ABSTRACT

"Condenser Tube Staking Eliminates Vibration-Induced Tube Leaks"

Technical Data

Quad Cities Nuclear Power Station has two boiling water reactors, each designed for 833 Megawatts electric. Both units are equipped with Ingersoll Rand Surface Condensers, Model No. 243-REBT-40.5. Each surface condenser consists of two tandem tube bundles in a single, rectangular-shaped shell. The condenser is a multi-pressure (3) unit of the single pass (series) design and vertically divided. The tubes are constructed of AISI 304 stainless steel and have an effective length of approximately 40'5". There are ten support plates per shell spaced between 40" to 56".

Problem Description and Root Cause

Both of the main condensers were experiencing a high frequency of tube leaks--on the average of one tube leak every 100 days. A tube leak would eventually cause reactor water chemistry to exceed technical specifications and lead to a unit shutdown to locate and plug the leaking tube. The leaking tube would be located by flooding the steam side of the condenser with condensate while personnel were in the waterboxes inspecting for visual water leaks. A very high percentage of the leaking tubes were located on the periphery of the tubesheet and were cracked at a point approximately 1" into the tube. The cracks were mostly circumferential through wall cracks. Four condenser tubes that were known to have circumferential through wall cracks were removed from the condenser and sent to Commonwealth Edison's System Material Analysis Department (SMAD) for failure analysis. The failure analysis report concluded that all four tubes failed by fatigue induced cracking that initiated on the outside diameter surface at the location where the tube is rolled into the tubesheet. These failures were probably initiated by flow-induced vibration caused by steam flow over the peripheral tubes which are subjected to the highest steam velocity.

Solution and Implementation

Two solutions were explored:

(1) To strengthen the location where the tube failure was occurring; and

(2) To remove the vibration by supporting the entire tube.

Quad Cities attempted to install tube sleeves in the condenser tubes to strengthen the tube-to-tubesheet area; however, the sleeves would not stay in place due to insufficient sleeve expansion. This attempt having failed, the second option to stake the condenser tubes was undertaken.

Various tube stake manufacturers were contacted to solicit their design. The Atlantic Group was chosen based on their experience with staking and their proven design. Their *Cradle-Lock*® design, which has been awarded two U.S. and several foreign patents, is stamped from stainless steel in a "V" shape, with dimples at tube locations. When installed, the spring action of the "V", coupled with the dimples, locks the stakes and the tubes into a single, vibration-free unit. Contact area between the stake and each tube is increased by hundreds of times (conventional stakes offer only a single point of contact--the *Cradle-Lock*® "cradles" the tube throughout the surface area of each indentation). The stakes do not shift over long periods of full capacity operation, as conventional stakes do, thereby reducing maintenance. The stakes have been installed in over 70 units worldwide, with no reports of further vibration problems.

Cradle-Lock® stakes were installed around the entire periphery of the Unit 2 condenser during the Spring of 1993. Since this installation, there have been zero tube leaks on Unit 2 that can be attributed to condenser tube vibration. *Cradle-Lock*® stakes were then installed around the periphery of the upper third of the Unit 1 condenser in May of 1994. Since this installation, there have been no tube leaks on Unit 1 that can be attributed to tube vibration.