

Nuclear System Design
NE 472/572
Spring 2011

Purpose of Project:

The purpose of the project is to develop an acoustic system to quickly determine the existence of cracking in steam generator tubes before leaks develop.

Project Description:

Introduction

The steam generator is probably the most costly component of a pressurized water reactor to maintain. The repeated wetting and drying environment of the secondary side of a steam generator contributes to corrosion and cracking mechanisms. Stress corrosion cracking, chemical corrosion, fretting-wear, and fatigue are only some of the more important failure mechanisms of steam generator tubes. Since a steam generator has from 4,000 to 16,000 tubes, and the tubes are in a U-shaped bundle, tube replacement is usually not a viable option. Instead, failed tubes are typically plugged. In the decade of 1980-1990, over 44,000 steam generator tubes were plugged world-wide. Plugging steam generator tubes decreases the capacity of the plant, so that in time it will become cost effective to replace the steam generator.

Because the steam generator tubes are a barrier between the radioactive primary coolant and the secondary system, the NRC requires regular inspection of the tubes. In many cases inspection is required every fuel cycle, and in some newer plants, every three fuel cycles. In cases where primary-to-secondary leakage is determined to exceed 5 gallons per day prior to shutdown for a refueling outage, a leaker-forced-outage is required.

Various non-destructive testing techniques have been used, but eddy current testing is the method of choice for most inspections. A tube with a standard flaw is needed to judge the size of the defect if one is detected. The method can be time consuming and subjective in many cases, but satisfactory results have been obtained.

Proposed Project

It is proposed that acoustic techniques be examined as a survey tool to identify failed steam generator tubes. The technique would be used to examine a large number of tubes simultaneously, and potentially cracked tubes would then be examined carefully, probably with eddy current inspection.

A crack in a tube will very significantly alter the resonant frequency of a tube. This is easily demonstrated by striking tubes with and without cracks and listening to the tone produced. It is proposed to attach a small transducer or pair of transducers to a tube during an outage and make a frequency scan in the audible range. The resulting spectrum of sonic vibration would then be analyzed, comparing tubes. A tube with a different spectrum would indicate a mechanical change such as a crack or crud build-up inside the tube. A threshold will be established for the shift in spectral peak frequency, combined with an overall tolerance on the allowable change in the signal RMS value. This would enable the detection of both structural integrity and/or tube fouling. An array of even ten or 100 such transducers might be placed on a single fixture and an automated sequence of testing be initiated.

The advantage of such a system is that it permits rapid inspection of a steam generator. However, considering the complexity of the steam generator tube bundle, the small perturbation resulting from a crack might not be detectable, but the payoff could be very large if the technique is shown to work. It might even be possible to identify the resonant frequency of a cracked tube during reactor operation. Refinement of the technique might lead to an on-line real-time monitor of the steam generator tubes.