UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA ST., N.W., SUITE 3100
ATLANTA, GEORGIA 30303

Report Nos. 50-390/81-02 and 50-391/81-02

Licensee: Tennessee Valley Authority
500A Chestnut Street
Chattanooga, TN 37401

Facility Name: Watts Bar

Docket Nos. 50-390 and 50-391

License Nos. CPPR-91 and CPPR-92

Inspection at: Watts Bar site near Dayton, Tennessee

Inspector: E. H. Girard — 2/19/81
E. H. Girard — Date Signed

Approved by: A. R. Herdt — 2/20/81
A. R. Herdt, Section Chief, RCES Branch — Date Signed

Date of Inspection: January 20 through 23, 1981

Areas Inspected

This special, unannounced inspection involved 32 inspector-hours onsite in the areas of licensee action on previous inspection findings (Unit 1), licensee identified items (50.55(e)) (Units 1 and 2), observation of removal and examinations of reactor vessel inlet nozzle underclad cracking (Unit 1), and worker concerns (Units 1 and 2).

Results

No violations or deviations were identified.

DETAILS

1. Persons Contacted

Licensee Employees

*J. E. Wilkins, Project Manager, WBNP (Watts Bar Nuclear Plant)
#*R. W. Olson, Construction Engineer, WBNP
*J. Weinbaum, QC&R Unit Supervisor, WBNP
#*A. D. Leff, Mechanical Engineer, WBNP
#J. Jackson, Engineering Associate, WBNP
#C. A. Myers, Head Nuclear Engineer, EN DES (Div. of Engineering Design)
#D. L. Wall, Licensing Engineer, EN DES
#C. F. Bowman, Senior Mechanical Engineer, EN DES
#L. H. Chin, Staff Engineer, EN DES
#J. Fox, Metallurgical Engineer, NUC PR (Div of Nuclear Power)
#M. Koss, Metallurgical Engineer, NUC PR
J. Polycyn, Engineer, EN DES
D. Hewette, TVA Singleton Labs

NRC Resident Inspectors

J. McDonald
T. Heatherly

*Attended Exit Interview

#Contacted on corrosion problem

2. Exit Interview

The inspection scope and findings were summarized on January 23, 1981, with those persons indicated in Paragraph 1 above.

3. Licensee Action On Previous Inspection Findings

(Open) Unresolved Item (390/80-10-03): Unacceptable RT Indication in RC System Piping Weld.

The NRC inspector was informed that stored radiographs could not be retrieved at this time because of changes in storage location including construction of a new vault. The QC&R Unit Supervisor was requested to have the radiographs for this item (Weld 1-068F-W001-01) available for review in a subsequent inspection.

4. Unresolved Items

Unresolved items are matters about which more information is required to determine whether they are acceptable or may involve noncompliance or

deviations. New unresolved items identified during this inspection are discussed in Paragraph 7.

5. Licensee Identified Item (50.55(e))

(Open) Item 390, 391/81-02-01: Corrosion of Carbon Steel Piping.

On December 30, 1980, the licensee informed Region II that experience indicated that carbon steel piping in their plant raw water systems may corrode to such a degree that pressure drop and flow fall outside the design conditions. The NRC inspector reviewed TVA's historical experience with this type of corrosion problem. Information for the review was obtained from documentation and from contacts with cognizant TVA personnel. The personnel contacted are listed in Paragraph 1 above. A list of documentation reviewed is given below, together with a chronology of TVA's experience with the corrosion and a summary of technical information on the corrosion and its effects.

a. Documentation

1. Annual Operating Report, Browns Ferry Nuclear Plant, January 1, 1976 - December 31, 1976.

2. Memorandum - J. E. McKelvey to Mechanical Engineering Branch (MEB) Files (MEB 761108012), Browns Ferry Nuclear Plant - Emergency Equipment Cooling Water (EECW) System - Investigation of the Scaling of the Pipe Interior, November 5, 1976.

3. Memorandum - R. H. Dunham to H. S. Fox (MEB 770223076), Scaling and Corrosion in Power Plant Raw Water Piping - GS-74, February 23, 1977.

4. Memorandum - R. O. Johnson to MEB Files (MEB 771103003), Long Term Effects of Corrosion in Raw Water Piping Systems at TVA Steam and Nuclear Power Plants - Interim Report on Pipe Sampling Program, November 3, 1977.

5. Division of Engineering Design (EN DES) Nonconformance Report (NCR) 71D, November 3, 1977.

6. Memorandum - R. H. Dunham to H. S. Fox (MEB 771228005), Corrosion and Scale Accumulation in Raw Water Piping Systems at TVA Steam Plants - Pipe Sampling and Pressure Drop Testing - GS-74, December 28, 1977.

7. Memorandum and Attached Study - D. R. Patterson to R. M. Pierce (MEB 780104021), Sequoyah Nuclear Plant Units 1 and 2 - Watts Bar Nuclear Plant Units 1 and 2 - Essential Raw Cooling Water (ERCW) System Corrosion/Constriction Study, January 4, 1978.

8. Memorandum - D. R. Patterson to L. M. Mills (MEB 780214359), Sequoyah Nuclear Plant - Reportable Deficiency - Excessive Head Loss in ERCW System Subloops - NCR 71D, February 14, 1978.

9. Letter - J. E. Gilleland (TVA) to J. P. O'Reilly (NRC Region II), Sequoyah Nuclear Plant Units 1 and 2 - Excessive ERCW System Head Loss - NCR 71D - Second Interim Report, February 15, 1978.

10. Memorandum - D. R. Patterson to L. M. Mills (MEB 780315374), Sequoyah Nuclear Plant - Discrepancies in TVA's Report to NRC-OIE on NCR 71D, March 14, 1978.

11. Memorandum - D. R. Patterson to L. M. Mills (MEB 780327361), Watts Bar Nuclear Plant - Excessive ERCW System Head Loss - Report No. 1 (Final) - NCR 1003, March 24, 1978.

12. Memorandum - L. M. Mills to D. R. Patterson (MEB 780331627), Sequoyah Nuclear Plant Units 1 and 2 - Excessive ERCW System Head Losses - NCR 71D, March 28, 1978.

13. Letter - J. E. Gilleland (TVA) to J. P. O'Reilly (NRC Region II), Watts Bar Nuclear Plant Units 1 and 2 - Excessive ERCW System Head Loss - NCR 1003 - Final Report, March 31, 1978.

14. Letter - J. E. Gilleland (TVA) to J. P. O'Reilly (NRC Region II), Sequoyah Nuclear Plant Units 1 and 2 - Excessive ERCW System Head Loss - NCR 71D - Final Report, April 3, 1978.

15. Report - by W. S. Bain, Study of Corrosion in Carbon Steel Raw Water Piping Systems, September 1979.

16. Memorandum - R. H. Dunham to C. E. Winn (MEB 791204034), Corrosion in Raw Water Carbon Steel Piping, November 29, 1979.

17. Mechanical Design Guide DG-M3.5 Revision 1, Design Concepts of Low Pressure Systems - Pressure Drop Calculations for Raw Water Piping and Fittings, April 30, 1980.

18. Magazine article - by C. F. Bowman and W. S. Bain, A New Look at Design of Raw Water Piping, Power Engineering, August 1980.

19. Memorandum - J. E. Wilkins to R. W. Cantrell, Watts Bar Nuclear Plant - Corrosion and/or Sedimentation Buildup Inside Carbon Steel Pipe Exposed to Raw Water, undated - reportedly written middle December 1980.

20. Division of Construction Nonconforming Condition Report (NCR) 2849R, December 30, 1980.

21. Memorandum - C. A. Myers to Nuclear Engineering Branch (NEB) Files (NEB 801230251), Watts Bar Nuclear Plant - NRC OIE Inspector

Concerns in Regard to Corrosion in Raw Water Systems, December 30, 1980.

22. Memorandum - C. A. Chandley to J. A. Raulston (MEB 810113028), Watts Bar Nuclear Plant - Corrosion in Carbon Steel Raw Water Piping, January 12, 1981.

23. Memorandum - R. W. Cantrell to J. A. Raulston (SWP 810120036), Sequoyah and Watts Bar Nuclear Plants - Changes in ERCW System Piping to Alleviate Corrosion Problems, January 20, 1980.

b. Chronology

Spring 1976 (Inadequate Raw Cooling Water Flows at Browns Ferry)

During preop tests at Browns Ferry Nuclear Plant, various components were found to be receiving inadequate cooling water from Emergency Equipment Cooling Water (EECW) System piping because of unanticipated large buildups of corrosion product on the inside diameter of the carbon steel piping. This piping system utilizes raw river water. TVA did not report the condition to the NRC as a design deficiency. The condition was, however, briefly described in TVA's 1976 Operating Report for Browns Ferry (Doc. 1). The report noted that the corrective action taken to assure adequate cooling water flow had included immediate replacement of some piping and issuance of a design change to replace all 2 inch and under EECW system piping with stainless steel. Periodic flow measurements and yearly sampling of pipe cross sections were reportedly instituted (Doc. 1) to maintain a check on the corrosion.

June and July 1976 (EECW System Corrosion Investigated at Browns Ferry)

A formal investigation of the corrosion problem at Browns Ferry was conducted and reported by TVA design engineering personnel (Doc. 2). The corrosion product deposit found in piping samples was stated to consist of scale and blisters (later referred to as tubercles). The scale deposits examined varied from 1/16 to 3/16 inch thick and the tubercles ranged from 1/8 to 3/8 inch in height (a few reached 9/16 inch). The size, distribution and number of tubercles was observed to be relatively constant regardless of pipe size. Hence, the tubercles could present a very significant obstruction to water flow in small diameter piping. Analyses of the corrosion product deposits indicated they were primarily iron oxide. One 1-inch pipe sample was noted to have a substantial corrosion product buildup after only 2 months of service (1/8 inch overall thickness with largest tubercles to 9/16 inch thick).

February through November 1977 (Expanded Investigation of Corrosion - Phase 1)

To obtain further information for use in design, TVA initiated additional investigation of the corrosion problem to include raw river water piping from a number of their fossil and nuclear plants (Doc. 3). They found the corrosion condition to be widespread. The study developed additional data on the distribution, physical and chemical characteristics of the deposits. The results were generally consistent with the data found at Browns Ferry. However, at one coal fired plant (John Sevier - on the Holston River), one of two layers of corrosion product in a pipe ID sample was found to be predominantly manganese oxide, rather than iron oxide. The other layer in that pipe and the depsoit on 11 other piping samples were found to be predominantly iron oxide. TVA decided to continue the investigative work into a second phase (referred to as Phase 2) and to perform analyses to determine the adequacy of raw water piping designs at their nuclear plants.

July Through December 1977 (Pressure Drop Analysis Performed on Sequoyah and Watts Bar ERCW System Piping)

In response to the unexpectedly large corrosion product buildups found in raw water piping at Browns Ferry and subsequently confirmed in the Phase 1 investigation described above, TVA decided to re-analyze their nuclear plant carbon steel raw water piping to determine its acceptability for planned 40-year plant lives. A design analysis performed for Sequoyah and Watts Bar Nuclear Plant Emergency Raw Cooling Water (ERCW) System piping, utilizing expected corrosion/constriction criteria based on data from the Phase 1 investigation, revealed that 14 of 19 subloops checked would not be capable of meeting flow requirements for the planned design lives (Doc. 7). Further, six of the subloops were found unsatisfactory for preoperation tests (no corrosion considered) because they had not been adequately analyzed previously. The six subloops not properly addressed in TVA's original design calculations were reported to NRC Region II (as 10CFR 50.55(e) items) for Sequoyah and Watts Bar. (Docs. 9, 13, and 14). Subloops determined inadequate for 40-year lives because of expected corrosion/ constriction were not reported. A report on the subloops not capable of meeting preop test requirements for the Sequoyah subloops prepared by TVA's Mechanical Engineering Branch (Doc. 8) for submittal to the NRC noted plans to replace piping to meet preoperational test requirements and, in addition, plans to replace piping that would become fouled (corroded) in operation. These latter changes would be made after operation. The operability of this piping until the latter changes were made would be assured by testing (similar to preoperational testing) to be performed every three months. Mention of these changes that might not be made before the start of operation and of problems due to fouling during operation were deleted from the response before TVA provided it to the NRC.

Note: The NRC inspector questioned TVA's cognizant supervisory design engineer as to why the corrosion/constriction problem was not reported (per 10CFR50.55(e)) and was informed that the design engineer did not consider the item reportable either in accordance with 10CFR50.55(e) or with the applicable Engineering Design Procedure EP 1.26.

December 1977 through September 1979 (Corrosion Investigation - Phase 2) (Doc. 15)

Phase 2 of the investigation of corrosion in carbon steel raw water piping provided additional data on the physical and chemical characteristics of the corrosion, indicated that chlorination was detrimental, and provided pressure drop data indicating that the corrosion product caused a more severe flow restriction than previously expected. New parameters were developed for pressure drop prediction, resulting in a revision to the TVA Design Guide for pressure drop calculations on raw cooling water piping (Doc. 17). Additional studies were recommended to include tests of pressure drop in large diameter piping, the detrimental effects of chlorination, variation of corrosion rate with time, and the effectiveness of corrosion resistant materials and corrosion inhibitors.

1979 (Raw Water Piping Being Analyzed to Revised Criteria)

Reanalysis of raw water piping systems for nuclear plants was initiated using criteria from the Phase 2 corrosion investigations. (Doc. 23).

November 1980 (Corrosion Discovered in ERCW System Bearing Prelube Water Lines at Watts Bar)

In the course of relocating ½ inch carbon steel ERCW prelube piping, the piping was accidentally discovered to contain a large amount of corrosion product. The corrosion was not documented as an apparent nonconforming condition and TVA was subsequently cited for this apparent violation by the NRC Resident Inspector at Watts Bar (violation 390/80-36-01, 391/80-28-01). It was found that the Watts Bar prelube piping as well as similar adjacent line supplying water to the ERCW pump motor thrust bearing cooler should have been identified for replacement in the earlier corrosion/constriction analysis (Doc. 7), but they had been missed in error. The failure to identify this piping for correction was also identified as a violation of requirements by the NRC Resident Inspector (violation 390/80-36-02, 391/80-28-02).

c. Summary Technical Information on Raw Cooling Water Corrosionof Carbon Steel Piping

The following is a summary listing of technical information on raw water corrosion obtained from TVA documents and contacts.

1. The mechanism is electrochemical corrosion of the carbon steel piping by aerated raw (i.e., river) water and redeposition of the

corrosion products.

2. The corrosion is general throughout the ID of the piping with random instances of pitting covered by heavy corrosion product deposits in the form of tubercles.

3. The corrosion product consists largely of iron oxide sometimes accompanied by silica (possibly silt or sand carried by the river water).

4. No significant differences are observed between the buildups in horizontal and vertical runs of piping as long as they are completely full of water.

5. Buildup does not appear to be dependent on pipe diameter.

6. Age is not the only parameter influencing corrosion product buildup. Considerable scatter of buildup thickness is found in pipe of a given age at a given site.

7. The upper limit of average pipe diameter reduction for a 40-year life is estimated to be 0.4 inch.

8. Estimated average pipe wall reduction due to corrosion is .0625 inch without exterior corrosion protection and .040 inch with exterior corrosion protection.

9. Maximum localized pipe wall reductions observed in investigations was .160 inch.

10. Galvanized pipe appears to have slightly smaller buildups of corrosion product.

11. Tubercles up to 2 inches in height have been found in 6 and 8 inch diameter pipe samples.

12. Corrosion pits occur beneath the tubercles and maximum wall reductions are associated with large tubercles.

13. Maximum tubercle height increases with increasing pipe size and frequency of tubercles apparently decreases with increasing pipe size.

14. Corrosion buildup does not vary in range significantly from near stagnant to continuously flowing lines.

15. Use of a corrosion inhibitor (zinc polyphosphate) injected into a line was not found to reduce corrosion buildup in a one year test.

16. Chlorination of water in a line appears to increase corrosion.

17. Based on measured pressure drop data from corroded piping, empirical relations for predicting pressure drop have been developed and are presented in Docs. 15, 17 and 18. Using these relations on piping with a nominal pipe inside diameter of 2.5 inches or less results in very high predictions of pressure drop at flow rates normally used in pipelines this size and it is recommended that either larger size or corrosion resistant lines be used.

6. Observation of Removal and Examinations of Reactor Vessel Inlet Nozzle Underclad Cracking (Unit 1)

The inspector observed grinding and examinations for removal of three examples of underclad cracking previously identified in loops 2 and 3 reactor vessel inlet nozzles. Removal was being accomplished in accordance with procedure WBNP-SP-1 which included examination requirements. Operations specifically viewed by the inspector included grinding, etching of the heat affected zone, visual inspection, and magnetic particle examination.

No violations or deviations were identified.

7. Worker Concerns (Units 1 and 2)

Prior to the inspection, the NRC inspector was advised of two worker concerns relative to welds and radiography. Actions taken by the inspector relative to these concerns are as follows:

a. Reactor Vessel Outlet Nozzle to Piping Weld (Unit 1)

From the worker's description and information provided by TVA, the NRC inspector determined that the reactor vessel nozzle to outlet piping weld about which concern had been expressed was identified as weld 1-068D-W001-01 on Operation Sheet 1-68-F-2-8. TVA was requested to have the radiographs for this weld available for review in a subsequent NRC inspection. Concerns regarding the acceptability of the weld and radiography are considered an unresolved item, identified item 390/81-02-02, Concerns on RC Piping to RV Outlet Nozzle Weld.

b. Penetration Welds (Unit 2)

From the worker's description and information provided by TVA, the NRC inspector determined that the worker was concerned about the containment vessel penetration field welds for penetrations identified as MK-X-15, 17, 20A, 20B, 21, 22, 24, 30, 32, 33, 45, 46, 81 and 107. TVA was requested to have the radiographs for these welds available for review in a subsequent NRC inspection. Concerns regarding the acceptability of these welds and radiographs are considered an unresolved item, identified 391/81-02-02, Concerns on Radiographs for Penetration Welds.