

SUBJECT: EVALUATION OF PALISADES ANCHOR BOLT DESIGN (TAC NO. M81937)

Reference: Letter from D. C. Kansal, Bechtel Power Corporation, to B. Holian, NRC dated October 21, 1991, same subject

The adequacy of anchor bolt design at Palisades has been at issue since it was identified during NRC inspections from September 1990 through April 1991. We met with Consumers Power Company and Bechtel Power Corporation on April 23, 1991, to discuss the application of the unique methodology used in calculating anchor bolt stress allowables. Our conclusions and recommendations were provided in letter from B. Holian, NRC to D. C. Kansal, Bechtel dated June 13, 1991. In that letter, the NRC staff again advised Consumers Power to verify that anchor bolt allowables were not exceeded by reducing the stress capacities in proportion to the ratio of anchor bolt separation distances in order to arrive at a conservative assessment of bolt capacities. A response to our recommendations was provided by Bechtel Power Corporation in the referenced letter.

We have reviewed the information provided in the October 21, 1991, letter. Based on our review, we have concluded that, although the approach described is more logical than the previous approach, it is still deficient and unacceptable. The basis for our conclusions is provided in the enclosed evaluation.

In order to speed up the reevaluation of the adequacy of anchor bolt design at Palisades, we have developed an alternative approach which is consistent with the approach developed by the Seismic Qualification Utility Group for the

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implementation of USI-46 (verification of seismic adequacy of mechanical and electrical equipment in operating nuclear power plants). The enclosed evaluation report provides our recommendations. We request that you inform us of your intended course of action for resolving the anchor bolt design problems.

Sincerely,

Original signed by

Armando Masciantonio, Project Manager
Project Directorate III-1
Project Division III/IV/V
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc w/enclosure:
See next page

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M. I. Miller, Esquire
Sidley & Austin
54th Floor
One First National Plaza
Chicago, Illinois 60603

Mr. Thomas A. McNish, Secretary
Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Judd L. Bacon, Esquire
212 West Michigan Avenue
Jackson, Michigan 49201

Regional Administrator, Region III
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, Illinois 60137

Jerry Sarno
Township Supervisor
Covert Township
36197 M-140 Highway
Covert, Michigan 49043

Office of the Governor
Room 1 - Capitol Building
Lansing, Michigan 48913

Mr. Patrick M. Donnelly
Director, Safety and Licensing
Palisades Plant
27780 Blue Star Memorial Hwy.
Covert, Michigan 49043

Resident Inspector
c/o U.S. Nuclear Regulatory Commission
Palisades Plant
27782 Blue Star Memorial Hwy.
Covert, Michigan 49043

Nuclear Facilities and
Environmental Monitoring
Section Office
Division of Radiological
Health
Department of Public Health
3423 N. Logan Street
P. O. Box 30195
Lansing, Michigan 30195

Gerald Charnoff, P.C.
Shaw, Pittman, Potts &
Trowbridge
2300 N. Street, N.W.
Washington, D.C. 20037

Mr. David L. Brannen
Vice President
Palisades Generating Company
c/o Bechtel Power Corporation
15740 Shady Grove Road
Gaithersburg, Maryland 20877

Roy W. Jones
Manager, Strategic Program
Development
Westinghouse Electric Corporation
4350 Northern Pike
Monroeville, Pennsylvania 15146

Mr. David Joos, Vice President
Energy Supply Services
Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Mr. Dinesh C. Kansal
Manager Quality Assurance
Bechtel Power Corporation
9801 Washington Blvd.
Gaithersburg, Maryland 20878

ENCLOSURE

EVALUATION OF PALISADES ANCHOR BOLT DESIGN

BACKGROUND

Bechtel submitted a report entitled "Response to June 13, 1991 NRC letter to Bechtel regarding Palisades anchor design", dated October 21, 1991. Bechtel developed a new approach, called detailed approach in the report, for reevaluation of anchor bolts' tensile capability at Palisades, and illustrated through mathematics that the new approach should yield only minor difference in results from that of the previous approach, called simplified approached in the report. Furthermore, the report stated that the results of the evaluations using the detailed approach were identical to those using the simplified approach, and in all cases the anchors were determined to have sufficient capacity to sustain the imposed loading without exceeding design limits. With respect to the extent of application of the simplified approach, the report stated that the approach was uniquely developed by Palisades project personnel solely for Palisades application.

EVALUATION

Both the detailed and simplified approaches were developed based on the 45 degree concrete-failure-cone theory put forth in Appendix B of the ACI-349 code without examining the validity of that theory. The assumed 45 degree concrete-failure-cone is only a hypothesis, and the validity of that assumption has been controversial and challenged by test data. Test data (see Reference 1) have shown that the concrete-failure-cone is about 30 degrees for a single headed stud embedded in concrete and loaded in tension. Test data for expansion anchors (see Reference 2) have also shown the concrete-failure-cone is about 30 degrees. Test data in References 1 and 2 have shown that the tensile capacity of anchors is affected (reduced) if an anchor is located less than a distance of 1.75 times the embedment length of the anchor from a concrete free edge, and if anchors are spaced less than a distance of 3.5 times the embedment length of the anchors. These test data have challenged the validity of design approaches based on the 45 degree concrete-failure-cone theory. Based on the 45 degree concrete-failure-cone theory, the tensile capacity of any anchors would not be affected (reduced) when anchors are spaced no less than 2.0 times the embedment length of the anchors. Therefore, as far as the anchor spacing effect on the tensile capacity of multi-anchors is concerned, which is the case in Palisades anchor design, the use of 45 degree concrete-failure-cone assumption is not only inaccurate but also unconservative.

The report stated that the two approaches developed by Bechtel were consistent with good structural engineering practice, and had employed the criteria of Appendix B of ACI-349 code. However, the NRC staff has not endorsed the Appendix B of ACI-349 code, and has rejected its use in a previous license submittal with respect to under-cut anchors. It is the staff's understanding that the ACI-349 and ACI-355 code committee members have been investigating the validity of the 45 degree concrete-cone-failure theory for a period of time and the investigation is still going on. Based on the available information to the staff, the two approaches developed by Bechtel are unacceptable to the staff. The anchor problem at Palisades is somewhat complex, because it involves Hilti expansion bolts (classified as non-ductile bolts by Bechtel) closely spaced with Drillco under-cut bolts (classified as ductile anchors by Bechtel), and the two kinds of bolts are embedded at different depths. Recognizing that the knowledge in anchorage has not advanced to such a stage that the complex problem at Palisades can be resolved by the simple application of the ACI code criteria and that there is a need to assess the adequacy of those anchors, the staff has specified its approach and criteria for the evaluation of anchors at Palisades in the next section.

APPROACH AND CRITERIA FOR PALISADES ANCHORS

The approach and criteria specified below are consistent with the approach and criteria for anchorage (see Reference 3) developed by the Seismic Qualification Utility Group (SQUG) for the implementation of USI A-46 (verification of seismic adequacy of mechanical and electrical equipment in operating nuclear power plants). The approach and criteria have been specified and adjusted in such a way that some of the concepts used by Bechtel, based on the 45 degree concrete-failure-cone theory, can still be used for calculations. The approach requires three-step verifications:

1. to verify that the allowable tensile force of single Drillco under-cut bolts is greater than the maximum tensile load for these bolts assuming no loads on the Hilti bolts. The allowable tensile force is one half of the concrete capacity. The concrete capacity is calculated by multiplying an assumed tensile capacity of the concrete with the projected cone area of a single Drillco bolt based on the 45 degree concrete-failure-cone assumption. This concrete capacity calculation is identical to the equation 2 in the Bechtel report, or the procedures in Appendix B of ACI-349 code. This step of verification assumes that the support, which is anchored by Drillco bolts, is subjected to the maximum tensile load, but the adjacent

support, which is anchored by HIlti bolts, is subjected to no tensile load.

2. to verify that the allowable tensile force of single Hilti expansion bolts is greater than the maximum tensile load for these bolts assuming no loads on the Drillco bolts. The allowable tensile force is one fourth of the average of the ultimate tensile capacity of test bolts. This step of verification assumes that the support, which is anchored by Hilti bolts, is subjected to the maximum tensile load, but the adjacent support, which is anchored by Drillco bolts, is subjected to no tensile load.

3. to verify that the allowable tensile force of the combined anchor system in the concrete is greater than the sum of the load capacity of the Drillco and Hilti bolts. The allowable tensile force is the ultimate concrete tensile capacity of the combined anchor system divided by a factor of 1.5. The ultimate concrete tensile capacity is calculated by multiplying an assumed tensile capacity of the concrete with the combined projected cone area based on the 45 degree concrete-failure-cone assumption. This concrete capacity calculation is identical to the equation 2 in the Bechtel report, or the procedures of Appendix B of ACI-349 code. The combined load capacity is the sum of the Drillco bolts'capacity and the Hilti bolts' capacity within the combined projected cone area. The Drillco bolts' capacity is calculated by multiplying the total effective areas of bolts with the minimum specified yield stress of the bolt. The Hilti bolts' capacity is the average of the ultimate tensile capacity of test bolts. This step of verification assumes that both supports are imposed with maximum tensile loads.

CONCLUSION AND RECOMMENDATION

The staff has reviewed the Bechtel submittal, dated October 21, 1991, and found that both the detailed and simplified approaches are deficient and unacceptable. The staff has specified its approach and criteria for Palisades anchor bolt reevaluation as an alternative. The staff's approach and criteria are consistent with that developed by the SQUG for the implementation of USI A-46 (verification of seismic adequacy of mechanical and electrical equipment in operating nuclear power plants).

References:

1. Bode, H., and Roik, K., "Headed Studs Embedded in Concrete and Loaded in Tension," Anchorage to Concrete, SP-103, American Concrete Institute, Detroit, 1987, pp.61-88.

2. Eligehausen, R., "Anchorage to Concrete by Metallic Expansion Anchors," Anchorage to Concrete, SP-103, American Concrete Institute, Detroit, 1987, pp.181-202.

3. Seismic Qualification Utility Group,"Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Section 4, and Appendix C, Revision 2, June 28, 1991.