ENCLOSURE

SAFETY EVALUATION REPORT
UNRESOLVED ITEM URI 90-05-01, "HVAC DUCT WELD DEFICIENCIES"
WATTS BAR NUCLEAR PLANT
DOCKET NUMBERS 50-390 AND 50-391

1. BACKGROUND

On February 26 - March 1, 1990, a special inspection was conducted by an NRC team at the Watts Bar Nuclear Plant to review the resolution of the technical issues in the CAPs related to heating, ventilation, and air-conditioning (HVAC) systems and equipment qualification (Reference 3). The purpose of the inspection was to assess the adequacy of the implementation of the corrective action programs for HVAC and equipment seismic qualification in resolving the known technical issues.

In addition to the HVAC source issues, the team reviewed the resolution of an HVAC duct welding issue described in the welding corrective action program as it pertains to the overall structural integrity of the HVAC ductwork. The issue arose when, during review of the welded HVAC ductwork, it was recognized that some partial-penetration welds existed where full-penetration welds are specified. This issue had been partially reviewed by an NRC inspection team from a welding perspective as documented in NRC Inspection Report 50-390/89-04 and 50-391/89-04 dated August 9, 1989.

After a thorough review and evaluation of the duct weld deficiencies and TVA's Safety Significance Report, WCG-1-324 (Reference 10), the inspection team stated that TVA's assumption of weld strength equivalency based on thickness replacement of a full penetration weld by a partial penetration/crown weld might not be valid. The inspection team concluded that tensile testing of the welded joints would provide conclusive evidence of the structural adequacy of the partial penetration welds. As a result, the inspection team considered the HVAC duct weld issue an unresolved item in the HVAC corrective action program (URI 90-05-01) as described in NRC Inspection Report (Reference 3).

Subsequently, TVA engaged a subcontractor, APTECH Engineering Services, Inc., to review the duct weld deficiencies and test results and to provide an evaluation report resolving the staff's concerns. At a meeting held at NRC's office in Rockville, MD, on May 31, 1990 (Reference 1), TVA presented its preliminary response to the team's questions regarding the structural adequacy of the HVAC duct welds. TVA's supplementary response (Reference 2) to its final report (Reference 4) was issued on June 29, 1990.

9011010301 901019
PDR ADOCK 05000390
A PDR

2. PURPOSE

The NRC Staff and its consultant, Brookhaven National Laboratory (BNL), attended TVA's presentation on May 31, 1990, and reviewed TVA's supplementary report (Reference 2). The purpose of this effort has been to verify the adequacy of the tests and analytical procedures used by TVA to qualify the HVAC safety related duct weld deficiencies and to resolve the staff's concern expressed during the special inspection at Watts Bar (Reference 3) held February 26 - March 1, 1990, in order to close out unresolved item URI 90-05-01.

3. DESCRIPTION OF DUCT WELD ISSUE

The issue of concern to the staff relates to the structural adequacy of the butt welds on safety-related HVAC ductwork (including the hydrogen collection system) which were fabricated and installed (1978 timeframe) without a Quality Assurance Program (QAP) and without specific welding requirements from engineering.

During review of the welded HVAC ductwork, TVA's Weld Evaluation Project (WEP) identified some partial penetration welds where full penetration welds are specified. The subject deficiency was initially reported by TVA to the NRC on March 12, 1987 in accordance with 10 CFR 50.55(e) (References 14 and 15). The first interim deficiency report was submitted on April 16, 1987 (Reference 11); subsequent deficiency reports were submitted on April 12, 1988 (Reference 12) and November 6, 1989 (Reference 13).

The primary safety concern of this issue is the structural adequacy of the existing partial penetration butt welds in safety-related ductwork of various ventilation and gas treatment systems. Should a weld fail, the ductwork could separate and fail to perform its design function. This could lead to a buildup of airborne radiation, gases, or contaminants during and/or following a design basis seismic event. The hydrogen collection system ductwork is part of the combustible gas control system and is designed to prevent hydrogen, which may be generated following a design basis accident, from reaching concentration levels sufficient for explosion. Failure of this ductwork during a seismic event could adversely affect safe operation of the plant.

4. DESCRIPTION OF SPECIAL INSPECTION AND UNRESOLVED ITEM URI 90-05-01

During the special inspection held at the Watts Bar Nuclear Plant from February 26 - March 1, 1990, the NRC inspection team (the team) reviewed the issues and corrective actions contained in the significant condition reports (SCR's) (References 14 and 15). The team also reviewed the resolutions discussed in the following documents: Phase II weld report, Section 7.6 (Reference 16); duct welding final report (Reference 4); design criteria document

(Reference 17); safety significance evaluation report (Reference 10); and, backup calculations reports (References 18 and 19). The team requested and were supplied with copies of the source documents, reports, calculations, test data and weld photographs. The issues and resolutions were discussed by the team with the cognizant TVA engineers. The team evaluated the adequacy of the documents, calculations and tests to resolve the issues.

The team reviewed TVA's Safety Significance Report, WCG-1-324 (Reference 10). The conclusions in the report were based on the premise that a partial penetration weld joint with a total thickness equal to the base material has the same tensile strength as the parent material. However, based on its review of photographic enlargements depicting the cross section of the weld joints, the team questioned the extent to which the weld reinforcement ("crown") thickness can be considered as part of the total weld thickness of the joint. The team found that TVA utilized a "thickness replacement" rule to evaluate the adequacy of the partial penetration welds without consideration of the weld offset with respect to the center line of the base material. The team also pointed out that the stress concentration at the root of the partial penetration weld is a built-in crack and would reduce the joint tensile strength.

The team reviewed the Singleton Materials Engineering Laboratory (SMEL) test report which is included as Attachment C to Report WCG-1-324 (Reference 10). The SMEL report discusses the weld throat measurements of specimens cut from duct. SMEL took measurements of the minimum effective throat of 17 butt weld samples and the crown or weld build-up above it. Two strips approximately 5/8-in. wide were cut transverse to the weld from each disc sample. These cross-sections were ground and then etched to reveal the weld. The measurements were made by constructing a line on the outside surface of the HVAC base material which cuts through the cross-section of the weld. The minimum effective throat thickness is the shortest distance between the constructed line and the weld penetration. The crown thickness is the distance above the line to the top of the weld at the point of the minimum throat. The total thickness of the weld is calculated in the SMEL report as the sum of the two measurements (i.e., the sum of the minimum effective throat thickness plus the crown thickness).

The team raised a concern that TVA's assumption of weld strength equivalency based on thickness replacement of a full penetration weld by a partial penetration/crown weld might not be valid and concluded that tensile testing of the welded joint would provide conclusive evidence of the structural adequacy of the partial penetration welds. As a result, the team considered the HVAC duct weld issue an unresolved item in the HVAC corrective action program (URI 90-05-01) as described in NRC Inspection Report (Reference 3).

5. REVIEW OF TVA's SUPPLEMENTAL REPORT

TVA's final report on the duct welding issues (Reference 4) was submitted to the NRC on March 1, 1990. The supplemental response (Reference 2) to the final report was submitted to the NRC on June 29, 1990; Enclosure 2 of the supplemental response contained evaluation report AES 90051243-1Q-1 including TVA weld coupon test results.

TVA's supplemental report describes the analytical methodology, evaluation criteria and test results of a structural integrity program conducted to determine the fitness for service of the HVAC ductwork at the Watts Bar Nuclear Plant, Units 1 and 2. Report chapters cover analysis methods, characterization of material properties, comparison of destructive test results with limit load predictions, apparent strength of worst case flaws and a fitness-for-service evaluation. Appendix A of the report contains a description of the statistical analysis used to determine the lower bounds of the uncracked percentage of weld thickness, acceptable percentage of weld length and the ultimate tensile strength.

The team reviewed TVA's supplemental report (Reference 2) in detail with respect to the methodology and criteria used in the evaluation and the team verified (by checking) the calculations performed. The team verified TVA's limit load analysis calculations contained in Section 5 of the supplemental report. A typical duct weld test specimen is shown in Figure 5-2(a) and the analytical model used to calculate the lower bound limit loads for various flaw sizes to section size ratios (a/t_w) is shown in Figure 5-2(b). Equation 5-1 provides the lower bound limit load solution for a pin loaded edge cracked panel and Equation 5-2 for a rigidly constrained panel loaded in tension. Solutions to these equations are shown graphically in Figure 5-3 for the weld metal material with a flow stress of 70 ksi and in Figure 5-4 for the duct material with a flow stress of 39.5 ksi.

The team reviewed the statistical analysis contained in Section 6 of the supplemental report. Statistical analyses were performed to determine the lower bounds of the uncracked percentage of weld thickness, acceptable percentage of weld length and ultimate tensile strength. The analytical procedure and results seem reasonable since no probabilistic model was assumed in the calculation. The difficulty in such a statistical analysis is in determining lower probability values e.g., less than 5-10% for this case, in which no data points are available for interpolation.

The extrapolation method was reviewed from additional references (Calculations 3 and 4, of Reference A-3 of TVA's supplementary report) provided by TVA. Based on these documents, the extrapolation method used to determine the lower probability values seems conservative.

TVA's supplementary report contains a limit load evaluation using the equations in the ASME B&PV Code, Nuclear Code Case N-463 (Reference 6) to evaluate the integrity and fitness-for-service of duct weldments which contain sections of missing weld and/or lack of penetration. The equations used in the analysis are given in A-5320 of Code Case N-463 and the circular pipe configuration containing circumferential flaws on which the method is based is shown in Figure A-4221-1.

The analytical procedures in Code Case N-463 are applicable to circular configurations, i.e., piping, and not to rectangular/square ducts. The issue of partial penetration welds where full penetration welds are required is of significance in the thick-walled HVAC duct sections such as spiral welded round duct and scheduled piping used as ducts. Rectangular/square ducts are thin walled members (12 gauge, 0.1046 inches) versus 1/4 to 5/16 inches for scheduled pipe wall.

The team does not agree with TVA's assumption in the supplementary report that the limit load condition for rectangular/square sections are approximated by the circular section calculations using Code Case N-463. However, the rectangular/square HVAC ducts, because of their thin walls, were not part of the staff's concern with regard to the partial penetration duct weld issue. The staff's primary concern in the HVAC duct weld issue was the structural adequacy of the partial penetration welds in the thick walled pipe sections which is appropriately addressed with the code case.

TVA performed limit load and crack growth calculations on square ducts because of their concern with regard to the applicability of the method to square/rectangular shapes (Reference 7). The results showed a maximum decrease in circle-based safety factor of 17%. TVA concluded that this decrease is acceptable because of ample conservatism in many other analysis assumptions.

6. CONCLUSIONS

The NRC team conducted an in-depth review of TVA's responses to resolve the safety concerns with regard to the HVAC duct partial penetration welds at the Watts Bar Nuclear Plant. On the basis of the review activities described above, the team concludes that:

(1) The results of the analytical procedures, evaluation criteria and tension tests used by TVA to demonstrate fitness-for-service of the HVAC duct partial penetration welds provide an adequate basis for resolving the staff's concerns.

(2) The reports submitted by TVA and its consultant, APTECH, provided the team with sufficient data, analyses and test results to enable the team to independently review and verify the results and conclusions.

(3) On the basis of the above discussion, unresolved item URI 90-50-01 is closed.

7. REFERENCES

1. "Minutes of May 31, 1990, meeting on the Structural Adequacy of the HVAC Duct Welds," Docket Numbers 50-390 and 50-391, June 15, 1990.

2. Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Safety-Related Heating, Ventilating, and Air Conditioning (HVAC) Duct Welding Supplemental Response to WBRD-50-390/87-09 and WBRD-50-391/87-09 Final Report, June 29, 1990, including APTECH Evaluation Report AES 90051243-1Q-1, Revision 1, June 1990.

3. NRC Inspection Report Nos. 50-390/90-05 and 50-391/90-05, "Special Inspection of the Watts Bar Corrective Action Programs," conducted February 26 - March 1, 1990, report dated May 10, 1990.

4. Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Safety-Related Heating, Ventilating, and Air Conditioning (HVAC) Duct Welding - WBRD-50-390/87-09 and WBRD-50-391/87-09 Final Report, March 1, 1990.

5. Letter from Steve Paterson (APTECH) to Roger Alley (TVA), Response to BNL's Question on a/t_w Measurements, July 30, 1990.

6. American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code Case N-463, Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping That Exceed the Acceptance Standards of IWB-3514.2, Section XI, Division 1" (Approval Date: November 30, 1988).

7. APTECH Memorandum, R. Cipolla to P. Besuner, "S. Paterson's Limit Load and Crack Growth Calculations," June 22, 1990.

8. Watts Bar Nuclear Plant - NCR 3761 - Purge Air System Spiral Welded Pipe, R.O. Lane, Singleton Materials Engineering Laboratory, December 18, 1981.

9. Watts Bar Nuclear Plant, Testing of HVAC Metal Coupons, Report #29025-03A, Singleton Materials Engineering Laboratory, May 21, 1990.

10. TVA Report WCG-1-324, "Safety Significance Evaluation for Seismic Category I HVAC Duct Welding Concerns," Rev. 1, 2/7/90, RIMS Accession Number B26-90-0207-101.

11. TVA First Interim Report, "Watts Bar Nuclear Plant - Units 1 and 2 - Safety-Related HVAC Duct Welding - WBRD-50-390/87-09, WBRD-50-391/87-09 - Interim Report," April 16, 1987.

12. TVA Second Interim Report, "Watts Bar Nuclear Plant (WBM) Units 1 and 2 - Safety-Related HVAC Duct Welding - WBRD-50-390/87-09 and WBRD-50-391/87-09 - Second Interim Report," April 12, 1988.

13. TVA Third Interim Report, "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Safety-Related Heating, Ventilating, and Air Conditioning (HVAC) Duct Welding - WBRD-50-390/87-09 and WBRD-50-391/87-09 - Third Interim Report," November 6, 1989.

14. TVA SCR WBN MEB 8721, Rev. 2, February 3, 1989, RIMS Accession Number B26-89-0203-204.

15. TVA SCR WBN MEB 8722, Rev. 2, February 7, 1989, RIMS Accession Number B26-89-0207-201.

16. TVA Phase II Weld Report, "Watts Bar Nuclear Plant (WBN) - Phase II Weld Report," December 1, 1989, RIMS Accession Number L44-891201-803.

17. TVA Design Criteria, No. WB-DC-40-31-8, "Seismically Qualifying Round and Rectangular Duct," Rev. 7, February 26, 1990, RIMS Accession Number B26-90-0226-151.

18. TVA Report, "Backup Calculations for Design Criteria DC-40-31.8," February 24, 1990, RIMS Accession Number B18-900224-807.

19. TVA Report WCG-1-500, "HVAC Ductwork - Evaluations for Safety Significance of Duct Welding Concerns," Rev. 1, January 22, 1990, RIMS Accession Number B26-90-0122-100.