U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Collaborators: None

Title: Development of Design Criteria for Fluid Induced Structural Vibration to Steam Generators and Heat Exchangers

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Present designs of heat exchangers and steam generators in pressurized water reactors (PWR) are based on past designs that worked, over design or difficult to obtain one-of-a-kind expensive empirical data. Although present guidelines provide an ad-hoc solution to the problem of fluid induced vibration, at present a unified approach based on simultaneous modeling of thermal-hydraulics and structural behavior does not exist. As a result designs are overly constrained with a resulting economic penalty. If, on the other hand, less constrained designs are developed, the possibility of occurrence of damaging component vibration exists. The objective of the proposed work is to develop complete models that will delineate stability boundaries for fluid-structural interactions that are supported by laboratory experiments and can be used for steam generator and heat exchanger design avoiding economic penalties resulting from overdesign and conservatisms needed to accommodate safety issues.

A basic study of single and two phase flow across tube bundles is proposed. The study has both experimental and theoretical components to it. Single phase studies will involve velocity and pressure measurements in tube arrays. Laser Doppler Anemometry will be used to determine the velocity field. In two phase flow studies, void profiles in the passages between tubes and pressure distribution around tubes will be measured. Most of the experiments will be conducted on arrays of flexible tubes. The tube arrangement and tube pitch to diameter ratio will be varied parametrically. In the experiments, data for transient fluid force acting on the tube, average void fraction around the tubes, damping factors in two phase flow, and displacement of the tubes from their initial position will be obtained. Instability maps for the onset of fluid-elastic instability in tube arrays will be developed. To study the effect of stiffness of the flow system, experiments will be conducted with air-water and steam-water mixtures. In the experiments with steam-water mixtures, tubes will be heated to initiate boiling on the tubes.

Theoretical work will include development of constitutive relations and the solution of governing fluid-structure equations with appropriate boundary conditions. Vorticity transport formulation will be used to solve the governing equations numerically. A combination of experimental data and modeling will be used to develop design guidelines that include the functional relationship of stability and the design parameters like tube material, wall thickness, distance between supports and type of support.
