INSERVICE INSPECTION SYSTEM DEVELOPMENT PROGRAM

A. Purpose

In the B&W steam generator design, single walled tubing separates sodium from water. A failure of the wall can produce a highly exothermic reaction between sodium and water. Periodic inservice inspection (ISI) is required to assure integrity of the wall during operation of the generator. Because conventional tubing inspection techniques do not apply to the proposed generator design, the goal of this task is for the B&W Lynchburg Research Center (LRC) to develop a new inservice inspection system.

The ISI system is being designed to inspect long helical tubing having thick ferromagnetic walls. Tubing parameters are listed in Table I. The purpose of periodic ISI inspections is to detect defects or wall thinning which may produce a tubing failure during the subsequent operation of the generator. Additionally, the system could provide information on the size, orientation, and location of defects (see objective for performance goals) so that the severity can be evaluated. UT Inspection has been selected as the most promising technique for the B&W steam generator design.

TABLE I

TUBING PARAMETERS

Material:	Croloy 2-1/4
Maximum Tubing Length:	580 feet
Minimum Bend Radius:	9 inch
Helix Diameter:	Min. 40 inch Max. 140 inch
Tub Cross Section:	(nominal)
I.D.	.89 inch
O.D.	1.25 inches
Wall	.18 inch

Ultrasonic techniques are being pursued in this feasibility study since present eddy current (EC) techniques do not seem practical for thick walled, ferromagnetic, helical tubing. From past and current work, the French eddy current system for helical tubing applies only to non-ferromagnetic materials, the British eddy current approach is not directly

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applicable to the BRP tubing configuration, and the investigations at Oak Ridge National Labs (ORNL) do not address the sharp bends and weld joints in the B&W tubing design. This work indicates that ferromagnetic tubing of Table I dimensions is impractical for eddy current inspection.

B. Objectives

The objectives in chronological order of this development project are as follows:

1. Develop an ultrasonic test technique that will detect simulated flaws >15% of nominal wall (ELOX notches .250" wide) oriented axially and circumferentially.

2. Develop an electronic system that can be miniaturized for in-pipe translation with the transducers that provide signals via a cable to the ISI operations console.

3. Develop a cable transport system that propels the transducers and electronics through the full length of steam generator tubing.

4. Demonstrate flaw detection sensitivity and electronic transducer switching and probe stability.

5. Develop full scale coverage (10% overlap) ultrasonic insonification in the tube axial and circumferential direction for code type flaw detection.

6. Develop thickness measurement sensitivity of 5 mils over the range of nominal wall sizes (.140" to .180").

7. Demonstrate full length cable transport system.

8. Develop a data acquisition system to perform demultiplexing and logging of data from all transducers.

9. Provide a single pass flaw and thickness detection and measurement system that can accomplish a test in less than 30 minutes per tube (UT sensitivity will not be sacrificed for speed of inspection).

10. Perform a baseline code type inspection of the B&W steam generator in both horizontal and vertical positions followed by an ISI after one year of steam generator service.

C. Technical Background

The problem of inspecting liquid metal steam generator tubing has been addressed in earlier investigations. At the Experimental Breeder Reactor-II in Idaho Falls, Mr. K. J. Longua et. al. of Argonne has

inspected duplex tubing using an ultrasonic technique. Preliminary ultrasonic, electromagnetic acoustic (EMAT) and eddy current techniques for inservice inspection were investigated at the Hanford Engineering Development Laboratory in programs of Mr. J. C. Spanner. At ORNL, Mr. C. V. Dodd has achieved eddy current detection sensitivities for ferromagnetic tube thinning of approximately 10%. At Atomics International, Mr. H. Neeley reports detecting 2% changes in wall thickness using an ultrasonic technique. He transported the probe through 70 ft. lengths of the "hockey-stick" steam generator configuration. The results of past efforts indicate that present EC inspection techniques for conventional steam generator tubing (nonferromagnetic) typically can detect defects that penetrate approximately 20% in the through-wall direction. This work contributes to and guides the current effort.

The B&W tubing design contains many bends producing far greater cumulative drag forces than in the single 90^{o} bend of the hockey-stick design. The drag force on a cable pushed or pulled through coiled tubing increases exponentially with the number of bends. To avoid these exponential drag forces, a patented B&W Limited process has fluid flowing around the cable and probe. If beads are placed along the cable, the driving force is uniformly distributed and the drag forces become linearly additive with respect to total length instead of exponentially with the number of beads.

D. Project Plan

The following project plan has the goal of developing an ISI system utilizing ultrasonic techniques which has a sensitivity to defects and wall thickness variations which are equal to or better than that of conventional eddy current techniques presently used to inspect nonferromagnetic steam generator tubing. The planned transport system consists of a flexible hose containing the probe with a beaded cable connected to one end of the tubing. A return hose to a pump is connected to the other end of the tubing. The cable plays out from a storage container when fluid is pumped through the hose into the tubing. As the probe passes through the tubing, electrical signals are transmitted via the cable into signal processors and then to the display system.

A preliminary investigation will select the optimum ultrasonic inspection technique. It is anticipated that multi-element sensors will be used to provide complete circumferential coverage for flaw detection. The goal is to develop arrays which will measure thickness (longitudinal waves), detect axial flaws (shear waves) and circumferential flaws (shear waves) and perform inspection in a single pass.

A prototype system will be designed and fabricated for operation at LRC on a full length of helical tubing (including pigtails). Based on the prototype operational results at LRC, the probe and cable will be redesigned and retrofitted for the fieldworthy version to perform baseline and inservice inspection at sodium components test installation (ETEC). System

inspections at Barberton will be performed by Engineers on selected tubing to provide proof of principle. The complete baseline will be performed at the California test site, and the ISI will be performed at the end of the test program.