UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W.
ATLANTA, GEORGIA 30323

Report Nos.: 50-338/91-18 and 50-339/91-18
50-280/91-22 and 50-281/91-22

Licensee: Virginia Electric and Power Company
Glen Allen, VA 23060

Docket Nos.: 50-338 and 50-339
50-280 and 50-281

License Nos.: NPF-4 and NPF-7
DPR-32 and DPR-37

Facility Name: North Anna 1 and 2
Surry 1 and 2

Inspection Conducted: July 31 and August 1-2, 1991

Inspector: [signature] 8/20/91
Nick Economos, Reactor Inspector — Date Signed

Approved by: [signature] 8/23/91
J. J. Blake, Chief — Date Signed
Material and Processes Section
Engineering Branch
Division of Reactor Safety

SUMMARY

Scope:

This special announced inspection was conducted for the purpose of evaluating the licensee's pipe wall thinning inspection and replacement program as directed by corporate engineering. Also, the licensee's program for ensuring that longitudinal fitting welds are included in station inservice inspection (ISI) program was reviewed.

Results:

Through interviews of corporate engineering supervisors and senior engineering staff, along with reviews of engineering reports, procedures and drawings, the inspector has ascertained that the licensee has implemented a very comprehensive predictive and preventive maintenance program to monitor piping components subject to erosion-corrosion (E/C) wear. The program utilizes EPRI computer codes to locate and examine piping components subject to E/C wear. Components showing degradation are closely monitored, trended and evaluated by engineering using sufficient conservatism before approving them for continued service. Replacements are generally made from chrome-moly P11 or P22 materials which have demonstrated good resistance to erosion-corrosion attack in secondary water piping systems. These measures provide adequate assurance that a pipe rupture event such as the one experienced at the Surry Power Station in 1986 will not reoccur.

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REPORT DETAILS

1. Persons Contacted

Licensee Employees

I. B. Choate, Staff Engineer, Mechanical
M. W. Henig, Project Engineer
C. M. Hooper, Staff Engineer, Mechanical
*D. A. Sommers, Licensing
W. A. Thomas, Senior Staff Engineer, Mechanical
*E. W. Throckmorton, Supervisor, ISI/NDE Programs

*Attended exit interview

2. Evaluation of Engineering Program(s) for the Control of Erosion/Corrosion Wear in Secondary Water Piping Systems (62700)

Following the feedwater pump suction piping rupture at Surry Power Station Unit 2 on December 9, 1986, the licensee investigated the accident to determine the root cause for the failure and began to develop a program to obtain field data through nondestructive examinations, engineering evaluations, and prescribed corrective measures to preclude the recurrence of similar events. Engineering reports and procedures reviewed were as follows:

- Erosion/Corrosion in Carbon Steel Piping, R&D Report #1880-0352, March 10, 1989
- Secondary Piping and Component Inspection Program, STD-GN-0033, Rev. 1
- Engineering and Evaluation Procedure for UT Inspected Components, ME-022, Rev. 1
- Recommendations to Upgrade Secondary Water Chemistry to Increase pH levels and Reduce Erosion/Corrosion Wear Rates at North Anna and Surry Power Stations
- A Review of the Virginia Power Erosion/Corrosion Inspection Program
- The Surry Pipe Failure Analysis Summary, April 1988
- Engineering Outage Summary Report, Secondary Piping and Component Inspection Program Surry Unit 2, 1991 Refueling Outage, IR-9734, June 18 1991

Through discussions with engineering management, engineering staff, and an in-depth review of the aforementioned engineering documents, the inspector ascertained that the licensee, as well as the nuclear industry, have

developed a relatively good understanding of the erosion/corrosion (E/C), phenomenon in secondary water system carbon steel piping where single and two phase liquid phase conditions exist. According to the literature referenced, E/C wear is caused by the electro-chemical (corrosive) mechanisms of flowing water.

Carbon steel piping under normal secondary system operating conditions corrodes to form a thin protective layer of iron oxide on the inside surface. If this protective layer is removed by the flow assisted corrosion process, the pipe's inside surface will start forming a new iron oxide layer. This cycle of iron oxide layer formation and subsequent removal, leads to a continuous pipe wall loss from the inside surface.

The erosive wear mechanism of non-cavitating single liquid phase flow involves the dissolution of the oxide layer by the liquid flowing over its surface. The oxide formed on the steel has some finite solubility, or equilibrium concentration, in the high temperature water regime. If liquid water with a lower concentrate of dissolved oxygen comes into contact with the oxide surface, a concentration gradient is established and some of the oxide dissolves. Furthermore, if the water is moving, even more oxide will dissolve as a result of convective mass transport. This combination of oxide solubility and convective mass transfer is called the corrosion-dissolution wear mechanism. This mechanism will occur whenever a flowing liquid film contacts the oxide surface.

The corrosion-dissolution mechanism is the reason that E/C occurs in two-phase and single liquid phase flows, but does not occur in single phase vapor (superheated steam) flows where no liquid is present.

Theoretical equations have been written which express the relationship between E/C wear rates and the mass transfer coefficient. According to the literature, this coefficient has been shown experimentally to be an interdependent function of flow velocity, geometry, temperature and pH. Variables known to effect E/C wear in piping are: flow hydrodynamics--velocity, geometry, and moisture (for two phase flow conditions); water chemistry--pH, oxygen level and temperature; piping material chemistry--alloying elements, i.e., chromium, copper and molybdenum. Therefore, from a practical point of view, the only viable means for reducing E/C wear in most secondary water piping made of carbon steel material is by controlling water chemistry and piping material.

Within these areas, the inspector ascertained that the licensee has utilized the Electric Power Research Institute (EPRI), computer code CHECMATE to investigate the effects of pH level on portions of the feedwater pump suction piping at Surry Unit 1 and determined that E/C wear rates can be reduced significantly by increasing the pH of the secondary water. This can be done by increasing the additions of the pH controlling agent or by changing the controlling agent to one which produces higher pH levels at the operating temperature. Subsequent to these findings and additional related investigations by engineering, the licensee implemented

several changes at North Anna and Surry. These include changing the pH controlling agent from hydrazine to morpholine; bypass of the powdered resin condensate polishers allowing for increased pH levels; replacement of feedwater heaters to help reduce copper in the systems; and installation of transport monitors to trend corrosion transport levels to the secondary side of the steam generators. In addition, the inspector ascertained that all feedwater heaters have been replaced with the exception of Surry Unit 2, which has four original feedwater heaters and two drain coolers. These are scheduled for replacement during the 1993 refueling outage.

In reference to component replacement from low carbon steel to chrome-moly material, the licensee, assisted by a contractor (Technicon) and the EPRI computer codes CHEC, CHECMATE and CHEC-NDE, has implemented a very comprehensive program involving inspections, analysis and trending. Through research and field experience, the licensee has determined that replacing existing low carbon steel material, which has zero chromium content, with chrome molybdenum, P11/P22, materials, can reduce the expected E/C wear rate by a factor of five.

Accordingly, the licensee is proceeding with their inspection and component replacement program which is currently referred to as the Virginia Power Secondary Piping and Component Inspection Program. This program is administered under an engineering standard that is within the Virginia Power Nuclear Design Control Program. This document controls all aspects of the inspection program at both sites. The corporate engineering programs group is responsible for the overall administration of the program and corporate mechanical engineering is responsible for overall program development, i.e., databases, criteria, system selection, etc. Site mechanical engineering implements and tracks the inspection program during the outages. It also evaluates inspection data, prepares procedures necessary to repair/replace degraded components and initiates procurement of replacement piping materials. Site construction is responsible for component repair/replacement while site NDE prepares components for inspection and conducts data acquisition.

Secondary water piping systems currently in the program include auxiliary steam, blowdown, condensate, extraction steam, feedwater, main steam, steam drains and water treatment. Approximately five-thousand components have been identified for each of the four Virginia Power nuclear units. Each component within the systems defined as susceptible to E/C attack is assigned a station-unique identifier. Isometric drawings have been specifically prepared for all lines within these systems and each component is identified. A separate database of these components exists for each unit. This database records not only the line, sketch, material, size and schedule for each component but provides for the tracking of inspections and component replacement. This sorting of information allows engineering to easily identify areas of systems which may be entirely replaced due to the projected piecemeal replacement of numerous individual components and to fine-tune the inspection program so as to eliminate areas which are consistently showing little wear.

By data review, the inspector ascertained the total number of components replaced in terms of the total number of components inspected for each plant to be as follows:

	Total Components	Percent Replacement
North Anna		
Unit 1	4,994	14.6%
Unit 2	4,859	20.8%
Surry		
Unit 1	4,334	12.8%
Unit 2	4,184	12.7%

A review of piping inspection results and follow-up actions disclosed that during the 1990/91 outages, 51 of the 1,095 components inspected required replacement. One hundred seventy-nine components are considered potential next outage replacements, and an additional 302 components require inspection next outage. Finally, 563 components will require reinspection after two or more refueling outages as a result of the programmatic evaluation in 1990/91.

Most of the piping replacements performed as a result of inspection at both sites utilized 2-1/4% chromium-1% molybdenum (chrome/moly) steel. This practice was established during the 1988/89 refueling outages to reduce susceptibility to erosion/corrosion wear. Initial inspections of the gland steam system at North Anna indicated a more severe E/C problem than originally anticipated. All immediate replacements were with "in kind" materials due to outage constraints. A gland steam system upgrade project is underway to replace much of the existing piping with either stainless steel or chrome/moly steel materials.

In addition, the inspector ascertained that heavy E/C wear was observed on each of the four crossunder lines of each unit. This damage was generally confined to the region downstream of the turning vanes and the area around the expansion joints. The latter region has been the location of previous through-wall stream leaks during power operation. All heavily eroded areas were built-up to minimum wall thickness or greater by internal weld overlay.

The records indicated that the condition of the crossover piping was generally very good. No weld repairs were required as a result of the programmatic inspections performed during the 1990/91 refueling outages.

By discussion with cognizant personnel, the inspector ascertained that in the interest of optimizing the inspection program and minimizing its impact on operation and maintenance costs, the licensee has undertaken a comprehensive overview of the inspection program focusing on cost reductions for inspection and replacement of components without impacting plant safety.

Within the areas inspected, violations or deviations were not identified.

3. Action Plan for Ensuring that Certain Longitudinal Fitting Welds are Included in Station ISI Program(s) (73755)

   On July 9, 1991, Beaver Valley determined that inspections of longitudinal welds in the low head safety inspection fittings were not performed as required by the ASME Section XI testing program. The subject plant's drawings did not depict the longitudinal welds, and thus they were not included in the site ISI inspection plan. As a result, both trains of the low head safety injection system were considered to be inoperable.

   In response to this information, on July 19, 1991, the licensee initiated an action plan to determine if the Beaver Valley finding is applicable to VEPCO's four units and at the same time prescribe a plan of corrective actions to be taken if it was determined that similar circumstances existed. The subject memorandum/action plan was forwarded to Region II staff and to NRR. At the time of this inspection, the licensee was in the preliminary stages of the action plan, attempting to sort out the applicable systems, code requirements, previously performed inspections, etc. The licensee provided the inspector with a listing of piping systems and potential lines which may contain fittings with longitudinal welds. These included safety injection, primary coolant, recirculation spray, main steam, residual heat removal and chemical volume control, systems. The licensee agreed to keep the inspector and the Region informed of developments as they occur.

   Within the areas inspected, violations or deviations were not identified.

4. Exit Interview

   The inspection scope and results were summarized on August 2, 1991, with those persons indicated in paragraph 1. The inspector described the areas inspected and discussed in detail the inspection findings. Dissenting comments were not received from the licensee.