SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

COMMONWEALTH EDISON COMPANY

DRESDEN STATION UNITS 2 AND 3

QUAD CITIES STATION UNITS 1 AND 2

DOCKET NOS. 50-237/249 AND 50-254/265

I. INTRODUCTION

On February 2, 1987, while performing piping system hanger and support inspections in accordance with the In-Service Inspection (ISI) Program Commonwealth Edison (CECo) personnel discovered that the embedment plate for support M1150D-62 was pulled away from the ceiling approximately 1/8 to 1/4 inch along one surface.

Investigation into the degraded embedment plate revealed a discrepancy between the shop drawing used for its fabrication and the design specifications. Although the design specified 9-inch hold down strap spacings, the shop drawing indicated 18-inch hold down strap spacings. The 18-inch spacings were confirmed on the degraded embedment plates by performing ultrasonic (UT) tests. Further UT tests performed on other embedment plates also revealed the existence of some 24-inch hold down strap spacings.

On April 16, 1987, a meeting was held in Bethesda, Maryland between the NRC staff and CECo, whereby CECo presented their assessment of the problem and the corrective actions that have been taken to resolve the issue.

As a result of the disclosed discrepancy between the design and the installed strap spacing, a further investigation of embedment plates on all related piping installations at Dresden, Units 2 and 3, was initiated by the licensee. Since the same contractors were engaged in design and installation of embedment plates at Quad Cities, Units 1 and 2, a similar program was also initiated of these plants as well.

CECo proposed a two-fold type of review program. The first part used interim acceptance limits - with an upper limit to ascertain that plant operation under as-found conditions does not present a safety hazard to the public. And the second part, a long term program to conduct modifications as needed, such that all embedment plates are confirmed to meet Final Safety Analysis Report (FSAR) stress allowables.

After an initial meeting of April 16, 1987, the staff embarked on a thorough review of the licensee's investigation into the adequacy of embedment plates and strap anchors. This review included meetings with the licensee, a visit to the Dresden plant, and several telephone conferences.

The licensee's effort culminated in the issuance of a "Summary Report on Assessment of Embedment Plates," dated October 16, 1987, (Reference 1). This report states that out of 1100 embedment plates at Dresden, and 1200 at Quad Cities, only three plates at each plant required modifications to satisfy plant FSAR allowable stress commitments. In spite of the discrepancies between design and fabrication of the embedment plates, anchor spacing for all embedment plates met operability criteria (the upper limit) stresses. The following is the staff's evaluation of this report and of the licensee's assessment of embedment plate adequacy.

II. DISCUSSION AND EVALUATION

The program proposed by the licensee consisted of a systematic evaluation of all embedment plates with staggered anchors where a potential discrepancy existed between design drawing and shop drawings regarding the strap anchor spacing at Dresden Station, Units 2 and 3, and the Quad Cities Station, Units 1 and 2. The licensee included in this program all safety and non-safety related large bore (greater than 4-inch diameter) pipe hanger and control rod drive (CRD) piping hanger attachments. Conduits, cable tray, HVAC and small bore piping attachments were generally not included because they were verified to be too light to have any effect on embedded plates. However, they were included when they were in close proximity to large bore support attachments which required a field review.

Program review criteria used by the licensee consisted of two sets of allowable loads:

1) Nominal load allowable stresses in accordance with the FSAR requirements were used as the final acceptance criteria, and

2) Upper limit load allowable stresses were developed as operability criteria to assure the functional integrity of the embedment plates should they be subjected to their design basis loading during the assessment program.

Acceptance criteria in accordance with the FSAR were based on the allowable nominal stresses consistent with the American Institute of Steel Construction (AISC) and the SRP requirements. Additionally, a finite element method (FEM) analysis was performed to determine the overall behavior of the embedment plates. The FEM analysis utilized compression springs for concrete and tension springs for strap anchors. The overall plate displacement limit of 0.25 inch for SSE loading has been imposed.

Upper limit criteria were established by plotting load-deflection curves obtained by the finite element method analysis. Two criteria were applied in establishing the limit allowable stress:

a) Strain limit of ten times yield strain was imposed for local extreme fiber strains at stress concentration points, and

b) Maximum plate deflection of 0.3 inch was used at the hanger attachment point.

The nominal stresses of the embedment plate in bending were set at 0.95Mp, where Mp is the plastic section modules times the yield stress of the plate material.

NRC staff found these criteria to be acceptable since they were in effect for a limited time only and they correspond to the requirements of the Standard Review Plan (SRP) for the factored load condition.

The licensee's formal assessment program consisted of the following aspects:

A. Screening - The locations of pipe hangers were plotted on plant drawings together with the embedment plates from data collected by CECo consultants who had previously performed the piping analysis. Allowable loads for Operating Basis Earthquake (OBE), Safe Shutdown Earthquake (SSE), and the upper limit were developed based on the FSAR criteria for OBE and SSE and criteria approved by the staff on an interim basis during the program for the upper limit. Attachment loads were compared with the allowable loads; as a result of this comparison embedment plates were divided into two categories:

1) Those which were found to be within the FSAR allowable loads and hence no further action was required, and

2) Those whose attachment loads exceeded the FSAR allowable loads and further investigation was necessary. This group was further subdivided as follows:

a) Pipe hangers for which the attachments loads were found to be greater than upper limit allowable loads, and

b) Pipe hangers for which the attachment loads were less than upper limit allowable loads but greater than FSAR allowable loads.

B. Plant Walkdowns - In order to obtain more exact information regarding the plates, such as location, size, etc., the licensee performed a walkdown of pipe hangers whose load demands exceeded the FSAR or upper limit allowable loads. On the basis of information obtained during the walkdown, supports were further examined to determine attachment size, attachment location relative to straps in the embedment plates, and location across the embedment width. When supports could not be qualified based on visual inspection, ultrasonic testing was performed to determine the exact strap anchor location with respect to the attachments.

The licensee reported that some embedment plates at Dresden and Quad Cities were inaccessible for walkdown. This was addressed in Reference 2. In Reference 3, the NRC inspector concluded that for the Dresden plant, due to a lack of significant problems as well as the justification provided in CECo's summary report, no further work is required to close this issue.

Inaccessibility of the embedment plates at the Quad Cities plant will be resolved following NRC inspection at that facility in the future. Review and evaluation of this item is not included in this SER.

C. Analysis and Evaluation

Acceptance criteria for embedment plates were in conformance with the FSAR requirements. They also satisfied the requirements of the AISC and the Standard Review Plan (SRP). The following is a summary of the licensee's analyses and the bases for acceptance of their results:

1. The licensee provided the results of tests on flat bar anchor, 1/4 inch and 3/8-inch thick and 2-inch wide. Anchors used at subject stations were 5/16-inch by 2.0-inch bars, and based on interpolation from the test results it has been agreed that ultimate loads on the anchors will be about 35.7 kips.

2. As indicated previously, the limiting displacement of the plate had been set as 0.25 inch for the FSAR Requirements and 0.3 inch for the Upper Limit Criteria.

3. Capacity of plates have been analyzed using ADINA and APLAN computer programs to develop the allowable plate stress. The ADINA program sets the acceptable strain and the APLAN program calculates the stresses corresponding to the strain established by the ADINA. The ADINA computer program is a program in public domain and does not need further verification. The APLAN program is the program developed by the Sargent & Lundy Engineers and has been verified against the ADINA. Allowable loads were calculated using the finite element method. From computer analysis, allowable loads (direct tension) and allowable moments (about two orthgonal axes) were determined. These loads and moments were combined in the interaction equations using a straight line relationship.

4. The licensee performed an analysis, using yield line theory, for tension loads applied to an exterior and interior regions of an embedment plate. Using the allowable loads determined by yield line theory, the nominal stresses corresponding to the Safe Shutdown Earthquake (SSE) have been calculated. In the yield line analysis, various plastic yield line patterns have been assumed and the collapse load calculated for each. The optimum yield line pattern corresponding to the smallest capacity has been determined as the controlling yield line pattern capacity.

Additionally, the licensee performed calculations comparing the tested strap anchor configuration at the Dresden/Quad Cities plants.

5. The licensee calculated the SSE allowable strap tension for the Dresden/Quad Cities strap anchors. The calculated strap tension of 18.1 kips was based on the appropriate criteria, such as those of the Final Safety Analysis Report (FSAR), American Institute of Steel Construction (AISC) and Standard Review Plan, NUREG-0800 (SRP). The 18.1 kips value which is about half of the available pullout load of 35.7 kips for the tested anchor straps, has been established on the basis of the criteria provided by the licensee and approved by the staff and by calculations presented by the licensee whereby the following modes of failure been considered:

   a) weld capacity
   b) anchor capacity
   c) bond and bearing capacity, and
   d) concrete cone pullout capacity

6. In their discussion of the Upper Limit Criteria (interim criteria which require that the embedment plate will maintain its functional integrity if subjected to its design basis loading), the licensee referred to AISC Specification for Design, Fabrication and Erection of Safety-Related Steel Structures for Nuclear Facilities (undated) and the AISC Load and Resistance Factor Design Specification for Structural Steel Buildings (undated). It should be pointed out that both of these documents are not accepted by the staff and the licensee's criteria have been evaluated independently by the staff.

7. During the licensee's investigation, it has been determined that some of the anchor straps are located at 24 inches apart. The licensee determined that the plates with 24-inch spacing are limited to the Dresden plant, Unit 2 Reactor Building at Elevation 517'-6". Ultrasonic testing disclosed a total of 12 plates and strap anchor spacing of 24 inches. For these plates the allowable loads of 10.8 kips for the Upper Limit Criteria and 9.0 kips for the SSE have been determined using the same methodology and criteria as for the plates with 18-inch spacings. These values give the respective factors of safety of 3.3 and 3.9 when compared with the capacity of anchors obtained by the tests. One plate with 24-inch anchor spacing required modifications.

III. CONCLUSION

On the basis of the information presented by the licensee, plant walkdowns, and audit work, the staff concluded there are reasonable assurances that as-built and modified embedment plates are capable of withstanding intended loads. This conclusion is based on the following:

1) Licensee conducted a comprehensive investigation of affected areas where the subject plates are located. This investigation included collecting the pipe hanger attachment loads, walkdown throughout the plant and ultrasonic testing.

2) Allowable loads, determined using analytical methods and computer programs, which are in public domain or otherwise verified, have been based on criteria which have been previously approved by the staff during the licensing process and are contained in the FSAR.

3) Allowable tension load of the anchors has been verified by analytical methods and by tests. This value has been set as 18.1 kips which is conservative in view of the pullout loads which are about twice as big as those which are expected. Allowable loads for plates of 2½" X 2½" attachment size have been set at 3.0 kips for the exterior region and at 9.0 kips for the interior region (as determined by the yield line analysis). These loads compared to the allowable strap anchor load of 18.1 kips provide factor of safety of two to six for the SSE loading condition.

It must be borne in mind that both stations are undergoing a Piping Configurations Verification Program (PCVP) which is not completed at this time. The above conclusion has been reached on the basis of the information hitherto available. Should the PCVP result in loads higher than those previously reported, appropriate corrective action must then be taken by the licensee to verify acceptability and/or affected embedment plates.

References

1. Summary Report "Assessment of Embedment Plates." Commonwealth Edison Co., Dresden Station Units 2&3, Quad Cities Units 1&2, October 16, 1987.

2. Letter from the Commonwealth Edison Co., to A. Bert Davis, dated September 30, 1987.

3. Inspection Reports Nos: 50-254/87028 (DRS) and 50-265/87028 (DRS) dated March 18, 1988.

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Dated: