ACOUSTIC TOOL FOR LEAK INSPECTIONS IN STEAM GENERATOR DIVIDER PLATES

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Abstract

Cross flow leakage through divider plates in the primary head of steam generators, may be a contributor to RIHT rise which can have a negative effect on the operation of a plant. A method to provide quick and reliable inspection of divider plate leakage can be very useful in helping make timely and effective maintenance decisions. A novel acoustic tool for performing inspections in drained steam generators during shutdowns has been developed by OH Technologies and successfully demonstrated in a field application. The technique, referred as ALIS (acoustic leak inspection system), performs a scan of the divider plate face and presents a graphic image of the leakage paths and an estimate of the total leakage area.

1. Introduction

Pressure differential between the inlet and outlet sections of the primary head can force primary coolant to flow across the divider plates through a number of potential leakage paths. The main concern is divider plate designs consisting of segmented, bolted panels. These present indirect leakage paths such as between lap joints, set bars, or bolt holes passing through the plate (about 3.5 cm thinckness). Suspect places are all the joints along the head, the tubesheet, and plate segments. Degradation may also take place along the leakage paths.

Leakage paths have been reported to vary in size, shape, and location over the divider plate wall. Consequently it is normally difficult to identify and to quantify these paths without considerable effort, particularly in a radioactive environment. Based on previous experience with acoustic techniques, this approach was explored.

2. Principle

Sound in an airborne medium has the capability for propagation through small apertures. Basically airborne sound, with selected characteristics, can "leak" through very small cracks of random shape and direction similar to a fluid with pressure differential (ΔP). Such acoustic leaks have been studied in architectural acoustics for evaluating divider walls in buildings. The advantage of this approach is that a ΔP is not required.

The basic principle adopted for this technique utilizes airborne sound transmission through the leakage paths of a divider plate assembly. Leaks can be assessed by measuring the amount of sound energy, of a predetermined sound signal, that transmits through the leak paths as illustrated in Figure 1.

3. Description

The acoustic leak inspection system (ALIS) developed thus far, for inspection of drained steam generators, utilizes the above basic principle with some custom designed equipment. The general configuration of the ALIS tool, applied for inspecting a steam generator is illustrated in Figure 2.

ALIS comprises a sound source which is attached at a fixed position on one side of the primary head. This emits a series of controlled sound bursts which are capable of propagating through air but are stopped by all metal surfaces. The sound bursts comprise three sinusoidal tones with frequencies between 35 to 40 kHz range (ie inaudible).

The acoustic sensor is positioned on the other side of the primary head, mounted on a custom designed scanning probe. The probe is suspended from a bracket which is attached to the tubesheet by three, mechanical clamps. These clamps align to fit a particular design array of tubesheets. The probe is articulated at two joints like a human arm, namely a shoulder joint and an elbow joint. These joints are articulated by their motors with gear transmission systems and encoder signals for indicating the exact position of the arm.

The acoustic sensor is a high-frequency microphone, 6 mm in diameter, which is the payload on the arm. Thus the microphone is made to scan over a plane about 5 cm parallel to the divider plate face. The acoustic signal received by the microphone is gated to receive only the inmediate sounds from plate leaks, while rejecting any delayed sounds passing through the tube bundle.

A portable case contains the acoustic leak processor which includes a computer, electronic hardware, and controls needed to operate the tool. The computer performs the acoustic signal generation, data acquisition, processing, and displays of the results in real-time. The ALIS equipment is powered by conventional 115 VAC, 60 Hz electricity. Low pressure service air is pumped through a connection in the portable case for cooling and preventing radioactive loose particle contamination of the equipment inside.

4. Operation

Installation of the ALIS tool for an inspection of a steam generator requires attaching the sound source at a predetermined position on one side of the primary head. This is done manually by activating a simple mechanical clamp onto the tubesheet. The probe is then positioned on the opposite side of the primary head, preferably on the side of the divider plates having no or minimal protrusions, ie bolts, clamps, etc.

The portable control case is positioned, within the containment area, at any closest convenient location to the steam generator(s) to be inspected. Cables permit the control case to be up to 30 m from the steam generator that is being inspected. From there the ALIS operator can remotely control the probe to scan the entire divider plate face of a steam generator.

While performing a scan, the operator is guided by the real-time graphic display of the divider plate face, the location of the probe, and indication of the sound intensity level (representing leaks). Data is collected, stored, and displayed on the computer screen at a rate of approximately two-times per second. A sample of the display during scanning is illustrated in Figure 3.

Each data point can be displayed on the screen as a colour coded dot (not shown in Figure 3) which are related to a calibrated sound intensity value in dB units. Once the scan is completed all the data points collected are integrated by the program and displayed as a colour map showing leakage locations and relative sizes. The total leakage through the primary head is computed based on current development which correlates sound intensities and areas to calculate an equivalent leakage path area represented in units of cm^2. A sample of the display (without coloured data) is shown in Figure 4.

Based on current development, a typical inspection of a steam generator after equipment installation, can be done in about one hour. Since scanning is done remotely, and the installation and removal of the sound source and the probe inside the primary head can be done relatively quickly, the radiation exposure to the workers is very low.

5. Results

A full scale mock-up of the PNGS B primary head (without tubesheet) was used for the development and verification of the ALIS tool and technique. Sample divider plates with lap joint configurations were fabricated having different size openings (leaks) machined in them to known cross sections. The available openings ranged in size from 0.2 cm^2 to a total of 6.0 cm^2 with locations including at segment, corner, tube sheet, and head joints.

Results indicated that the technique is capable of detecting and showing the relative severity of leak paths with adequate resolution. The accuracy of the results for total leak areas and for the dominant leaks was found to be generally 70 percent or better.

A field application of the prototype tool was performed on two steam generators inspected at Bruce NGS-B. Results showed clearly areas of leakages (colured in red) that were found in both steam generators. One of these is shown in Figure 5.

6. Conclusions

A practical instrument for leak inspections based on acoustic transmission, was demonstrated and preliminary results were found to be promising. Inspections can be done quickly, with results on the same day, and with minimal radiation exposure to the workers. The technique is adaptable to steam generators and divider plates of various configurations.

Acknowledgments

This project was funded primarily by the CANDU Owners Group (COG). Special support for the field demonstration and some development was received from OH Bruce NGS-B. Additional support was also received from Pickering NGS.

Figure 1

Basic Principle

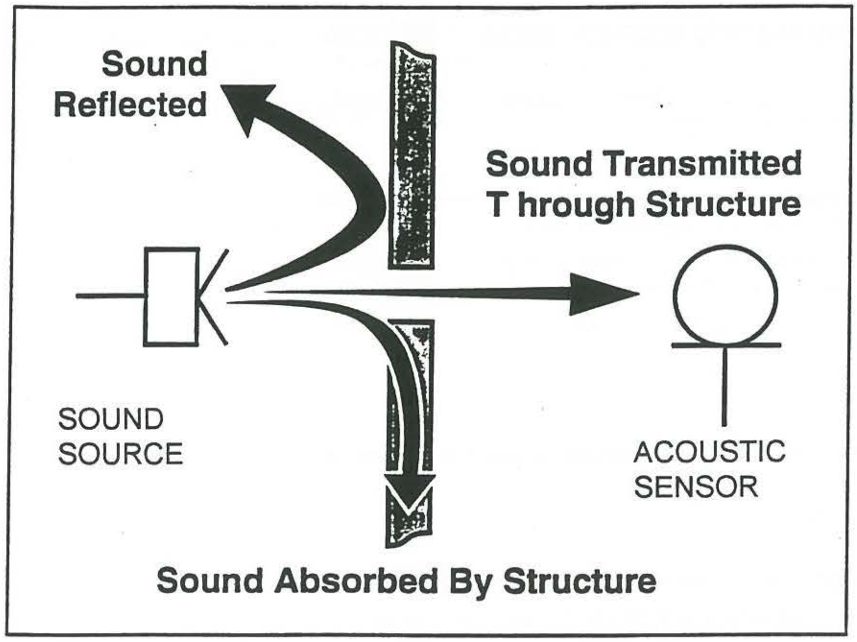


Figure 2

General Configuration of ALIS Tool
in a Steam Generator

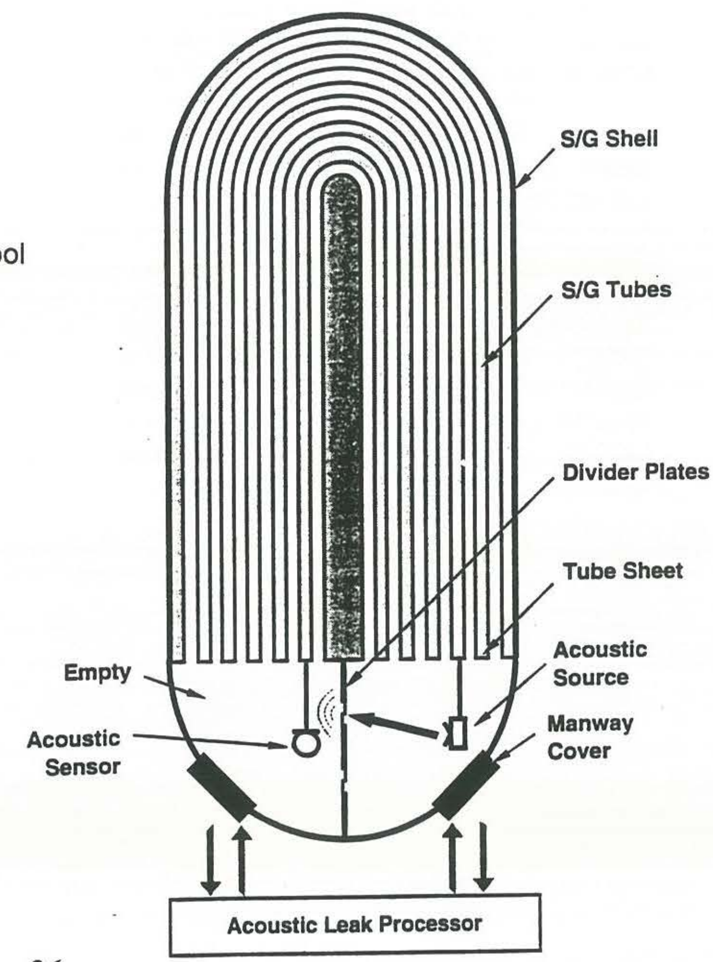


Figure 3 Scanning Operation Display and Control Panel

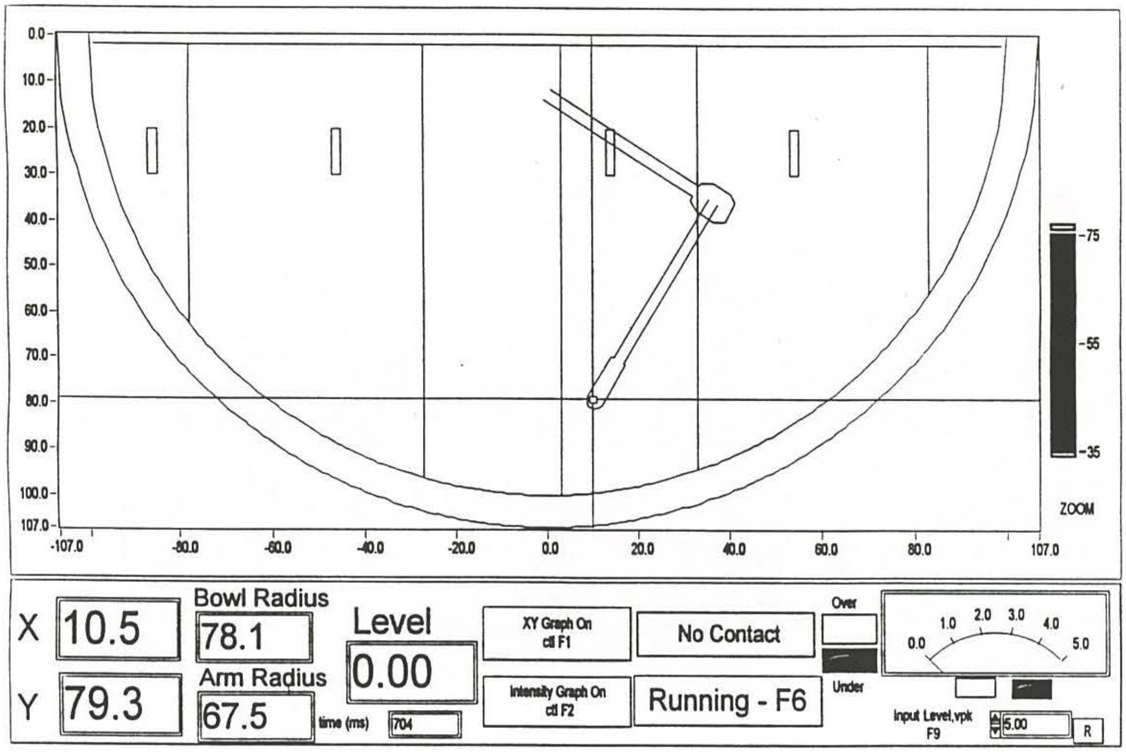


Figure 4 Leakage Calculation Panel

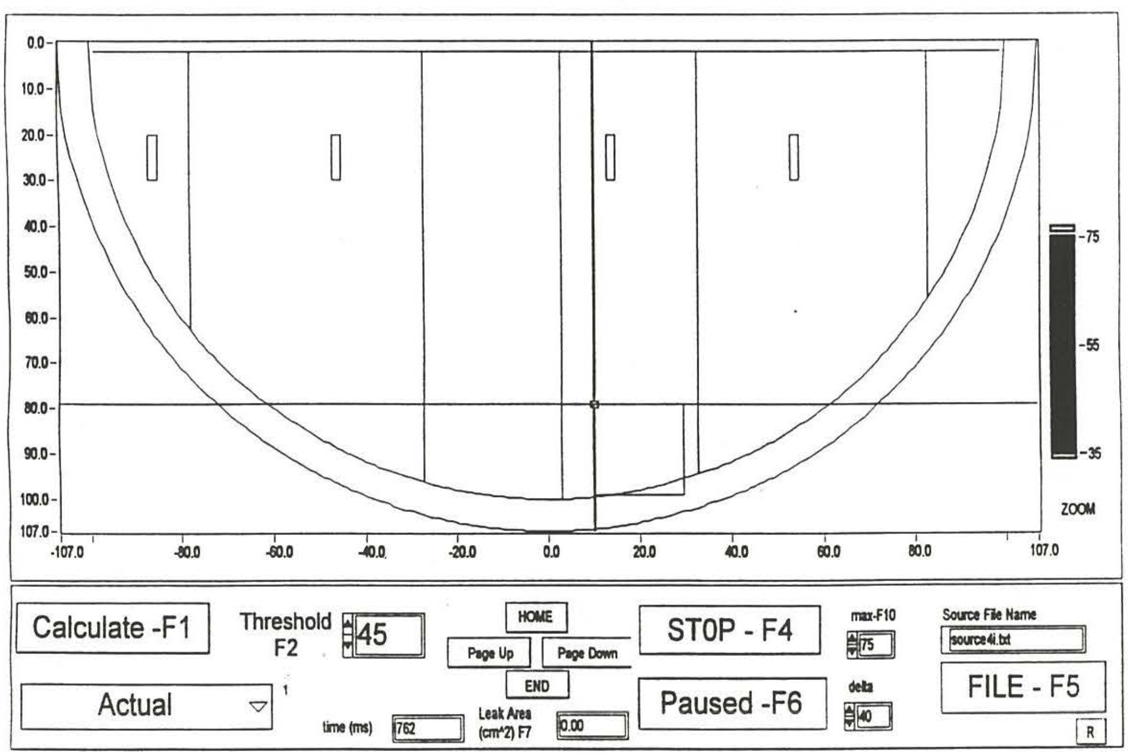
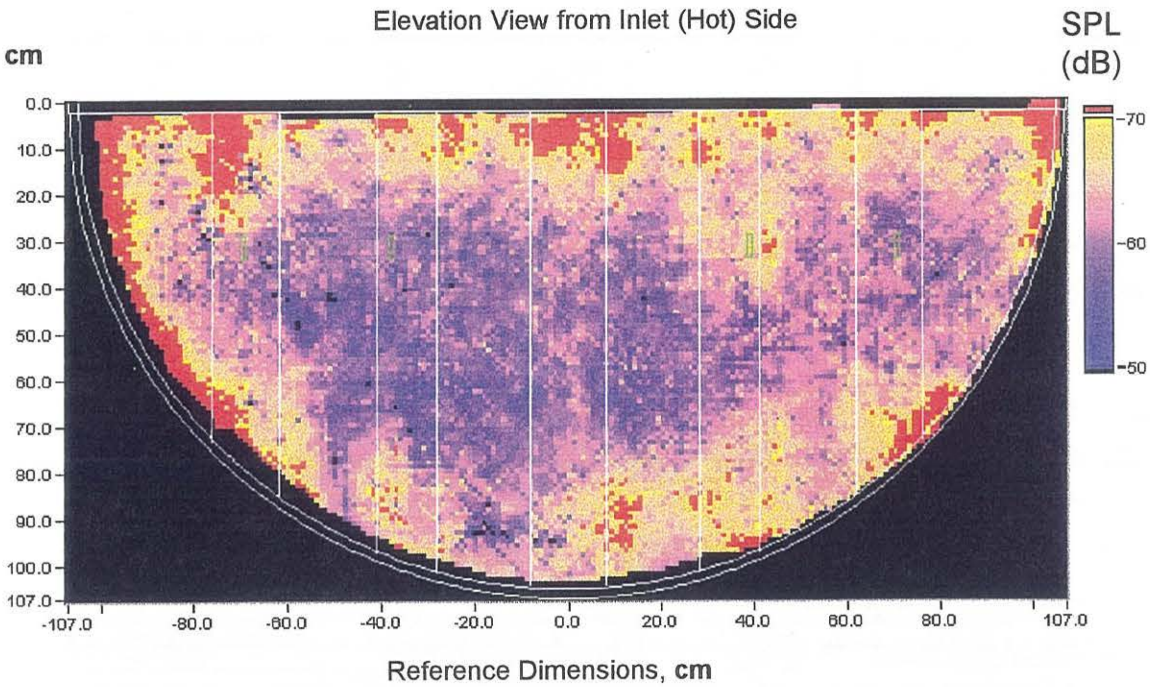


Figure 5

Results from Field Test at a Bruce NGS-B Steam Generator



Estimated Total Leak Area: 50 cm^2

- SPL refers to "sound pressure level" in decibels that is transmitted through air space in the leakage paths.
- Red colored areas indicate locations of leakage paths.