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Alabama Power
the southern electric system

August 5, 1979

Docket No. 50-348
IE Bulletin 79-02

Mr. James P. O'Reilly
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, N. W.
Suite 3100
Atlanta, Georgia 30303

Dear Sir:

Enclosed is the revised response to IE Bulletin 79-02 concerning pipe support base plate designs using concrete expansion anchor bolts. The specific responses to the bulletin are enclosed.

Yours very truly,

F. L. Clayton, Jr.

F. L. Clayton, Jr.

FLCjr/KAP/mmb
Enclosure
cc: Messrs. R. A. Thomas
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I&E Reactor Operations
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Response to Item 1:
Originally, flexibility of the base plate was not specifically taken into account in determining the concrete anchor bolt loads. Alabama Power Company is in the process of performing a design review that takes base plate flexibility into account in determining the concrete anchor bolt loads. This design review is described below.

Grinnell, Southern Company Services, Inc. (SCS) and Bechtel Power Corporation (as appropriate) are utilizing the calculated Westinghouse/Bechtel piping system hanger/seismic restraint design loads and the ICES STRUDL Program to develop design loading conditions (forces and moments) at the centroid of each attachment to the hanger/seismic restraint base plates. For simple cases the forces and moments are obtained by hand calculations. Bechtel then utilizes this information in conjunction with the inspection and test data for analyses of all base plate anchor bolts to determine if the existing base plate anchorage is adequate to meet the design loads with the prescribed safety factor or if corrective action is necessary. This determination is performed in accordance with FNP-1-ETP-123 (a Farley Nuclear Plant Engineering Technical Procedure) which has been reviewed by NRC, I&E Region II Staff.

More specifically, a summary of the evaluation of base plate design by Bechtel is as follows:

1. The method of analysis is based on an empirical-analytic technique developed by Bechtel which takes into account design parameters such as flexibility of the base plate and concrete anchor stiffness (based on actual pre-loaded load-displacement curves furnished by the manufacturer). This method has been verified with appropriate finite element analytical solutions. Description of this empirical-analytic technique is provided in Attachment I.

   A computer program for the empirical-analytical technique has been implemented for determining the anchor bolt loads for the majority of applications. For other cases refer to Item 3 below. This 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 safety factor.

   The program computes the forces on the bolt and calculates a shear-tension interaction based on allowable loads. An interaction value greater than the allowable is accepted as failure of the bolt (safety factor less than required). Unit 1 shear-tension interactions analyses are computed utilizing a linear relation. Even though a subsequent squared interaction formula is acceptable and its use has been justified by Bechtel in representing the shear-tension interaction, Alabama Power has chosen to continue with the use of linear relationship recognizing that the results from this technique are more conservative.

The empirical-analytic method does not consider prying action for the following reasons:

a. 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 on the cone and would not affect the anchorage capacity.

b. 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 extensions will be such that the corners of the base plate will separate from the concrete and the prying action will be relieved. This phenomena has been found to occur even when the bolt stiffnesses in the finite element analysis were varied from a high to a low value corresponding to both typical initial stiffnesses and to values beyond the allowable design load.

2. Calculated bolt loads are used to check stresses in the support base plate to ensure they are less than the allowable stress as specified by the American Institute of Steel Construction (AISC) code.

3. For special cases where the design of the support plate does not lend itself to this method, standard engineering analytical techniques with conservative assumptions are being employed.

All anchor bolts within the scope of this program are being evaluated by Bechtel in accordance with the bolt acceptance criteria, "as built" drawings reflecting the existing plant conditions, and the bolt design loads to determine if corrective action is required.

If any bolt on a base plate fails the Bechtel evaluation as described in FNP-1-ETP-123, one or more of the following actions are being taken:

a. Re-analyze the base plate assuming that the bolt is failed (bolts carries zero load).

b. Re-analyze the base plate incorporating bolt replacement as corrective action.

c. In those instances where repair corrective actions result in a piping support modification, Bechtel Westinghouse (as appropriate) will analyze the effect of such modifications on the analysis of the piping system.

Response to Item 2:

In the original design of Unit 1 at Farley Nuclear Plant a factor of safety of four was used for wedge type and shell type anchor bolts. Because of this (the original design factor of safety of four), the current verification program (described in the response to Item 4) requires the existing anchor bolts to withstand a load equivalent to 1/4 of the manufacturer's published pullout load. The original design factor of safety of four is consistent with the current industry design practices. In general, the current industry approach concerning the use of safety factors for various design loading conditions are described below. This information is provided as additional support for the factor of safety used in our evaluation/repair program.

1. Factors of safety (i.e. ratio of bolt ultimate capacity to design load) of four for wedge type and shell type anchor bolts, for service (operating) load cases, are used.

2. For factored loadings (which include accident/extreme environmental loads) safety factors of 1.2 and 3.0 are used commensurate with the provisions of Section B.7.2 of the Proposed Addition to Code Requirements for Nuclear Safety Related Concrete Structures (ACI-349-76) August, 1978. The factors of safety are consistent with the ultimate strength design method. A factor of safety of 1.2 is used if the failure mechanism for the anchor is controlled by the bolt material. If the failure mechanism is controlled by concrete shear cone action, a factor of safety of 3.0 is used. The utilization of sampling and quality control methods used are integral to selecting the factor of safety of 3.0.

3. For general structural design in steel, the AISC Specification has an approximate factor of safety of 1.7 for services loading (for example, a column buckling). For factored accident/extreme environmental loads, a factor of safety of 1.1 is used on nuclear structures for both ductile (yielding) and non-ductile (column buckling) failures. In concrete design for factored loads, a factor of safety of 1.1 is used for flexural and tension action and 1.2 for shear action. It can be observed that a higher factor of safety is assigned to the expansion anchor only if its capacity is governed by the shear cone.

Based on the above interaction of design parameters and on the following additional factors, Alabama Power Company has concluded that a safety factor of 2 is sufficient to ensure operability of Seismic Category I piping system in the event of a seismic event:

a. 100% verification testing program with total Quality Control coverage of scoped systems (described in question 4) which minimizes installation uncertainties (e.g. verification of torque, embedment depth, nut engagement, plate configuration, expansion of shell, etc.) which were allowed for in the original design by the factor of safety of four.

b. Verification that plates are not overstressed by bolt loadings (e.g. consideration of minimum edge distance and proper bolt spacing).

Response to Item 3:
In the original design of the piping systems Bechtel/Westinghouse considered deadweight, thermal stresses, seismic loads, and dynamic loads (e.g. certain rapid valve openings and closings) in the generation of the static equivalent pipe support design loads.

The safety factors used for concrete expansion anchors, installed on supports for safety related piping systems, were not increased for loads which are cyslic in nature. The use of the same safety factor for cyclic and static loads is based on the Fast Flux Test Facility (FFTF) Tests*. The test results indicate:

1. 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 steadily increased 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.

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

* Drilled - In Expansion Bolts Under Static and Alternating Loads, Report No. BR-5853-C-4, Rev. 1, by Bechtel Power Corporation, October 1976.

Response to Item 4:
Since existing Q.C. documentation is not adequate to document the installation parameters associated with each anchor bolt, the following programs have been undertaken:

Test Program
Alabama Power Company initiated a program to randomly select and test a sample of anchor bolts installed in Seismic Category I, Safety Related, 2-1/2 inch and greater piping systems. Initial results of that program revealed that statistical sampling would not be sufficient to provide a 95% confidence level in anchor bolt reliability. As a result, the anchor bolt testing program was expanded to include 100% verification of anchorages associated with pipe hangers for those systems or portions of systems required to meet design basis accidents and those required to bring the plant to cold shutdown condition. These piping systems included in the program are:

a. Seismic Category I; Safety Related 2-1/2 inches and above.

b. Seismic Category I; Safety Related ASME Section III, Class 1 piping, under 2-1/2 inch.

c. Seismic Category I; Safety Related of other classes for which the designer performed detailed analysis.

d. All piping through containment penetrations.

The scope of this program given above has been reviewed and approved by the NRC I&E Region II Staff.

The specific systems involved in this testing program are listed in LER 79-21/01T.

Anchor bolts on hangers within the scope of this program are tested for the following parameters:

a. embedment - Actual embedment depth is determined.

b. grout - The presence of grout and leveling nuts is determined to ensure proper torque test.

c. type of bolts - Verification is made that installed bolts are in accordance with design bill of material.

d. number of bolts - Verification is made that the installed number of bolts is in accordance with design bill of material.

e. bolt dimensional measurements - Dimensional measurements are taken to determine the degree of compliance with the manufacturers' recommended bolt installation requirements.

f. torque - Bolts are torqued to a level such that the resultant tensile load on the anchor is equal to 1/4 of the manufacturers' published pull-out load. For shell type bolt torque tests to be considered valid, the shell shoulder must not touch the base plate.

NOTE: A torque/tension relationship was developed for Hilti wedge type anchors based on tests performed at Farley. Torque/tension relationships were developed for Phillips shell type anchors under the direction of Bechtel Corporation with technical consultation from ITT-Phillips Drill Division at Plant Hatch. Since these relationships were completed and the majority of anchor bolt field verification was performed prior to I&E Bulletin 79-02 Revision 1 issuance no site specific testing for the shell type anchors was performed. Torque requirements for Wej-it wedge type anchors were obtained from vendor data.

g. base plate dimensional measurements - Dimensional measurements of base plate parameters which could affect bolt loading or capacity (e.g. bolt spacing, edge distance) are taken.

Based on the results of the test program and the empirical-analytic evaluation, anchors are being repaired according to the following criteria:

i. Repair individual base plate anchorages not having a safety factor of at least 2.0.

ii. Repairs are done so that all repaired bolts have a safety factor of at least 4.0 and all base plate anchorages have a safety factor of at least 2.0.

iii. All repairs are done in accordance with written procedures and quality control checks.

The failure to test inaccessible anchor bolts will be justified by analysis which substantiates operability of the affected systems without assuming integrity of the anchorages which are not tested.

Preloading

Even though Alabama Power is preloading all anchor bolts to the design load, available test data indicates that it is not necessary that the bolt preload should be equal to or greater than the bolt design load because pipe supports and anchors are subjected to both static and dynamic loads. The dynamic loads such as the seismic loads are short duration cyclic loads and are not fatigue type loads, therefore, the amount of preload on the bolts will not greatly affect the performance of the anchorage. The initial installation torque on the bolt accomplishes the purpose of setting the anchor, but the ultimate capacity of the bolt is not affected by the amount of preload present in the bolt at the time of cyclic loading. For vibratory loads, the expansion anchors have successfully withstood long term fatigue conditions as discussed in the previous section (FFTF tests).

Response to Item 5:
The Alabama Power Company testing, analysis and repair program will not be completed by July 6, 1979; however, Farley Nuclear Plant Unit 1 is currently shutdown during the present critical power demand period to complete the above program. The testing, analysis and repair program described in Items 1 and 4 will be completed prior to return to power generation.

Response to Item 6:
A program for the verification of Unit 2 anchorages, similar to that of Unit 1, will be developed incorporating the experience gained from the Unit 1 activities. A full and detailed description of the Unit 2 program will be transmitted to the NRC by a supplement to this bulletin response. Currently, the construction activities associated with Unit 2 are temporarily suspended due to the Company's financial condition. The verification program for Unit 2 anchorages will be completed prior to the initial criticality of the unit.