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

Report Nos.: 50-327/84-16 and 50-328/84-16

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

Docket Nos.: 50-327 and 50-328

License Nos.: DPR-77 and DPR-79

Facility Name: Sequoyah 1 and 2

Inspection Dates: July 9 - 13, 1984

Inspection at Sequoyah site near Chattanooga, Tennessee

Inspector: for W. J. Ross — 8/2/84 Date Signed

Approved by: J. J. Blake, Section Chief — 8/2/84 Date Signed
Engineering Branch
Division of Reactor Safety

SUMMARY

Areas Inspected:

This routine, unannounced inspection involved 42 inspector-hours on site in the areas of plant chemistry and inservice inspection of pumps and valves.

Results:

No violations or deviations were identified.

REPORT DETAILS

1. Person Contacted

Licensee Employees

*L. M. Nobles, Plant Superintendent (D&E)
*M. R. Harding, Engineering Group Supervisor
*R. W. Fortenberry, Engineering Supervisor
*W. L. Williams, Chemistry Unit Supervisor
*J. M. Anthony, Operations Supervisor
*R. E. Alsup, Compliance Supervisor
H. D. Elkins, Instrument Maintenance Supervisor
D. Goetcheus, Staff Specialist
J. Dills, Chemical Engineer
J. Mullenix, Chemical Engineer
A. Lones, Chemical Engineer

Other licensee employees contacted included three engineering test engineers, three technicians, two operators, and two mechanics.

NRC Resident Inspectors

*E. J. Ford
S. D. Butler

*Attended exit interview

2. Exit Interview

The inspection scope and findings were summarized on July 13, 1984, with those persons indicated in paragraph 1 above. The licensee acknowledged the inspection results with no dissenting comments.

3. Licensee Action on Previous Enforcement Matters

Not inspected.

4. Unresolved Items

Unresolved items were not identified during this inspection.

5. Plant Water Chemistry (92706)

This inspection consisted of the following interrelated efforts:

° Assessment of the capability of the major components of the secondary water system to protect the primary coolant pressure boundary by ensuring the absence of corrosive environments in the steam generator.

- Assessment of the adequacy of the Sequoyah water chemistry program to monitor the quality of water in the primary, secondary, and auxiliary water systems, and

- Assessment of the licensee's ability to control the quality of water in the plant through implementation of the Sequoyah water chemistry program.

a. Assessment of the Design of Components in the Secondary Water System

At the time of this inspection, both Sequoyah units were operating at full power; Unit 1 in its third fuel cycle and Unit 2 nearing the end of its second fuel cycle. The inspector reviewed the "as-built" secondary water system against the description that is in the 1982 revision of the Final Safety Analysis Report (FSAR), especially Section 10.0, "Steam and Power Conversion". The inspector followed up on previous interviews of cognizant plant personnel (c.f., Inspection Report Nos. 50-327/83-17 and 50-328/83-17) to review the operational history of the following components of the secondary water system and to determine what efforts have been taken to maximize the effectiveness of this system.

(1) Main Condenser

The two Sequoyah units dissipate waste heat energy through the main condenser into a circulating cooling water (CCW) system that takes water from the Tennessee River (Chickamauga Reservoir). The CCW can be used, in conjunction with two natural draft cooling towers, in either an open, closed, or helper mode of cooling. Industry experience has shown that the main condenser is a principal pathway for air and water inleakage into the secondary water system of a power plant. Through contamination of the condensate/feedwater, such inleakage may provide the inorganic and organic impurities that cause corrosive environments in the steam generators and in the low-pressure turbines.

The inspector established that the water in the Chickamauga Reservoir has relatively low concentrations (5-15 ppm) of silica and anions of strong, corrosive acids (i.e., chloride, nitrate, sulfate) and is, therefore, compatible with the copper-steel tubes of the main condenser. The licensee uses an Amertap system to polish the inner surfaces of these tubes to prevent fouling by bio-organisms. (Water taken from the river for other cooling purposes is chlorinated to inhibit growth of aquatic organisms, such as asiatic clams, in the piping, valves, and heat exchangers of these cooling systems.

The licensee performed a 100% eddy-current test of condenser tubes prior to initial startup and continues to perform visual inspections and partial eddy-current tests during each refueling outage. To date, there have not been any significant tube leaks. The licensee monitors the integrity of the condensers by continually measuring the cation conductivity of the water in each hotwell, as well as the dissolved oxygen of this water, when the inline oxygen analyzer is operable. In addition, the quality of the condensate (i.e., cation and specific conductivity, pH, and concentrations of sodium and dissolved oxygen) is also monitored continually at the discharge of the hotwell pumps. Other parameters may also be determined, as a means of establishing the quality of the condensed steam, by means of 'grab' samples also taken at the discharge of the hotwell pumps.

The inspector considers the condensers to be providing an effective barrier against ingress of air and CCW water. The licensee's monitoring program also takes into consideration the possibility that copper may be removed from the condenser tubes by erosion or corrosion and transported to the steam generator where localized corrosive environments could be induced through plating of the metal on steam generator tubes or precipitation of copper oxide sludge on the tube sheets. Further discussion related to the transport of copper will be presented in later sections of this report.

(2) Condensate Makeup Water

A second potential source of corrosive contaminants in the condensate/feedwater is the water used for condensate makeup, to replace water lost as blowdown, and for regenerating the condensate polisher resin beds. As will be discussed in the next section, large amounts of water are required to operate the condensate polishing system. Consequently, the licensee has increased the capacity of the plant's original output to ~360 gpm by temporarily installing two additional water treatment facilities while a larger, permanent facility is being constructed. The overall water treatment process includes the use of a flocculating and clarifying step followed by passage of the water through a deaerator and a series of ion exchange resin beds, before the purified water is transferred to the Primary Water Storage Tank (PWST) or to Condensate Storage Tank (CST).

Acceptable criteria have been set for the efficiency of the cation and mixed resin beds in the water treatment plant, and the effluents of these beds are monitored daily. Also, the specific conductivity and silica content of the final product are monitored continually.

The product of the water treatment plant is protected from ingress of air by cover 'bladders' that have been installed in both the PWST and the CST. In addition, a nitrogen purge system has been installed on the CST to continually agitate the water and to remove any air that penetrates the bladder.

The inspectors considers that these precautions will enable the licensee to produce water of acceptable quality for the following uses: reactor coolant makeup; suction for the Auxiliary Feedwater Pumps during plant startups and for emergencies; regeneration of condensate polisher resin beds; and condensate makeup. When used for the last purpose, water is pumped from the CST to the hotwells; thereby, undergoing further deaeration. The inspector was informed that the vacuum in the hotwell does not provide complete degassification of makeup water, however, and 'spikes' are usually observed in the dissolved oxygen monitor during the addition of water from the CST.

The inspector was informed that occasionally there are indications that the product of the water treatment plant contains organic and/or dissolved carbon dioxide. An investigation is underway to establish if transients in the conductivity of the CST water is associated with such species.

(3) Condensate Polishing System

The inspector observed that each of the Sequoyah units has a condensate cleanup system that is manufactured by the L&A Water Treatment Corporation and which consists of six deep beds of ion exchange resins and common regeneration vessels. Through the use of 5 of the 6 vessels, 100% flow can be achieved during plant startup or whenever significant filtrations or polishing is needed. When the quality of condensate/feedwater meets the criteria established the licensee's water chemistry program, four of the resin beds are bypassed and placed in standby so that only 20% of the condensate is pumped through the remaining resin bed. This procedure minimizes contamination of high quality feedwater through inleakage of resin or 'throw' of silica or regenerate chemicals (sodium hydroxide and sulfuric acid) while still providing standby protection against contaminants that may enter the condensate through the main condenser or makeup water.

The effectiveness of the condensate polishers is monitored through the continual measurement of sodium, silica, cation and specific conductivity and through the analysis of 'grab' samples for sodium and sulfate (for indication of 'throw' of regenerate chemicals). As will be discussed further, in Section 5.c, the inspector considers that the design and operation of the condensate polishing system provides effective removal of potentially corrosive contaminants in the condensate.

(4) Chemical Addition

The Sequoyah secondary water chemistry program is based on the control of pH and oxygen through the addition of all-volatile chemicals; i.e., ammonia and hydrazine. At present, these chemicals are added immediately downstream of the condensate polishers in Unit 1 and downstream of the feedwater pump turbine-condenser in Unit 2. The inspector was informed that the injection point in Unit 2 will be moved closer to the polishers during the next refueling outage so that the desired chemical conditions will be established earlier in the feedwater cycle.

(5) Feedwater Lines

A third potential cause of steam-generator tube corrosion is the transport of soluble and/or solid corrosion products from other parts of the secondary water system to the steam generator. These materials, through plating out on the tubes or precipitating as sludge on the tube sheet or in the tube-tube support plate annular gaps, increase the possibility for localized stress corrosion or for denting of the tubes. Of special concern is the transfer of oxides of iron (because of the large mass of sludge that may be generated) and oxides of copper (because of the increased probability of the initiation of localized corrosion).

In the Sequoyah secondary water system, the chemically treated feedwater is pumped, in three parallel lines, through the gland steam condenser, feedwater pump condenser, and three low-pressure heaters to the suction of three condensate booster pumps. The water is then pumped through three intermediate-pressure heaters to the feedwater pumps, and then through high-pressure heaters to the four steam generators. During startup, the condensate is cleaned to the desired quality for use in the steam generators by pumping the water to and from the hotwells through increasingly longer paths that cycle through the condensate polishers. Through this procedure all of the pipes (except ~100 feet immediately upstream of the steam generators) that carry water from the hotwell to the steam generators are flushed of solids and the condensate/feedwater purified to the desired quality. However, at Sequoyah, the auxiliary feedwater pumps are used during the first stages of plant startup and these pumps take suction directly from the CST. Consequently, the licensee places a 'hold' in power ascension at 5% power to permit the condensate/feedwater to be cycled through the condensate polishers until any loss of water quality caused by the injection of CST water has been recovered.

Approximately 45% of the total feedwater used by each unit at full power is supplied from condensed extraction steam. During startup, the extraction steam lines and drain tanks are also flushed by cycling the drains back to the hotwell. The licensee cycles these drains forward to the suction of the feedwater pumps when additional feedwater is required (~30% power) and when the quality of the drain water has been determined to be acceptable.

The inspector was informed that the licensee has developed a plan to replace the presently installed feedwater heaters that have tubes fabricated from 90-10 copper-nickel alloy so that transport of copper to the steam generator can be eliminated. In the interim, copper and iron are monitored in grab samples of feedwater. The licensee also continually analyzes the feedwater for the following chemical parameters: cation and specific conductivity, pH, sodium, and dissolved oxygen. The inspector considers that the licensee is taking the proper steps to prevent contamination of the water in the steam generator by ensuring that only water of acceptable quality is pumped into the steam generators.

(6) Steam Generators

Each Sequoyah unit has four Model 51 steam generators, the units differ in that the steam generators in Unit 1 blowdown (~50 gpm per steam generator), through a heat exchanger, to the condensate lines upstream of the condensate polishers. Consequently, all of the blowdown subsequently passes through an ion exchange bed. The blowdown from the steam generators in Unit 2 currently is cooled in a flash tank rather than by a heat exchanger. The licensee believes that ~50% of the chemical impurities in the blowdown are retained in the steam and are being cycled back, through extraction steam drains, to the feedwater without being cleaned by the condensate polisher.

Both units have experienced operational perturbations that have been detrimental to the integrity of the steam generator tubes, and denting was observed in Unit 1 after only 160 effective-full-power-days of operation. As a consequence, the licensee has initiated a program to curtail corrosion of the steam generator and to extend that life of the two units. In addition to increased control over chemistry and the quality of water in the steam generators (see Sections 5.b and 5.c of this report), this program also includes modifications to the steam generators that will permit better conditions to be maintained during layup; i.e., through the use of a nitrogen cover and continual recirculation of the water in the steam generator under the desired chemical control.

As the result of concerns about the degradation of the steam generators (Unit 2 currently has a very small primary/secondary leak), the licensee has sludge lanced the steam generators in Unit 1 four times and those in Unit 2 twice since the units became operational in 1980. From 150 to 500 pounds of sludge were removed from each steam generator in Unit 1 each lancing and

100-180 pounds of sludge were recovered from each steam generator in Unit 2 both times. The inspector was briefed on the licensee's evaluation of these lancing results and on subsequent inspections of the internals of the steam generators. The inspector was also briefed on a new approach to removing sludge and scale that will be tested during the upcoming refueling outage for Unit 2.

(7) Steam Lines

The inspector reviewed the operation and surveillance of the steam components of the secondary water system relative to two concerns. During outages, it is not usually possible to keep the steam lines in a layed-up environment that will prevent rusting of the inner surfaces. Consequently, relatively large amounts of iron oxides may be transferred to the turbines or the hotwell during startup. The licensee informed the inspector that large scale transport iron oxides had not been observed at Sequoyah, although the steam lines had been exposed to air during refueling outages.

During plant operation, the steam lines are potential pathways for carry-over of silica and acidic components of the feedwater (chlorides, sulfates) that might corrode or erode the blades and disks of the high and low pressure turbines. Again, the inspector was informed that no evidence of stress corrosion cracking had been observed when the Unit 1 turbines were inspected after the first fuel cycle. At least two Unit 2 rotors will be inspected during the upcoming outage.

SUMMARY

The inspector considers the major components of the secondary water system in the currently "as built" units at Sequoyah to be consistent with the description provided in Sections 10.4.1 (Condenser), 10.4.6 (Condensate Polisher), and 10.4.7 (Feedwater System and Steam Generator) of the FSAR. The integrity of the main condenser meets the design limits for air inleakage (0.005cc of oxygen per liter of condensate) and, together with the temporarily expanded water treatment plant, is ensuring that the quality of the condensate/feedwater is acceptably high, even when only 20% of the flow passes through the condensate polishers. Likewise, the licensee's startup procedures ensure that all water pumped into the steam generators meets the criteria established in the water chemistry program. The licensee recognizes the potential for incompatibility of the condensate/feedwater and the cast iron and/or copper-containing process piping and heat exchangers and, especially the potential for corrosion if the pH of the water is not kept within narrow bounds. Consequently, one of the major elements of the licensee's corrosion mitigation program is the removal of copper-containing components.

b. Scope and Adequacy of the Licensee's Water Chemistry Program

Technical Specification 3.4.7 identifies the chemical parameters in the primary (reactor) water system that must be monitored to protect the components of the reactor water system against corrosion. Similarly, Technical Specification 6.8.5.c requires that the licensee have a secondary water chemistry program designed to inhibit steam generator tube degradation and defines this program as including the following elements:

(1) Identification of a sampling schedule for the critical variables and control points for these variables,

(2) Identification of the procedures used to measure the values of the critical variables,

(3) Identification of process sampling points,

(4) Procedures for the recording and management of data,

(5) Procedures defining corrective actions for off-control point chemistry conditions,

(6) Procedures identifying (a) the authority responsible for the interpretation of the data; and (b) the sequence and timing of administrative events required to initiate corrective action, and

(7) Monitoring of the condensate at the discharge of the condensate pumps for evidence of condenser in-leakage. When condenser in-leakage is confirmed, the leak shall be repaired, plugged, or isolated within 96 hours.

In Table 10.3.5-1 of the Sequoyah FSAR, the licensee has summarized the specifications that are to be met for selected key chemical parameters in the feedwater and blowdown during the following modes of plant operations: cold wet-layups, hot shutdown/standby, startup, and power operation. Likewise, in Table 10.3.5.2 are given the limits for specific conductivity, sodium, and dissolved oxygen in the condensate makeup water for all modes of operation. A similar set of specifications for the quality of the condensate polisher effluent is given in Table 10.4.6-1 of the FSAR.

The inspector established that the licensee has developed a water chemistry program that implements the requirements of the Technical Specifications. This program also has been designed to incorporate the guidelines of the Steam Generators Owners Group (SGOG) and the Electric Power Research Institute (EPRI) and to take into consideration the NSSS vendor's specifications.

The inspector reviewed current procedures and drafts of proposed revisions to these procedures and established that responsibilities had been designated and guidance had been provided for the following administrative activities that are required to implement Technical Specification 6.8.5.c.

- Establishing key parameters to be monitored when the plant is in wet layup, hot shutdown/standby, and power operation, and setting acceptable limits for these parameters,
- Developing, reviewing, approving, and updating chemical procedures,
- Scheduling tests and analyses,
- Training analysts,
- Performing chemical measurements,
- Providing calibrations and quality control,
- Documenting and reviewing tests results, and
- Taking required action on the basis of test results.

Through interviews of licensee personnel, the inspector was informed that the management of the plant and in corporate positions are cognizant of the need to meet the objectives listed in the FSAR and in the SGOG/EPRI guidelines and are supportive of the water chemistry program. The inspector also verified that the plant's table of organization provides for the chain of responsibility and authority needed to implement the day-to-day chemistry control program.

On the basis of this review, the inspector concluded that the licensee has developed the framework for an effective water chemistry program.

c. Implementation of the Sequoyah Water Chemistry Program

The inspector assessed the degree to which the licensee is fulfilling the requirements of the Sequoyah Technical Specifications and is implementing the water chemistry program that is currently being used to meet the FSAR objectives. This assessment was based on discussions with licensee personnel, review of procedures, observations of the performance of chemistry tests, and an audit of recent test results. This part of the inspection is summarized as follows:

(1) Activities related to the water chemistry program are performed by personnel in both the Chemistry Section, under the Chemistry Unit Supervisor (who reports to the Engineering Supervisor), and in the

Operations Department. The Operations Department has responsibility for operating the water treatment plant, the condensate polishers, and the demineralizers in the primary water system. Normally there is one or more Assistant Unit Operators (AUOs) and possibly an Auxiliary Operator (AO), dedicated to each of these two systems during each shift.

Surveillance, control, and R&D activities required to implement the plant's Technical Specifications and the licensee's secondary water chemistry program are performed by the personnel in the Chemistry Section. Currently, the Chemistry Section has a staff of ~38 personnel that consists of the Unit Supervisor, ~6 support chemical engineers and six shifts of ~5 technicians each (headed by a senior technician on each shift and under the direction of the Laboratory Supervisor).

(2) Technical training is provided to both the AUOs and Chemical Technicians through formal qualification courses and through on-the-job-training under the supervision of experienced AUOs or Chemical Technician. The inspector was informed that ~50% of the plant's complement of 60 AUOs are qualified to operate the condensate polishing system as prescribed in System Operating Instructions SOI-14.1 and SOI-14.2. Likewise, all of the Chemical Technicians meet the basic qualifications required by the ANSI standards (for training in science and mathematics) and most have been qualified to perform all chemical tests and operate all chemical instruments (except radiochemistry instrumentation).

(3) The licensee is able to monitor all key chemical parameters by means of a comprehensive system of inline analytical chemistry instrumentation that includes displays at panels in the chemical laboratory (Titration Room) and/or at panels for the condensate polishers. No chemical parameter is displayed in the Control Room. 'Grab' samples from key control points can also be taken at a sampling sink in the chemical laboratory and in the Hot Chemistry Sampling Room (primary water system and steam generator blowdown).

(4) The inspector verified that written procedures have been developed for the following: sampling process streams (Technical Instruction TI-16); calibrating analytical instrumentation (TI-20) and procedural calibrations (TI-11); determining specific chemical parameters (TI-16), scheduling analyses (Section Instruction Letter C-10; logging and reviewing test results (TI-37), and taking the necessary corrective action based on the deviation of a test result from a Technical Specification limit or from an administrative limit specified for the parameter. These actions are specified in TI-27 and are applicable also to the AUOs who operate the demineralizers and to Control Room Operators after the Control Room is alerted to an abnormal chemical situation.

SUMMARY

The degradation of steam generator tubes that was observed early in the life of Unit 1 has been attributed, in part, to failures in chemistry control as well as to operational perturbations that allowed low quality water to be injected into the steam generators. Likewise, several hundred pounds of iron oxide sludge was transported into the steam generators of Unit 2 during an operational transient in 1983. These events have given the licensee the incentive to investigate, in mockup experiments, the effect of sludge and trace quantities of corrosive ions on steam generator tubes. The licensee has also investigated, with analytical instrumentation of state-of-the-art sensitivity, the role of condensate polishers as cleanup systems and as potential causes of contamination of the feedwater.

Initial results of the corrosion studies have indicated that the concentration of such potentially corrosive ions as chloride, sulfate, and copper in the blowdown should be kept <20 ppb. Inasmuch as all non-volatile constitutes of the feedwater are concentrated >100 times in the steam generator, when the blowdown rate is ~50 gpm, the concentrations of corrosive ions in the feedwater must be maintained at levels that challenge the sensitivity of detection. The inspector was informed that the concentration of sulfate in the feedwater remains >1 ppb for several hours after a regenerated resin bed has been placed in service in the condensate polishing system. In an effort to reduce this amount of 'throw,' the licensee has increased the number of backwashes of freshly regenerated resin until ~80,000 gallons of high purity water now used whenever a bed is regenerated. This amount of water exceeded the capacity of the plant's water treatment plant and required the installation of additional temporary facilities until a water treatment plant of greater capacity can be constructed. Even after these measures have been taken, the amount of sulfate found in the feedwater remains unacceptably high when more than one resin bed is in service.

To achieve the analytical sensitivity required to control the concentrations of sulfate and chloride, the licensee has acquired ultra-sensitive ion chromatographs for use in analyzing 'grab' samples from the secondary (and primary water systems) and is planning to install another ion-chromatograph as an inline monitor of the quality of feedwater. The inspector was informed that ~10 technicians and engineers are already qualified to operate these state-of-the-art analytical instruments. Continuous sodium and chloride analyzers are also to be installed as inline monitors of steam generator blowdown. In addition, digital temperature indicators are to be installed on inline instrumentation to increase the accuracy of these instruments.

These planned additions to a surveillance system that is already highly automated will increase the responsibilities of the plant's instrument maintenance personnel. During this inspection, the inspector observed that essentially all surveillance and control instrumentation associated with the condensate polisher system and the chemistry laboratory was in operable condition. The inspector considered this excellent situation to reflect the licensee's clear understanding of the role this instrumentation has in an effective water chemistry program and the resources that must be dedicated to the upkeep of this instrumentation.

6. Inservice Testing of Pumps and Valves (92706)

During this inspection, Sequoyah Unit 2 was placed in a 72-hour action condition because of the failure of centrifugal charging Pump 2A-A. The failure of Pump 2A-A resulted in the violation of Technical Specification 3.5.2 because this Unit no longer had two operable ECCS systems.

Although a problem was indicated on July 3, 1984, when the smoke detector in the pump room was actuated, the two centrifugal charging pumps were operated interchangeably until July 8, 1984, when Pump 2A-A failed as the result of failure of the pump motor and motor bearings. Pump 2A-A had been tested on July 5, 1984, per Surveillance Instruction SI-40 Part A to implement the requirements of Subsection IWP-3000 of Section XI of the ASME Boiler and Pressure Vessel Code. All test parameters were observed to be within allowable ranges.

Pump 2A-A had been changed out in October 1983; however, the motor was original issue - as are motors for all centrifugal charging pumps at Sequoyah. Replacement of the failed motor was delayed until a new coupling could be obtained to mate the new motor with the speed-increasing gear of the pump.

Post-maintenance tests were performed on Pump 2A-A on July 12, 1984, per SI-40 Part B. All tests parameters were acceptable except for the differential pump pressure (2416.5 psid) that was in the Low Alert range. Per directions of Section IWP-3230, the licensee will double the frequency of testing (i.e., 45 days rather than 90 days) until the cause of the deviation is determined and the condition corrected.

Failure of Pump 2A-A alerted the inspectors to two possible generic concerns. The 72-hour action condition was invoked because two of the three charging pumps at Unit 2 were inoperable. The licensee informed the inspectors that credit is not taken for the positive displacement (PD) charging pump to inject coolant into the Reactor Coolant System of either unit because these pumps continually exhibit operational problems. The PD charging pumps are used to pressurize the Upper Head Injection System but are not included in the inservice inspection program for safety-related pumps, as required by Subsection IWP of Section XI of the ASME Code. Consequently, the PD charging pumps are not tested per the requirements of the Code. Therefore, failure of either centrifugal charging pumps at each Sequoyah Unit will result in a violation of Technical Specification 3.5.2.

This subject is designated for inspector followup as item IFI 327-328/84-16-01, "Reliability and Use of Positive-Displacement Charging Pumps."

The second concern relates to the scope of the ASME Code, i.e., pumps are covered pump but motors are not. Although such parameters as vibration and current are frequently measured on pump motors, the ASME Code does not identify or require such tests. This concern will be brought to the attention of appropriate personnel in NRC.