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# BALTIMORE GAS AND ELECTRIC COMPANY

GAS AND ELECTRIC BUILDING

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SUPPLY

July 6, 1979

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

Subject: Calvert Cliffs Nuclear Power Plant
Units Nos. 1 and 2
Docket Nos. 50-317 and 50-318
IE Bulletin No. 79-02
Concrete Expansion Anchor Bolts

Dear Mr. Grier:

Your Bulletin No. 79-02 dated March 8, 1979 and Revision 1 dated June 21, 1979 required a written report within 120 days as to our status of compliance with Items 1, 2, 3, and 4 of that bulletin. Accordingly, the following summarizes our status as of this date, and is in addition to our interim report letter of June 11, 1979.

Action Item 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. If the base plate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis which will account for the effects of shear-tension interaction, minimum edge distance and proper bolt spacing. This is to be done prior to testing of anchor bolts. These calculated bolt loads are referred to hereafter as the bolt design loads.

Response

For the current design review, all pipe anchor and support base plates using expansion anchor bolts for larger than 2" diameter pipes are being analyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance and proper bolt spacing. Depending upon the complexity of the individual base plate configuration one of the following methods of analysis was used to determine the bolt forces:

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(i) A quasi analytical method, developed by our Architect/ Engineer, Bechtel Power Corporation, was used for base plates with eight bolts or less. A review of the typical base plates used in supporting the subject piping systems indicate that the majority of them were anchored either by 4, 6 or 8 bolts. The plate thickness usually varied from 1/2" to 2" and are not generally stiffened. 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 the results of a number of representative finite element analyses (FEM) 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 (b) 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 siz 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 larger bolt loads in comparison to the FEM.

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:

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 in the cone and would not, therefore, 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 extension will be such that the corners of the base plate will lift off and the prying action will be relieved. This phenomena 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 (BOLTS) 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 equations:

$$\left(\frac{t}{T_A}\right)^{5/3} + \left(\frac{s}{S_A}\right)^{5/3} \leq 1.0$$

$$\frac{t}{T_A} + \frac{s}{S_A} \leq 1.0$$

Where t and s are the calculated tensile and shear forces and $T_A$ and $S_A$ are the respective allowable values.

However, the circular interaction equation is also considered to be adequate.

(ii) For special cases where the design of the support didn't lend itself to the foregoing method, other standard engineering analytical techniques with conservative assumptions were employed in the analysis.

Action Item 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.

Response

In the current design review, factors of safety (i.e., ratio of bolt ultimate capacity to design load) of four for wedge type and five for shell type anchor bolts were used.

For factored loads, however, a safety factor of three is considered adequate in agreement with provisions of Section B.7.2 of the "Proposed Addition to Code Requirements for Nuclear Safety Related Concrete Structures" (ACI 349-76) August, 1978.

Action Item 3

Describe the design requirements if applicable for anchor bolts to withstand cyclic loads (e.g., seismic loads and high cycle operating loads).

Response

In the original design of the piping systems our Architect/Engineer considered deadweight, thermal stresses, cyclic vibration, seismic loads, and dynamic loads (including water hammer in the feedwater and main steam systems) in the generation of the static equivalent 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, 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 Fast Flux Test Facility, FFTF, Tests*. The test results indicate:

1. The expansion anchors successfully withstood two million cycles of long term fatique 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.

Action Item 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.

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

(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. 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.

Response

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, then 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 environment as discussed in the previous section.

As described in our letter of June 11, 1979, we conducted an inspection and test program for Unit No. 1 that was designed to assure that the concrete expansion anchors for safety related, 2½" and larger pipe supports were installed as required by the design drawings and would function as required under both static and cyclic loads. The program consisted of a verification phase, a test, phase, an evaluation phase and, finally, a repair phase.

The verification phase was implemented by plant personnel walking each safety related pipe line and comparing the design hanger sketches with the as-built condition. Any discrepancies as to configuration, location, number of bolts, etc. were noted and returned to our Architect/Engineer for reanalysis.

Working closely behind our verification crews were test crews comprised of pipe fitters and a quality control inspector. Each crew was thoroughly trained in our test procedures by our plant personnel prior to participation in the program. The test crew's responsibilities consisted of dimensional checks of the bolt extension and diameter, etc. Tables were provided that listed the required torque values for each different bolt diameter. As these torque loads were applied to each bolt, the quality control crew member noted on a data sheet a pass or fail status. For shell type bolts,

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shims and feeler gages were utilized to insure no contact with the back of the plate. Any hanger which contained one or more bolt failures was designated as requiring evaluation and was forwarded to our Architect/Engineer to determine if the entire support was inadequate or if the support could still function as designed without credit for those bolts which had failed the torque test. In addition to the test crews, we utilized trained personnel from our Metallurgical Laboratory to perform ultrasonic inspections of all the wedge type bolts to insure that the actual embedment depths were in accordance with the design drawings. Any bolt which was found to be embedded less than the design requirement was noted and sent to our Architect/Engineer for evaluation of the entire support. Minimum thread engagement or thread extension and perpendicularity were also checked for each bolt type as additional acceptance criteria.

The next phase of the program consisted of evaluation of the test results for those hangers that had been designated as requiring further evaluation. This was performed by our Architect/Engineer and resulted in the issuance of a Drawing Change Notice for every support that required evaluation. These change notices instructed our repair crews to make the necessary repairs in the case of an inadequate support or to leave the support as is in the case of a support which could function without the bolts which had failed one or more of our acceptance criteria.

In order to validate that the test torque loads which we utilized were equal to or greater than the design loads for each bolt, a test program was conducted by an independent testing agency. This program consisted of installing a minimum of four bolts of each type and diameter utilized in the plant within the concrete slab covering our intake structure. This site was chosen because the mix design, aggregate, type of cement, etc. was the same as that utilized in our Auxiliary Building where the majority of the anchors are installed. The object of the test program was to develop curves of torque versus tension for each of the different manufacturer's bolt diameters utilizing minimum embedment depths. It should be noted, however, that our test torque values were based on manufacturer's ultimate divided by the appropriate safety factor of four or five and then multiplied by the factor 1.15. As our actual design loads are in most cases considerably below the allowable loads, our torque loads produced preloads considerably in excess of that which the bolt would encounter in the worst loading condition. This preload, substantiated by actual field testing will provide adequate assurance that the bolt is properly seated. Documentation of this test effort as our entire program effort is available for inspection at the plant site.

Summary of Results and Schedule of Outstanding Items

To date, our overall status for Unit No. 1 large pipe hangers is as follows:

| | | |
|---|---|---|
| Safety Related Hangers | - | 1090 |
| Hangers analyzed | - | 1090 |
| Hangers verified and tested | - | 1077 |
| Hangers requiring repairs | - | 526 |
| Hangers repaired | - | 400 |

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As you are aware, our Unit No. 1 is presently shut down for refueling. Prior to return to full power operation on or about July 11, 1979, we will have repaired all large pipe supports within the containment and other areas outside the containment which would not be easily accessible during operation. It is anticipated that there will be a small number of other hangers remaining to be repaired. However, all such supports will be those which have demonstrated their required load carrying capability by successfully passing our torque testing program, but required repair due to some other criterion such as thread engagement or minimum embedment. As these criteria relate to additional load carrying capability beyond that which is ever hypothesized to occur, system operability is not impaired. These remaining supports will be repaired expeditiously.

Our Unit No. 2 hanger analysis program is underway and as our Unit No. 1 verification, test and repair crews become available, they will be moved on to the Unit No. 2 program. As Unit No. 2 is now operating, we will not be able to utilize as large a manpower effort due to the safety considerations of limited work spaces in an operating plant. Our plan is to test 100% of the Unit No. 2 large pipe hangers and to immediately repair those supports which cannot demonstrate the required load carrying capacity by torque or direct tension testing. Those supports which are found to violate other criteria but can still carry the required load will be noted as requiring further evaluation. If these supports are found to require repair in order to maintain a reasonable factor of safety, they will be scheduled for repair during our planned outage in October - November of this year.

Our experience in Unit No. 1 resulted in an overall failure rate of approximately 32% for the Hilti type concrete expansion anchor supports. Approximately 3% of the Hilti supports failed due to torque test limitations. The remaining Hilti failures were primarily due to minimum embedment or thread engagement criteria. As approximately 90% of the large pipe supports in Unit No. 2 are installed with the Hilti type concrete expansion anchor, we feel confident that system operability is not impaired.

All Safety Related pipe supports for piping 2" and under were designed by a "chart" or "standardized" method by our Architect/Engineer. The only computer analysis utilized wasfor support locations. The standard design documents utilized, WO-30, have a high degree of conservatism. A comparison to a computer analysis method (ME-101) showed a factor of four in conservatism. As the resulting bolt loads are small (200-400#), a torque testing program is not considered necessary. However, in order to assure that the supports were installed as required by the design, an inspection program of a statistical sample will be conducted and the results reported upon completion.

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Our schedule for the remaining effort is as follows:

| Activity | Start | Completion |
|---|---|---|
| Unit No. 2 | | |
| Large Pipe Hanger Analysis | June, 1979 | September, 1979 |
| Large Pipe Hanger Verification and Testing | July, 1979 | October, 1979 |
| Large Pipe Hanger Repair | July, 1979 | November, 1979 |
| Small Pipe Hanger Verification | October, 1979 | November, 1979 |
| Unit No. 1 | | |
| Small Pipe Hanger Verification* | November, 1979 | July, 1980 |

*The July, 1980 completion date anticipated and therefore makes allowance, that a portion of the statistical sample may be inside the containment or within high radiation areas outside the containment.

Very truly yours,

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