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July 20, 1979

Mr. Boyce H. Grier, Director
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Region 1
631 Park Avenue
King of Prussia, Pennsylvania 19406

Dear Mr. Grier:

NRC IE BULLETIN NO. 79-02 (REV. 1)
PIPE SUPPORT BASE PLATE DESIGNS USING CONCRETE
EXPANSION ANCHOR BOLTS
NO. 1 AND 2 UNITS
HOPE CREEK GENERATING STATION

On July 3, 1979 we submitted a preliminary response to IE Bulletin No. 79-02 (Revision No. 1). Bechtel Power Corporation has completed its evaluation of the subject bulletin and PSE&G offers the information in the attached enclosure as a complete response to the concerns raised in NRC IE Bulletin 79-02, and Revision No. 1.

Should additional information be desired, we will be pleased to further discuss it with you.

Sincerely,

T J Martin

Attach.

CC: Office of Inspection and Enforcement
Division of Reactor Construction Inspection
Washington, D. C.

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REPLY TO NRC IE BULLETIN 79-02

Response To Item 1:

All pipe anchor and support base plates using expansion anchor bolts will be analyzed 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 will be used to determine the bolt forces:

a. A quasi-analytical method, developed by Bechtel Power Corporation, is used for base plates with eight bolts or less. For these types of base plates, an analytical formulation has been developed 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 on the results of a number of representative finite element analyses of base plates (using the ANSYS Code), certain empirical factors are introduced in the simplified beam model to account for the effect of the concrete foundation and the two-way action of load transfer in a plate. These factors essentially provided a way for introducing the interaction effect of such parametric variables as plate dimensions, attachment size, bolt spacings, and stiffnesses on the distribution of external loads to the bolts.

   The results of a number of case studies indicate excellent correlation between the results of the present formulation and those obtained by the finite element method (using the ANSYS Code). The quasi-analytical method generally gives bolt loads that are greater than calculated by the finite element method.

   Although the effect of plate flexibility has been explicitly considered 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. When 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 expansion 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.

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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 in the following manner:

1. Where the applied shear force is less than the frictional force developed in the shear plane between the steel and the concrete surface for balancing the imposed loads, no additional provisions are required for shear.

2. Otherwise, the total applied shear is required to be carried by the bolts in accordance with the following interaction formula.

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

   Where T and S are the calculated tensile and shear forces and TA and SA are the respective allowable values.

b. For special cases where the design of the support does not lend itself to the foregoing method, the finite element method using the ANSYS Code and/or other standard engineering analytical techniques with conservative assumptions will be employed in the analysis. To date it has not been necessary to use this technique on pipe support base plates designed for Hope Creek Generating Station.

c. Other cases may be solved using an approach based on the strength design method given in the ACI 318 Code. To date it has not been necessary to use this technique on pipe support base plates designed for Hope Creek Generating Station.

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Response To Item 2:

The required minimum factor of safety between the bolt design, load and the bolt ultimate capacity, determined from static load tests which simulate the actual conditions of installation (i.e., type of concrete and its strength properties) will be as follows:

a. Four for wedge and sleeve type anchor bolts.

   When extreme environmental loads are included, a factor of safety of three is acceptable in accordance with Section B.7.2 of the Proposed Addition to Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76) August 1978. Where an effective program of 100% verification of acceptable anchor bolts had been implemented, a safety factor of two is considered satisfactory with extreme environmental loads.

Hope Creek will not use shell type anchor bolts for pipe supports.

Response To Item 3:

In the original design of the piping systems Bechtel considers deadweight, thermal stresses, seismic loads, and dynamic loads in the generation of the pipe support design loads. To the extent that these loads include cyclic considerations, these effects would be 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, are not increased for loads which are cyclic in nature. The use of the same safety factor for cyclic and static loads is based on Bechtel's Fast Flux Test Facility (FFTF) Test.

(Drilled-in Expansion Bolts Under Static and Alternating Loads. Report No. BR-5853-C-4 by Bechtel Power Corporation, January 1975.) 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 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.

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

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Response To Item 4:

All concrete expansion anchors are installed and verified per detailed specifications which provide adequate inspection and testing procedures and also adequate acceptance criteria.

It is not necessary that the bolt preload be equal to or greater than the bolt design load. Pipe supports and anchors are subjected to static and dynamic loads. The dynamic loads are seismic loads which are short duration cyclic loads. This type of cyclic load is not a fatigue load, so the amount of preload on the bolts will not greatly affect the performance of the anchorage. In addition, preload is lost over the life of the plant due to creep and other similar phenomena. Therefore, if the initial installation torque on the bolt accomplishes the purpose of setting the wedge, 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 during plant operation, the expansion anchors have successfully withstood long-term fatigue environments as discussed in the previous section.

The procedures described in these specifications require all expansion anchors to be visually inspected for proper installation. The proper documentation, indicating the location of the expansion anchor and group represented, method of test (torque or tension), test results, type of failure when applicable, and date of test along with name and signature of the inspector, is maintained at the jobsite.

Response To Item 5:

This action item applies only to plants with an operating license.

Response To Item 6:

Each seismic expansion anchor installation in seismic Category I systems will be under surveillance of the field QC program. The documentation required by the technical specification and a quality control inspection record will be filed for each application. The inspection record will be kept at the site in the records vault and will be available for NRC review at any time.

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