AEOD ENGINEERING EVALUATION REPORT*

UNIT: Davis-Besse 1
DOCKET NO: 50-346
LICENSEE: Toledo Edison
NSSS/AE: B&W/Bechtel Corp.

EE REPORT NO. AEOD/E424
DATE: October 1, 1984
EVALUATOR/CONTACT: C. HSU

SUBJECT: FAILURE OF ANCHOR BOLT ON DIESEL GENERATOR DAY TANK

EVENT DATE: August 14, 1982 (LER 82-38/03L-0)

SUMMARY

At Davis-Besse Unit 1 on August 14, 1982 with the unit in cold shutdown, a 3/4" concrete expansion anchor bolt on a saddle support of the diesel generator day tank was found to be broken during construction of a design modification for the base plates of the day tank saddle supports. The architect engineer performed an evaluation and concluded that the remaining anchor bolts would not be capable of withstanding seismic loads. Since the emergency generator fuel oil system at Davis-Besse 1 has two separate trains and is designed to meet the single-failure criteria as well as seismic requirements, had the damaged anchor bolt been left uncorrected, in the event of an earthquake, a single-failure of a component of the other fuel oil train could result in a total loss of the emergency diesel AC power generation.

It appears that the damage of the anchor bolt may be related to overtightening during installation. The damaged anchor bolt was discovered during a modification for the base plate supports approximately five years after commercial operation of the plant and was not the result of the licensee's routine inspection program. There are no specific requirements for inspection of support bolting connections in the applicable codes or the regulatory review guidance.

This report suggests that NRR consider the following actions:

1. Review the adequacy of current requirements of inservice inspection for concrete expansion anchor bolts for equipment supports and modify them as necessary.

2. Investigate and verify whether the deviation from rigid plate assumption in design of base plates has resulted in underdesign of anchor bolts on the diesel day tanks at other operating plants.

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*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

INTRODUCTION

At Besse-Davis 1 on August 14, 1982, with the unit in cold shutdown (Mode 5) while adding filler pieces to the slotted holes on the diesel generator day tank saddle type supports per Facility Change Request 80-059, a 3/4" anchor bolt on the saddle of diesel generator day tank 1-1 was found to be defective. The bolt broke while the nut was being removed. This bolt was one of the two bolts anchoring one of the two saddle base plates of day tank 1-1 to the floor. The cause of failure of this bolt was attributed to installation error during original construction. The presence of original paint and rust on the cross sectional surface where the bolt sheared indicates that the bolt was damaged during initial installation.

An analysis performed by Bechtel Power Corporation has determined that the remaining anchor bolts would not have been overstressed during normal operational loads. However, the remaining bolts would have been overstressed during a seismic event. The defective bolt was replaced on August 15, 1982. The remaining bolts on diesel generator day tank 1-1 and the bolts on diesel generator day tank 1-2 were checked to assure that no other bolts were defective and that the torque requirements for these bolts were appropriate. The check showed that the remaining bolts were intact and properly installed.

The diesel fuel oil system for the emergency diesel generators at Davis-Besse 1 is comprised of two separate trains in order to meet the single-failure criteria. If damage to one of the bolts on the day tank of one train occurs and goes undetected, a single-failure of a component on the other train could result in a loss of onsite emergency AC power in the event of a seismic occurrence. The concern is further compounded by the fact the NRC currently provides no bolting control regulaton or guidance for bolting other than reactor vessel head bolting.

DISCUSSION

Since some original paint was on the cross sectional surface where the bolt sheared, this may indicate that the bolt was damaged during initial installation. The possible causes of bolt damage during initial installation could be one or a combination of improper torque (over torque), defective fabrication and/or design deficiency. In the review of this event, a search was conducted to identify the most likely cause of the bolt failure and the reason why the defective bolt was not discovered until five years after commercial operation of the plant. The design criteria for vessel supports are provided in Table 3-10a of the plant Final Safety Analysis (FSAR) and the day tank anchor bolts are analyzed in Subsection 3.9.2.9 of the FSAR. In that analysis, the design loading of the anchor bolts consisted of seismic and normal operating loads, shear and maximum tensile stresses were calculated, and a considerable safety margin was provided for these items in the design of the anchor bolts. In view of this, design deficiency is unlikely as the cause of the bolt failure. In addition, defective fabrication is also unlikely as the cause of the failure since the licensee's and the supplier's QA inspection programs should prevent defective parts from being used. Therefore, the damage to the bolt may be related to overtightening during initial installation. The broken bolt was discovered during installation of a design modification for the base plates and was not the result of the licensee's inspection program. We are not able to verify the reason why the design modification had taken place.

The test and inspection program addressed in the plant FSAR for the fuel oil system states that (1) the fuel quality and component operability shall be verified at regular intervals in accordance with Technical Specificatons and (2) the storage tank, transfer pump, day tank, and transfer piping receive test and inspection in accordance with the applicable code. However, the technical specifications define only the requirement of an inspection program for ASME code Class 1, 2, and 3 components to be in compliance with Section XI of the ASME B&PV code. None of the requirements provided in the Technical Specifications address an inspection program for component supports and structural bolting connections to ensure structural integrity of the fuel oil system. Although Subsection IWF in Section XI of the ASME B&PV Code (Ref. 1) addresses the requirements pertaining to inspection programs for ASME Code 1, 2, and 3 component supports, under this rule, the visual examination VT-3 appears to be the only method to detect the loss of integrity at bolted connections during preservice examination. In some cases, especially floor mounting bolts, the defective or broken bolts can not be visually detected since the degraded section is always covered under the base plate or supporting structure and could not be accessible for direct visual inspection for damage. As for the inservice inspection, the code addresses only the frequency and schedule for bolting inspections. An acceptance standard for bolting inspection was not defined until in the latest edition (1983 edition, July 1, 1983). Furthermore, Appendix B "Steel Embedment" to ACI 349-80 "Code Requirement for Nuclear Safety Related Concrete Structure " (Ref. 2) specifically addresses the subject of embedded anchor bolts in concrete in the areas of design, construction and performance testing. However, it does not include requirements for an anchor inspection program needed to cover the construction installation and inservice condition of anchors. Additionally, NRC current regulatory guidance does not provide definite requirements of design and inspection for bolting application such as component supports and embedded anchor bolts or studs other than reactor vessel head bolting (Ref. 3). It appears that due to lack of specific requirements in the applicable codes and the regulatory review guidance, the broken bolt such as the expansion anchor bolt of the fuel day tank for the emergency diesel generators at Davis-Besse 1 was not detected by the plant inservice inspection program, even though the anchor bolts were used to support a component important to safety and are essential for withstanding transient loads created during abnormal or accident conditions.

The day tank for an emergency diesel generator at Davis-Besse 1 has a capacity of approximately 6000 gallons. The tank is a horizontal type and is supported on two saddles which are in turn anchored to the concrete floor on base plates with expansion anchor bolts. Generally, in the design of concrete expansion anchor bolts and base plates, from an analytical standpoint the load distribution in a base plate anchorage system is fairly complex, and it is necessary, therefore, that certain simplifying assumptions be made to arrive at conservative yet practical solutions. However, such assumptions should take into consideration the flexibility of the base plate. It appeared that the original design of some base plates using rigid plate assumptions has resulted in underestimation of loads on the expansion anchor bolts, thus, the licensee's reevaluation of the base plates for flexibility lead to an increase in the design safety factor from two to four and an increase in the number of bolts for each tank. An additional support was also installed to accommodate the deviation from the original assumption. Although the current technique used for analyzing base plates and anchor bolts is flexible plate theory, rigid plate assumptions in designing base plate anchorage supports could have been a common practice in

design of day tank anchorage supports for some operating plants. Whether other architect engineers have used the same design configuration for day tank of the diesel generator fuel oil system is not known. However, a particular AE tends to apply a certain design method as a common practice to the plants they design. Hence there are likely to be similar design configuration for day tanks in other operating plants, which may have underdesigned anchor bolts. In the review of this event, a search resulted in the identification of two other plants having their fuel oil day tank system designed to the configuration similar to that of Davis-Besse 1. The AE for Davis-Besse 1 was also the AE of these two operating plants.

In design of base plate anchorage support, flexible plate theory for analyzing base plates anchorage provides a more conservative analysis of anchor bolt pullout than rigid plate theory because of the reduced moment arm used in the calculation. Questions concerning a large number of existing pipe support base plates using concrete expansion anchor bolts could not be assumed to behave as rigid plate led to the issue of IEB 79-02 "pipe support base plate design using concrete expansion anchor bolts" (Ref. 4). The basic items addressed by this Bulletin were the reevaluation of base plates for flexibility, safety factors, quality control and inspection during and after installation. The scope of this Bulletin was limited to the pipe support. Base plate concrete anchors for day tank supports were not included. Since the technique used in analyzing base plate concrete anchors is somewhat common for the design of both pipe and day tank supports, we believe base plates in the supports of day tanks at some other plants may be similar to that of the day tank at Davis-Besse 1 which could not be assumed to behave in rigid manner.

Two emergency diesel generators were set up to supply onsite emergency AC power at Besse-Davis 1. The diesel fuel oil storage and transfer system for the emergency diesel generators is comprised of two separate trains. Each train has one fuel oil day tank. Since the two emergency diesel generators shall be operable along with their associated fuel oil system in Mode 1 through Mode 4, the diesel fuel oil system is designed to meet the single-failure criteria as well as seismic requirements. Failure of one anchor bolt on a day tank could result in the loss of tank capacity to withstand sesmic loading. Therefore, had the damaged anchor bolt been left uncorrected, in the event of an earthquake, a single-failure of a component of the other fuel oil train could result in a total loss of the onsite emergency AC power supplies. Inoperability of these back-up power sources significantly increase the risk of plant damage should a loss of offsite AC power occur. The loss of offsite AC power is very likely in the event of an earthquake since the components of the offsite AC power system are not designed and installed to meet seismic requirements. Hence, a station blackout (loss of all AC power) could occur which, according to the results of the Reactor Safety Study (Ref. 5), could be a relatively important contributor to the total risk from nuclear power plant accidents.

FINDINGS & CONCLUSIONS

Based on the preceding discussion and related follow-up activities in this evaluation, the following findings and conclusions are provided:

1. The damaged anchor bolt was discovered during installation of a design modification for the base plates of day tank support and was not the result

of the licensee's inspection program. This design modification resulted in the licensee's reevaluation of base plate for flexibility which had not been considered in the original design.

2. Based on the presence of original paint and rust on the cross sectional surface where the bolt sheared, it appears that the bolt may have been damaged during initial installation.

3. The plant FSAR indicates that the anchor bolts of the day tank were designed with considerable safety margin provided for shear and tensil strength. Therefore, design deficiency is unlikely as the cause of the bolt damage. In addition, both the licensee's and the supplier's programs should prevent defective parts from being used, hence the bolt damage may not be related to defective fabrication. In view of the above, the damage could be attributed to the overtorquing of the anchor bolt during initial installation.

4. Under the present inspection program addressed in Section XI of the ASME B&PV Code, visual examination is the only reliable method to discover the component support bolting degradation. In some cases, this required disassembly of the support component in order to inspect the bolts or studs. If there is no clear evidence of loosening, bolting degradation due to improper torque or design deficiency could not be detected. Moreover, the visual inspection of bolting is not a mandatory requirement under the present inservice inspection program (Ref. 6).

5. Although Appendix B to ACI 349-80 (Ref. 2) defines the requirements pertaining to design, construction and performance test for steel embedment of nuclear safety related concrete structure, the inspection program needed to cover the construction installation and inservice conditions of expansion anchor bolts is not being adequately addressed.

6. The architect engineer of Davis-Besse 1, performed an analysis with one anchor bolt failed and determined that the remaining anchor bolts would have been overstressed during a seismic event. The bolt damage could constitute a potential loss of fuel oil system structural integrity and, in the extensive case, a total loss of the onsite emergency AC power could occur, should the damage not be detected.

7. In the design modification for the day tank anchorage supports, the licensee found that the original design of some base plates using rigid plate assumption had resulted in underestimation of loads on the anchor bolts of the day tanks. The licensee reevaluated the base plates design by considering base plate flexibility which led to an increase in the design safety factor and the number of anchor bolts for the day tanks.

It appears that the damage of anchor bolt could be attributed to the overtorquing of the anchor bolt during initial installation. The presence of original paint and rust on the broken sectional surface of the damaged bolt indicates overtightening during construction installation could have been the cause of anchor bolt damage. Failure of one anchor bolt in the support of a day tank could result in the loss of tank capacity to withstanding seismic loads. The diesel fuel oil system for the emergency diesel generators at Davis-Besse 1

is comprised of two separate trains in order to meet the single-failure criteria. If damage of one anchor bolt on one of the day tanks goes undetected, a single-failure of a component on the other train could lead to a total loss of onsite emergency AC power in the event of an earthquake. The inadequacy in the plant inservice inspection program to detect the damaged anchor bolt may be due to lack of specific requirements in the applicable codes and the regulatory review guidance. It would be appropriate to inform NRR of the inadequacy with the inspection program to ensure the structural integrity of base plate bolted connections for equipments important to safety and suggest that they consider the following actions.

1. Review the adequacy of current requirements of inservice inspections for anchor bolts installed in the anchorage support of day tank and suggest modifications as appropriate.

2. As a particular AE tends to use the same design configuration for certain systems in different plants they designed, there are likely to be similar design in other operating plant in which failure of only one anchor bolt in the support of a day tank could lead to a potential loss of the onsite emergency AC power. Also, base plates in the anchorage supports of other day tanks may not behave in a rigid manner as was being assumed in the original design. This should be investigated and verified whether the deviation from rigid plate assumption has resulted in underdesign of anchor bolts on the day tanks at other operating plants.

REFERENCES

1. American Society of Mechanical Engineers (ASME), "Boiler and Pressure Vessel Code," Subsection IWF of Section XI, "Inservice Inspection of Class 1, 2, 3, and MC Component Supports."

2. American Concrete Institute, ACI 349-80, "Code Requirements for Nuclear Safety Related Concrete Structure," Appendix B, "Steel Embedment," 1980 Supplement.

3. U.S. NRC, Regulatory Guide 1.65, "Materials and Inspections for Reactor Vessel Closure Studs," October 1973.

4. U.S. NRC, IE Bulletin 79-02, "Pipe Support Base Plate Design Using Concrete Expansion Anchor Bolts," March 1979.

5. "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," U.S. NRC Report NUREG-75/014 (WASH-1400), October 1975.

6. U.S. NRC, "Threaded-Fastener Experience in Nuclear Power Plant," USNRC Report NUREG-0943, January 1983.