UNITED STATES
NUCLEAR REGULATORY COMMISSION
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ENCLOSURE

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

CONCERNING THE USE OF U-BOLT PIPE CLAMPS

TENNESSEE VALLEY AUTHORITY

WATTS BAR UNITS 1 AND 2

DOCKETS 50-390 AND 50-391

1.0 INTRODUCTION

The staff's Integrated Design Inspection (IDI) at Watts Bar, Unit 1 (Inspection Report 50-390/92-201) identified a finding concerning the applicant's use of U-bolts as pipe support clamps. As discussed in the inspection report, the issue was first identified by the applicant's quality assurance program. The issue involves the use of U-bolts as pipe clamps in conjunction with pin-connected standard support members such as snubbers. Since the U-bolt can potentially rotate or slide along the pipe when it is loaded, there is a concern with the stability of these installations. The issue was closed by the applicant based on an independent review of the issue by a consultant. On the basis of calculations, both the applicant and its consultant concluded that the low torque values required to prevent rotation of the U-bolts under design loading conditions would be achieved during the routine installation of the U-bolts.

The NRC inspection team did not agree with the validity of the calculations performed by the applicant and its consultant. In addition, a field examination of one support by an NRC team member found that the U-bolt support assembly rotated around the pipe when a minimal load was applied. The applicant's support calculation indicated that the U-bolt torque necessary to prevent rotation was substantially lower than the torque value required during the installation of the support. Therefore, if the applicant's evaluation was correct, the U-bolt support should not have rotated under such a minimal load.

As a result of the IDI finding, the applicant developed an action plan to address the U-bolt support designs at Watts Bar. The action plan, transmitted in a September 21, 1992, letter to the staff, called for the development of an updated design methodology and revised installation procedures. The applicant's October 13, 1992, response to the IDI finding provided the updated design methodology. The applicant provided additional reference documents used to develop this methodology in a December 22, 1992, submittal. A meeting was held between the staff and the applicant to discuss technical issues regarding the use of the U-bolts on March 2, 1993. In response to questions raised during this meeting, the applicant provided additional information in April 8, 1993, and June 21, 1993, submittals. The applicant further discussed the information in the submittals in an August 3, 1993, meeting with the staff.

2.0 EVALUATION

The pipe supports in question use a U-bolt tightened down on the pipe with a crosspiece on the bottom. In some cases a stanchion is mounted on the crosspiece and the pipe is tightened down on the stanchion. This assembly is then attached to the building by either a single strut/snubber or by a double strut/snubber trapeze arrangement. The struts or snubbers have pinned connections at each end and are designed for both tension and compression loads. Since the struts or snubbers have pinned connections at each end, the support assembly requires the friction force produced by the U-bolt tightening to maintain the support in a stable arrangement under compressive loads. Pipe support manufacturers make standard pipe support clamps which are normally used in these situations. These standard pipe clamps have a much larger load bearing area between the clamp and the pipe which results in lower local stresses in the pipe wall. In addition, the standard pipe clamps have years of proven service experience. In contrast, the U-bolt assemblies used at Watts Bar introduce highly localized loads in the pipe especially at the location of the crosspiece.

This type of support assembly was reviewed during the licensing of Comanche Peak. Because of the technical concerns that had been raised regarding their use, the applicant decided to replace all of these designs at Comanche Peak (NUREG-0797, Supplement No. 14). The use of cinched U-bolts in trapeze support assemblies is also discussed in the industry standard on pipe supports, WRC Bulletin 353. Section 2.4.5.3 of the WRC Bulletin states, "Tight-fit U-bolts are often used in support assemblies to provide support in one direction for rod hangers and two directions for struts and snubbers. The latter design is not recommended (refer to Section 2.4.1) for stability reasons." The tight-fit U-bolt assembly with struts and snubbers is the design of concern at Watts Bar. The applicant has used U-bolts in both trapeze assemblies and with single struts and snubbers at Watts Bar. Because the U-bolt support assemblies were replaced at Comanche Peak, and because the industry standard does not recommend their use in trapeze assemblies, the staff questioned whether sufficient technical justification could be developed to provide reasonable assurance that the Watts Bar designs will function under all anticipated loading conditions.

The applicant's October 13, 1992, response to the IDI provides the new criteria for evaluating the U-bolt pipe clamp designs at Watts Bar. The applicant's criteria contain design formulas to calculate the required U-bolt installation preloads and to evaluate the local stresses in the pipe wall. The required installation preload is based on the calculated preload required to maintain support stability under design loading conditions. The criteria for local stresses in the pipe wall is based on criteria contained in Section III of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. The applicant's design criteria are supported, in part, by tests and detailed finite element analyses performed by Westinghouse for Comanche Peak. This has been supplemented by additional detailed finite element analyses performed by the applicant's consultant Robert L. Cloud and Associates, Inc. (RLCA). The staff's review of these documents has identified several concerns.

The applicant's new design procedure referred to the results of tests performed by Westinghouse for Texas Utilities Generating Company reported in WCAP-10620, "Comanche Peak Steam Electric Station U-Bolt Support/Pipe Test," as confirmation of the design methodology. WCAP-10620, submitted by the applicant's December 22, 1992, letter, contains the results of tests of several sizes of U-bolt clamp assemblies to evaluate preload stresses, thermal stresses, etc. However, the staff review of this document found that only one seismic test of a 10-inch diameter pipe and U-bolt support assembly was performed. The U-bolt was reported to have actually slid axially along the pipe during the test. There is no discussion of the amount of gross bending stress in the pipe section during this test to determine at what stress level in the pipe the test would be applicable. In addition, this test is not directly applicable to the applicant's U-bolt designs that have stanchions mounted on the crosspiece since these designs have longer U-bolt legs than the U-bolt used in the Westinghouse test. Also, the applicant uses Belleville washers to maintain U-bolt preload, the use of which were not included in the Westinghouse test. For the reasons stated above, the staff does not consider the Westinghouse test to provide adequate demonstration of stability of the Watts Bar U-bolt designs for seismic loads.

The applicant also provided the results of finite element analyses performed by Westinghouse in WCAP-10627, "Comanche Peak Steam Electric Station U-Bolt Piping Support Assembly Finite Element Analysis," and RLCA in RLCA/P142/01-86/005, "Acceptable Support Bearing Loads on Pipe Based on Plastic Analysis," as additional confirmation of the design methodology. WCAP-10627 contains comparisons between the tests performed by Westinghouse and detailed finite element models of the test assemblies. The report did identify that differences in piping stresses existed between the test results and the finite element analyses. These differences were attributed to differences in the fit-up between the pipe and U-bolt in the test and in the finite element model. The staff considers that these results demonstrate the sensitivity of this support arrangement to the exact geometry of the U-bolt support assembly. As discussed previously, the applicant's U-bolt designs incorporate some different features than the designs tested by Westinghouse. Since the Westinghouse analyses demonstrated a sensitivity to actual fit-up between the pipe and U-bolt, the staff considers these analyses to be of limited use for evaluating some of the Watts Bar designs.

The RLCA report provides the results of finite element analyses of several pipe sizes to determine acceptable local bearing loads on the piping. The analyses used acceptance criteria based on plastic analysis concepts contained in Section III, Subsection NB of the ASME Code. The finite element models included a straight section of pipe loaded with a uniform loading. The results of the finite element analyses are then compared to the formulas used in the design procedure for computing the allowable bearing loads. Since the allowable local bearing load would be impacted by the stresses in the pipe due to design loads, the staff questioned whether the finite element analyses enveloped the stresses that are allowed by the piping design criteria. The applicant's response was that the finite element analyses bounded the calculated stresses at the location of the U-bolts. However, in making this evaluation, the applicant removed the stress intensification factors at the U-bolt locations. When this was questioned by the staff, the applicant responded that this was done to be

consistent with limit load calculations performed to evaluate the allowable local bearing loads. However, the finite element analyses were all performed using a straight section of pipe in the model for which there is no stress intensification factor. It appears that the applicant has used the U-bolt clamps on piping components other than straight sections of pipe. Neither the finite element analyses nor the Westinghouse test is applicable to these configurations. The staff finds that the applicant has not provided any technical basis for the use of U-bolt pipe clamps on fittings other than straight pipe. The staff considers the applicant's response unacceptable with regard to this issue.

The finite element analyses in the RLCA report also show large local deflections at the proposed allowable bearing load limits for larger pipe sizes. The staff questioned whether these deflections exceed the allowable global deflection limits specified in the applicant's FSAR. The applicant's response was that these local deflections take place during the initial tightening and are not part of the variable deformation that takes place under variable support loads. In addition, the applicant argued the U-bolt arrangement is less prone to local deformation than a frame support arrangement and that the ASME Code does not require local pipe deformation to be calculated for a frame support arrangement. The staff considers the applicant's second argument to be irrelevant to the issue of allowable deflections. With respect to the applicant's first argument, the staff would agree a tightened joint generally does not exhibit large deflections under load. However, the applicant's use of Belleville washers in the U-bolt pipe clamp design has resulted in a more flexible joint design under compressive load conditions. In fact, the applicant's response to the IDI finding provides a discussion of the stiffness of the pipe U-bolt assembly. As reported in the applicant's submittal, the effect of the Belleville washers is to cause the assembly to have a lower bound stiffness value. The result of the lower stiffness value is increased deflections under the applied loads. The staff considers the applicant's latest response to be contradicted by its previous submittal. The staff concludes that the applicant's response did not adequately address this issue.

CONCLUSION

On the basis of the review of the referenced submittals, the staff finds that TVA has not provided sufficient justification to demonstrate that the U-bolt pipe clamps as used at Watts Bar are acceptable. Further, the staff considers the U-bolt pipe clamp a poor design that is not recommended by the industry standard on pipe support design, WRC Bulletin 353. The staff recommends that the applicant replace the U-bolt pipe clamps with either standard pipe clamp designs or other standard industry pipe support designs.

Principal contributor: John Fair
Dated: September 13, 1993

REFERENCES

1. NRC letter from S. A. Varga to M. O. Medford transmitting Inspection Report 50-390/92-201, September 21, 1992.

2. TVA letter from W. J. Museler to NRC providing the proposed corrective action plan for the IDI finding regarding U-bolts, September 21, 1992.

3. TVA letter from W. J. Museler to NRC providing the response to Inspection Report 50-390/92-201, October 13, 1992.

4. TVA letter from W. J. Museler to NRC providing supplemental reference information on the U-bolt support arrangements at Watts Bar, December 22, 1992.

5. NRC summary of a March 2, 1993, meeting with TVA to discuss the use of U-bolts at Watts Bar, March 11, 1993.

6. TVA letter from W. J. Museler to NRC providing a response to questions raised in the March 2, 1993, meeting, April 8, 1993.

7. TVA letter from W. J. Museler to providing additional information regarding the response to previous NRC staff questions, June 21, 1993.

8. U.S. Nuclear Regulatory Commission, NUREG-0797, Supplement 14, "Safety Evaluation Report related to the operation of Comanche Peak Steam Electric Station, Units 1 and 2, Docket Nos. 50-445 and 50-446, Texas Utilities Electric Company, et al.," March 1988.

9. Welding Research Council Bulletin 353, "Position Paper on Nuclear Plant Pipe Supports," May 1990.