FLORIDA POWER & LIGHT COMPANY

TURKEY POINT UNITS 3 & 4

FINAL REPORT

ON

PIPE SUPPORT BASE PLATE DESIGNS

USING CONCRETE EXPANSION ANCHOR BOLTS

(In Response to NRC IE Bulletin 79-02, March 8, 1979,
NRC IE Bulletin 79-02 (Revision 1), June 21, 1979, and
NRC IE Bulletin 79-02 (Revision 2), November 8, 1979)

Bechtel Power Corporation
Gaithersburg, Maryland

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ATTACHMENT

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I. INTRODUCTION

This report is a final response to NRC I.E. Bulletin 79-02 (including Revisions 1 & 2) for Turkey Point Units 3 and 4. The information pertaining to Unit 4 supplements the final report previously submitted to the NRC on July 9, 1979, under transmittal by Florida Power and Light letter L-79-186.

I.E. Bulletin 79-02 required all licensees and permit holders for nuclear power plants to review the design and installation procedures for concrete expansion anchors used in pipe support base plates in systems defined as Seismic Category I by NRC Regulatory Guide 1.29, "Seismic Design Classification", Revision 1, August 1973, or by the applicable SAR. Exhibit I provides the list of systems covered by this response to this Bulletin.

Since the submittal of the final report for Unit 4, additional supports with expansion anchors have been identified as requiring further evaluation in response to NRC Audit Reports 50/250/80-18 and 50/251/80-18. Furthermore, inspections have been performed in response to this Bulletin on Turkey Point Unit 3 including the supports identified by the NRC Audit Reports noted above. Inspection and evaluation of these remaining supports will be conducted in conjunction with the in-progress work under I.E. Bulletin 79-14. A summary of these supports is provided in Section III of this report.

Section II of this report provides responses to action items as presented in Revision 2 of I.E. Bulletin 79-02. These responses were previously provided in the initial report submitted under this Bulletin.

II. RESPONSE TO BULLETIN ACTION ITEMS

Bulletin Action Item No. 1. Verify that pipe support base plate flexibility was accounted for in the calculation of anchor bolt loads. In lieu of supporting analysis justifying the assumption of rigidity, the base plates should be considered flexible if the unstiffened distance between the member welded to the plate and the edge of the base plate is greater than twice the thickness of the plate. It is recognized that this criterion is conservative. Less conservative acceptance criteria must be justified and the justification submitted as part of the response to the Bulletin. If the base plate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis. If possible, this is to be done prior to testing of anchor bolts. These calculated bolt loads are referred to hereafter as the bolt design loads.

A description of the analytical model used to verify that pipe support base plate flexibility is accounted for in the calculation of anchor bolt loads is to be submitted with your response to the Bulletin.

It has been noted that the schedule for analytical work on base plate flexibility for some facilities extends beyond the Bulletin reporting time frame of July 6, 1979. For those facilities for which an anchor bolt testing program is required (i.e., sufficient QC documentation does not exist), the anchor bolt testing program should not be delayed.

Response to Bulletin Action Item No. 1. All Seismic Category I pipe anchor and support base plates using expansion anchor/bolts were reanalyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance, and proper bolt spacing. Depending on the complexity of the individual base plate configuration, one of the following methods of analysis was used to determine the bolt forces:

a. A quasi-analytical method, developed by Bechtel, was used for base plates with eight bolts or less. An analytical formulation has been developed for the base plates which treats the plates as a beam on multiple spring supports subjected to moments and forces in three orthogonal directions. Based on analytical considerations as well as the results of a number of representative finite element analyses of base plates (using the "ANSYS" Code), certain empirical factors were introduced in the simplified beam model to account for (a) the effect of concrete foundation and (b) the two-way action of load transfer in a plate. These factors provided a way to account for effects of variable parameters such as plate dimensions, attachment sizes, bolt spacings, and stiffnesses on the distribution of external loads to the bolts.

The results of a number of case studies indicated excellent correlation between the results of the present formulation and those by the finite element method (using the ANSYS Code). The quasi-analytical method generally predicts bolt loads larger than the finite element method.

Although the effect of plate flexibility has been considered explicitly in the quasi-analytical formulation described above, the impact of prying action on the anchor bolts was determined not to be critical for the following reasons:

1) Where the anchorage system capacity is governed by the concrete shear cone, the prying action would result in an application of an external compressive load in the cone and would not therefore affect the anchorage capacity.

2) Where the bolt pull out determines the anchorage capacity, the additional load carried by the bolt due to the prying action will be self-limiting since the bolt stiffness decreases with increasing load. At higher loads the bolt extension will be such that the corners of the base plate will lift off and the prying action will be relieved. This phenomenon has been found to occur when the bolt stiffness in the Finite Element Analysis was varied from a high to a low value, to correspond typically to the initial stiffness and that beyond the allowable design load.

A computer program for the analytical technique described above has been implemented for determining the bolt loads for routine applications. The program requires plate dimensions, number of bolts, bolt size, bolt spacing, bolt stiffness, the applied forces, and the allowable bolt shear and tension loads as inputs. The allowable loads for a given bolt are determined based on the concrete edge distance, bolt spacing, embedment length, shear cone overlapping, manufacturer's ultimate capacity, and a design safety factor. The program computes the bolt forces and calculates a shear-tension interaction value based on the allowable loads.

The shear-tension interaction in the anchor bolts has been accounted for by the conservatively assuming that the total applied shear is carried by the bolts in accordance with the following interaction formula

$$\left(\frac{T}{T_A}\right)^2 + \left(\frac{S}{S_A}\right)^2 = 1.0$$

Where T and S are the calculated tensile and shear forces and T_A and S_A are the respective allowable values.

b. For special cases where the design of the support did not lend itself to the foregoing method, one of the following standard engineering analytical techniques with conservative assumptions was employed in the analysis:

1) Conventional rigid plate analysis was performed to determine actual bolt tension load. An amplification factor of 1.5 was applied to account for base plate flexibility with the exception of two bolt and four bolt symmetrical attachments under pure tension. This amplification factor is considered conservative based on the AISC Manual of Steel Construction, Part 4 (Connections in Tension) and the results of case studies performed by the finite element method to verify the quasi-analytical method.

2) Conventional rigid plate analysis was performed with the exception that a conservative moment arm equal to the distance between the centerline of bolt and the outer-most face of the welded attachment was used.

Bulletin Action Item No. 2. Verify that the concrete expansion anchor bolts have the following minimum factor of safety between the bolt design load and the bolt ultimate capacity determined from static load tests (e.g. anchor bolt manufacturer's) which simulate the actual conditions of installation (i.e., type of concrete and its strength properties):

a. Four - For wedge and sleeve type anchor bolts,
b. Five - For shell type anchor bolts.

The bolt ultimate capacity should account for the effects of shear-tension interaction, minimum edge distance and proper bolt spacing.

If the minimum factor of safety of four for wedge type anchor bolts and five for shell type anchors cannot be shown, then justification must be provided. The Bulletin factors of safety were intended for the maximum support load including the SSE. The NRC has not yet been provided adequate justification that lower factors of safety are acceptable on a long term basis. Lower factors of safety are allowed on an interim basis by the provisions of Supplement No. 1 to IE Bulletin No. 79-02. The use of reduced factors of safety in the factored load approach of ACI 349-76 has not yet been accepted by the NRC.

Response to Bulletin Action Item 2. A reanalysis of all expansion bolts for pipe anchors and pipe supports for the systems presented in Exhibit I was performed for Units 3 and 4 using the analytical methods described in the response to Bulletin Action Item No. 1. Less than one percent was found not to be in conformance with the minimum factors of safety of 4 for wedge type or 5 for self-drilling type, as appropriate, and repaired per response to Bulletin Action Item No. 4.

Bulletin Action Item No. 3. Describe the design requirements if applicable for anchor bolts to withstand cyclic loads (e.g., seismic loads and high cycle operating loads).

Response To Bulletin Action Item 3. The original design of the piping systems considered deadweight, thermal stresses, seismic loads, and dynamic loads (including steam hammer in the main steam system) in the generation of the static equivalent pipe support design loads. To the extent that these loads include cyclic considerations, these effects are included in the design of the hangers, base plates, and anchorages.

The safety factors used for concrete expansion anchors installed on supports for safety-related piping systems were not increased for loads which are cyclic in nature.

The use of the same safety factor for cyclic and static loads is based on the FFTF Tests*. The test results indicate:

a. The expansion anchors successfully withstood two million cycles of long-term fatigue loading at a maximum intensity of 0.20 of the static ultimate capacity. When the maximum load intensity was increased steadily beyond the aforementioned value and cycled for 2,000 times at each load step, the observed failure load was about the same as the static ultimate capacity.

b. The dynamic load capacity of the expansion anchors, under simulated seismic loading, was about the same as their corresponding static ultimate capacities.

Bulletin Action Item No. 4. Verify from existing QC documentation that design requirements have been met for each anchor bolt in the following areas:

a. Cyclic loads have been considered (e.g., anchor bolt preload is equal to or greater than bolt design load). In the case of the shell type, assure that it is not in contact with the back of the support plate prior to preload testing.

b. Specified design size and type is correctly installed (e.g., proper embedment depth).

If sufficient documentation does not exist, then initiate a testing program that will assure that minimum design requirements have been met with respect to sub-items a. and b. above. A sampling technique is acceptable. One acceptable technique is to randomly select and test one anchor bolt in each base plate (i.e., some supports may have more than one base plate). The test should provide verification of sub-items a. and b. above.

*Drilled-In Expansion Bolts Under Static and Alternating Loads, Report BR-5853-C-4, Revision 1, Bechtel Power Corp., October 1976.

If the test fails, all other bolts on the base plate should be similarly tested. In any event, the test program should assure that each Seismic Category I system will perform its intended function.

The preferred test method to demonstrate that bolt preload has been accomplished is using a direct pull (tensile test) equal to or greater than design load. Recognizing this method may be difficult due to accessibility in some areas an alternative test method such as torque testing may be used. If torque testing is used, it must be shown and substantiated that a correlation between torque and tension exists. If manufacturer's data for the specific bolt used is not available, or is not used, then site specific data must be developed by qualification tests.

Bolt test values of one-fourth (wedge type) or one-fifth (shell type) of bolt ultimate capacity may be used in lieu of individually calculated bolt design loads where the test value can be shown to be conservative.

The purpose of the Bulletin is to assure the operability of each seismic Category I piping system. In all cases an evaluation to confirm system operability must be performed. If a base plate or anchor bolt failure rate is identified at one unit of a mult-unit site which threatens operability of safety related piping systems of that unit, continued operation of the remaining units at that site must be immediately evaluated and reported to the NRC. The evaluation must consider the generic applicability of the identified failures.

Appendix A describes two sampling methods for testing that can be used. Other sampling methods may be used but must be justified. Those options may be selected on a system by system basis.

Justification for omitting certain bolts from sample testing which are in high radiation areas during an outage must be based on other testing or analysis which substantiates operability of the affected system.

Bolts which are found during the testing program not to be preloaded to a load equal to or greater than bolt design load, must be properly preloaded or it must be shown that the lack of preloading is not detrimetal to cyclic loading capability. Those licensees that have not verified anchor bolt preload are not required to go back and establish preload. However, additional information should be submitted which demonstrates the effects of preload on the anchor bolt ultimate capacity under dynamic loading. If it can be established that a tension load on any of the bolts does not exist for all loading cases, then no preload or testing of the bolts is required.

If anchor bolt testing is done prior to completion of the analytical work on base plate flexibility, the bolt testing must be performed to at least the original calculated bolt load. For testing purposes, factors may be used to conservatively estimate the potential increase in the calculated bolt load due to base plate flexibility. After completion of the analytical work on the base plates, the conservatism of these factors must be verified.

For base plate supports using expansion anchors, but raised from the supporting surface with grout placed under the base plate, for testing purposes, it must be verified that leveling nuts were not used. If leveling nuts were used, then they must be backed off such that they are not in contact with the base plate before applying tension or torque testing.

The Bulletin requires verification by inspection that bolts are properly installed and are of the specified size and type. Parameters which should be included are embedment depth, thread engagement, plate bolt hole size, bolt spacing, edge distance to the side of a concrete member and full expansion of the shell for shell type anchor bolts.

If piping systems 2 1/2-inch in diameter or less were computer analyzed, then they must be treated the same as the larger piping. If a chart analysis method was used and this method can be shown to be highly conservative, then the proper installation of the base plate and anchor bolts should be verified by a sampling inspection. The parameters inspected should include those described in the preceding paragraph. If small diameter piping is not inspected, then justification of system operability must be provided.

Response to Bulletin Action Item No. 4. Design requirements of anchor bolts for cyclic loads have been discussed in the response to Bulletin Action Item No. 3.

A jobsite inspection and testing program provided for verification of expansion bolts for both large bore (greater than 2 inches) and small bore (2 inches or less) pipe anchors and supports for Seismic Category I portions of the Units 3 and 4 systems presented in Exhibit I.

For those supports where it could be established that a tension load on any of the bolts does not exist for all loading cases, then no preload or testing of the bolts was performed. All inspection, testing, evaluating and corrective actions were performed in accordance with written procedures. These procedures and records of inspection, testing, and repairs are available at the Turkey Point Jobsite for inspection.

The program provided that the following information be verified, recorded, evaluated and corrected, as required:

1) Support plate conforms to design details, plate dimensions, plate thickness, and bolt configuration (number of bolts, spacing, edge distance, bolt hole size).

2) Anchor bolt length, diameter, embedment depth, type.

3) Anchor bolt projection.

4) Nut/thread engagement.

5) Pins and washers (on wedge type).

6) Washers (on self-drilling type).

7) Gap between plate and self-drill anchor sleeve.

8) Leveling nuts backed off prior to torquing.

9) Minimum torque achieved equivalent to preload of one-fourth ultimate tension capacity for wedge anchors and one-fifth ultimate tension capacity for self-drilling anchors.

10) Full expansion of shell (on self-drilling type).

Hangers/restraints were inspected for oversized bolt holes when the magnitude of loads, hanger/restraint configuration, and load application produced combined axial tension and shear or shear only. All other hangers/restraints including small bore pipe hangers have nominal loads which require minimal bolt to plate clamping capacity or surface contact area.

All supports with inaccessible or nonconforming bolts were re-analyzed using one of the analytical methods discussed in the response to Bulletin Action Item 1 and repaired in accordance with written procedures. When required, self-drilling type anchor bolts were replaced with wedge type anchor bolts.

Bulletin Action Item No. 5. Determine the extent that expansion anchor bolts were used in concrete block (masonry) walls to attach piping supports in Seismic Category 1 systems (or safety related systems as defined by Revision 1 the Bulletin).
If expansion anchor bolts were used in concrete block walls:

a. Provide a list of the systems involved, with the number of supports, type of anchor bolt, line size, and whether these supports are accessible during normal plant operation.

b. Describe in detail any design consideration used to account for this type of installation.

c. Provide a detailed evaluation of the capability of the supports, including the anchor bolts, and block wall to meet the design loads. The evaluation must describe how the allowable loads on anchor bolts in concrete block walls were determined and also what analytical method was used to determine the integrity of the block walls under the imposed loads. Also describe the acceptance criteria, including the numerical values, used to perform this evaluation. Review the deficiencies identified in the Information Notice of the pipe supports and walls at Trojan to determine if a similar situation exists at your facility with regard to supports using anchor bolts in concrete block walls.

d. Describe the results of testing of anchor bolts in concrete block walls and your plans and schedule for any further action.

Response to Bulletin Action Item No. 5. A field walkdown of all Turkey Point Unit 3 & 4 concrete block walls has been completed to determine the extent to which expansion bolts were used to attach piping supports for Seismic Category I systems. Results of this walkdown verified that no expansion bolts were used to support any Category I system piping off block walls.

Bulletin Action Item No. 6. Determine the extent that pipe supports with expansion anchor bolts used structural steel shapes instead of base plates. The systems and lines reviewed must be consistent with the criteria defined in Revision 1 of the Bulletin. If expansion anchor bolts were used as described above, verify that the anchor bolt and structural steel shapes in these supports were included in the actions performed for the Bulletin. If these supports cannot be verified to have been included in the Bulletin actions:

a. Provide a list of the systems involved, with the number of supports, type of anchor bolt, line size, and whether the supports are accessible during normal plant operation.

b. Provide a detailed evaluation of the adequacy of the anchor bolt design and installation. The evaluation should address the assumed distribution of loads on the anchor bolts. The evaluation can be based on the results of previous anchor bolt testing and/or analysis which substantiates operability of the affected system.

c. Describe your plans and schedule for any further action necessary to assure the affected systems meet Technical Specifications operability requirements in the event of an SSE.

Response to Bulletin Action Item No. 6. Structural steel shapes were used to a minor extent instead of base plates for pipe supports with expansion anchor bolts. The anchor bolts and structural steel shapes in these supports were included in the actions performed under Revision 1 of the Bulletin. For analytical methods used, refer to Part b this report's response to Bulletin Action Item No. 1.

III. SUMMARY OF REMAINING INSPECTIONS

As noted in the Introduction to this report, some supports with expansion anchors have been identified as requiring further inspection or evaluation as a result of a previous audit conducted by the NRC. A summary of these supports is provided below:

1. A total of 135 supports on Turkey Point Unit 3 were identified as requiring inspection based on a comparison in the scope of inspections previously performed with the scope of Seismic Category I systems defined under I.E. Bulletin 79-14. A total of 26 supports on Seismic Category I systems shared by Turkey Point Units 3 and 4 were identified as requiring inspection based on a similar comparison in scope.

2. A total of 234 supports on Turkey Point Unit 4 were identified as requiring further inspection based on a review of previous inspection documentation for these supports.

The expansion anchors for these remaining supports will be evaluated and reported as an integral part of the in-progress work under I.E. Bulletin 79-14. This approach is justified based on the following reasons:

1. The Seismic Category I systems associated with these supports have been designed for Safe Shutdown Earthquake loads equivalent to three times the Operating Basis Earthquake. Current state of the art indicates that loads based upon two times the Operating Basis Earthquake would be conservative. In addition, the probability of a seismic event is considered remote since the Turkey Point site is located within Zone 1 on the Seismic Probability Map specified by ANSI A58.1, 1972.

2. The occurrence of a seismic event would only require 25 percent of the anchorage capacity of the bolts in the remaining supports.

3. The I.E. Bulletin 79-14 program currently includes evaluation of all seismic Category I large bore and dynamically analyzed small bore piping supports and associated expansion anchor bolts based upon as-built conditions. This program provides for inspection, evaluation or repair of the expansion anchors based on final verified loads.

EXHIBIT 1

TURKEY POINT UNITS 3 AND 4 - SYSTEMS COVERED BY SURVEILLANCE PROGRAM
IN RESPONSE TO NRC IE BULLETIN 79-02, MARCH 8, 1979,
REVISION 1, JUNE 21, 1979 and REVISION 2, NOVEMBER 8, 1979.

1. Reactor Coolant System
2. Residual Heat Removal/Low Head Safety Injection System
3. Containment Spray System
4. High Head Safety Injection System
5. Chemical and Volume Control System
6. Post-Accident Containment Vent System
7. Main Steam System
8. Auxiliary Feed Water System
9. Feedwater System
10. Component Cooling Water System
11. Intake Cooling Water System
12. Diesel Generator Fuel Oil System
13. Containment Isolation System