DIVIDER PLATE LEAK INSPECTIONS USING AN ACOUSTIC TOOL 'ALIS'

John Kowalewski and Mike Colbert

ABSTRACT

Divider plate leakage in the primary head of steam generators may be a contributor to high Reactor Inlet Header Temperature (RIHT) which can have a negative effect on the operation of a plant. A method to provide quick information of divider plate leakage can be very useful in helping operators to make timely and cost effective repair and maintenance decisions. As part of a CANDU Owners Group (COG) funded program, a novel acoustic tool for performing inspections in empty steam generators during a shutdown has been developed and successfully demonstrated by Ontario Hydro Technologies (OHT).

The basic principle of this technique utilizes sound transmission through the leakage paths of a divider plate assembly for creating a graphic image which reveals the locations and relative sizes of leaks. This is accomplished by injecting one side of the primary head with a series of airborne, ultrasonic sound bursts while scanning the divider plates from the opposite side and collecting transmitted sound pressure levels. Once a scan is completed the results are processed and displayed graphically as a color mapping of the entire divider plate assembly showing an image of the leakage locations and relative severity.

The special transducers of the acoustic leak inspection system (ALIS) are installed through the manways of the steam generator at both sides of the primary head. These are clamped to the tube sheet and operated from a convenient remote location within the containment building. This process minimizes radiation exposure of the workers; as well, it reduces risk of contamination of the ALIS equipment. The current version of this tool performs the scans by remote manual control.

Ontario Hydro Technologies
800 Kipling Avenue, KB 214
Toronto, Ontario, Canada
M8Z 5S4

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INTRODUCTION

In a CANDU steam generator, 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 with divider plate designs consisting of segmented, bolted panels. Suspect places are all the joints along the tube sheet, divider plate segments, and curvature of the bowl. Degradation may also take place along the leakage paths and this can contribute to unwanted increases in RIHT (reactor inlet header temperature).

Potential leakage paths are typically through indirect routes between lap joints, set bars, or bolt holes. These can be expected to vary in size, shape, and location over the divider plate wall, which is typically 3.5 cm in thickness. Consequently it is not easy to identify and to quantify these paths without considerable effort, particularly while working in a radioactive environment and likely with limited outage time.

In order to address this problem, the use of sound energy transmission through the leakage paths of a divider plate assembly was investigated. The basic principle is that sound, in an airborne medium, has the capability for effective propagation through apertures passing across a dividing barrier. Basically, airborne sound with specific 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.

Based on this principle, the approach taken was to develop a technique for identifying the locations and obtaining a measure of the total path size corresponding to such leaks. This would be done with the SG (steam generator) primary head open for inspection (ie during an outage) but with minimal intrusion inside. Given the estimated size of the leakage paths would then allow the leak rate to be calculated.

The technique developed comprises a novel tool referred to as ALIS (acoustic leak inspection system) and a procedure for leakage path assessment.

DESCRIPTION

The ALIS tool measures the amount of airborne sound energy of a predetermined sound signal that transmits through the leakage paths. This is done by sending a sound burst into one side of the divider plates and receiving the same but attenuated sound at the opposite side. The advantage of this approach is that a ΔP is not required. The general configuration of this tool, as applied for inspecting a CANDU steam generator, is illustrated in Figure 1.

A specially made sound source attaches at a fixed position on one side of the primary head. This emits a series of controlled, ultrasonic sound bursts which propagate through air but cannot penetrate the metallic structures. Any sounds passing through leakage paths in the divider plates are received by an acoustic sensor which is positioned on the other side of the primary head. The acoustic sensor is comprised of a high-frequency microphone, which is mounted on a specially designed scanning probe. Both the source and the probe are suspended by clamps which attach to the steam generator tube sheet. The management of the acoustic signals and probe positioning are done by a computer-based processor and a remote control which are connected via cables outside the steam generator.

The source emits sound burst at the rate of about three burst per second. The acoustic signal received by the microphone is "gated" to receive only the immediate sounds from plate leaks, while rejecting any delayed sounds that are transmitted through the tube bundle. This synchronization occurs within a 30 ms time window as illustrated by the test verification in Figure 2.

A portable case contains the computer-based processor and electronic hardware needed to operate the ALIS tool. The computer performs the acoustic signal generation, data acquisition, processing, and displays of the results in real-time. The equipment is powered by conventional (115 VAC, 60 Hz) power supply. A hand-held control is used for positioning the probe. An overall view of this equipment, as it was being prepared for use at a plant, is shown in Figure 3.

The probe which performs the scans is capable of positioning the acoustic microphone and tracking its location relative to the divider plates. It is supported by three, manually operated clamps which align to fit the given array of the tube sheet. Form there the probe is articulated at two joints, like a human arm, in a two dimensional plane parallel to the divider plates. Thus the microphone is made to scan at about 5 cm in front of the divider plate wall, while collecting any sound from the source that may be transmitting through leak paths. The probe is shown in Figure 4.

OPERATION

During an outage, with the SG drained and manways open, a divider plate inspection may be readily carried out using the ALIS tool. Normally two trained operators are required for installing and removing the tool equipment and one of them can perform the scanning. The probe is positioned inside the primary head, preferably on the side of the divider plates having least interference (ie bolts, clamps, or protrusions). The sound source is then installed at a predetermined position on the opposite side of the primary head. Both are secured to the tube sheet using a quick clamping mechanism operated by hand.

The processor and probe control are positioned within the containment area, at a close convenient location to the steam generator(s) to be inspected. Cables permit the control to be up to 30 m from the SG that is being inspected. Once all connections are made and the power to the equipment is switched on, a set of reference points are obtained by the probe which set the processor program. Subsequently the divider plates are scanned using the manual remote control.

While performing a scan the operator is guided by a graphic display of the divider plate face. The display shows, in real-time, the location of the probe and the magnitude of sound signals detected by the microphone. The magnitude is represented by a colour-coded dot which is calibrated in terms of sound pressure levels in decibels (dB). As the scan is made the display shows a trace of the dots so the entire divider plate area can be inspected. The display panel during the scanning procedure is illustrated in Figure 5.

Once a scan is completed the data are stored on disk for final processing. The probe and source are removed and if needed may be installed on another SG for inspection. 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 divider plates is computed, based on correlation between sound intensities and known opening areas. This gives an estimate of the equivalent leakage path area and is represented in units of cm^2.

RESULTS

Initially, ALIS was demonstrated using a mock-up of a Pickering NGS-B type primary head in controlled test conditions. Results indicated that the technique is capable of detecting and showing the relative severity of leak paths with adequate resolution. This included leaks as small as 0.5 cm^2 and in locations such as corners, tube sheet, segments, and head joints.

Field implementation of this tool was performed successfully on SGs at the Bruce NGS-B plant during planned outages. Each inspection revealed clearly the leakage patterns along some of the joints (coloured in red by the graphic display). A sample of a typical result is shown in Figure 6.

Depending on the physical size of the SG the time required for a complete scan (after installation) was found to be about 90 minutes. Initial set up and scan of one SG was found to take up to one regular shift. Analysis and a print of the findings can be produced within a day.

The radiation exposure of the workers involved in this procedure was found acceptable since scanning is done remotely from the SG, and the time for installation/removal of the equipment inside the primary head is very short.

CONCLUSIONS

A practical tool for inspecting divider plate leakage, based on acoustic transmission, was implemented. Inspections can be done relatively quickly and with minimal radiation exposure to the workers. The technique is adaptable for steam generators and divider plates of various configurations.

ACKNOWLEDGMENTS

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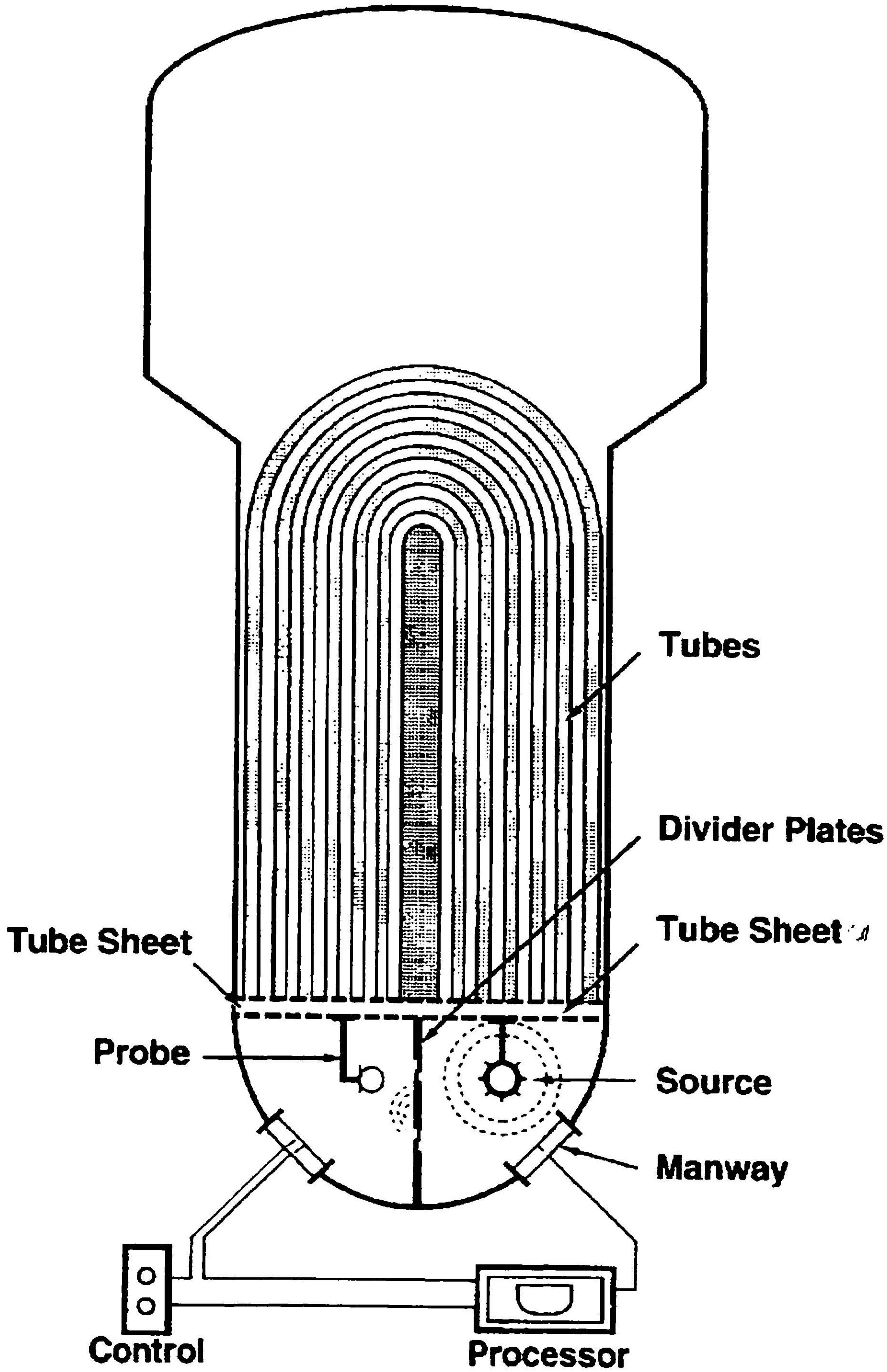

Figure 1
General Configuration of ALIS Tool

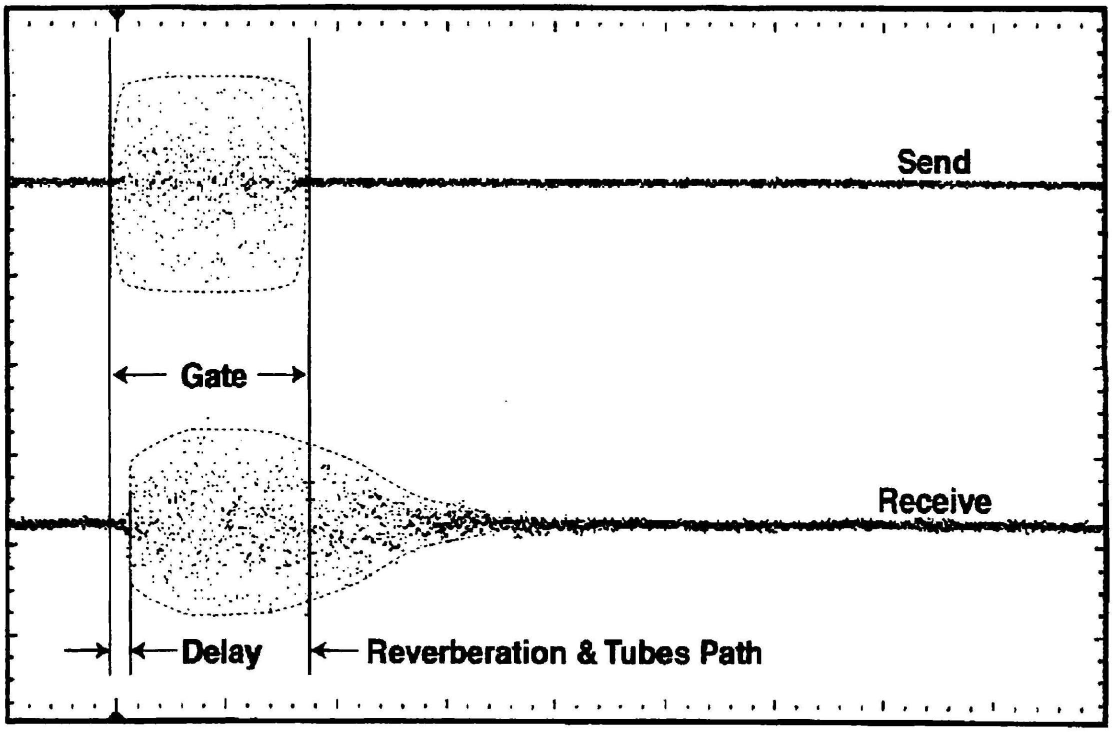

Figure 2
Synchronization of Sound Burst Signals Tested in a Full-Scale Mockup

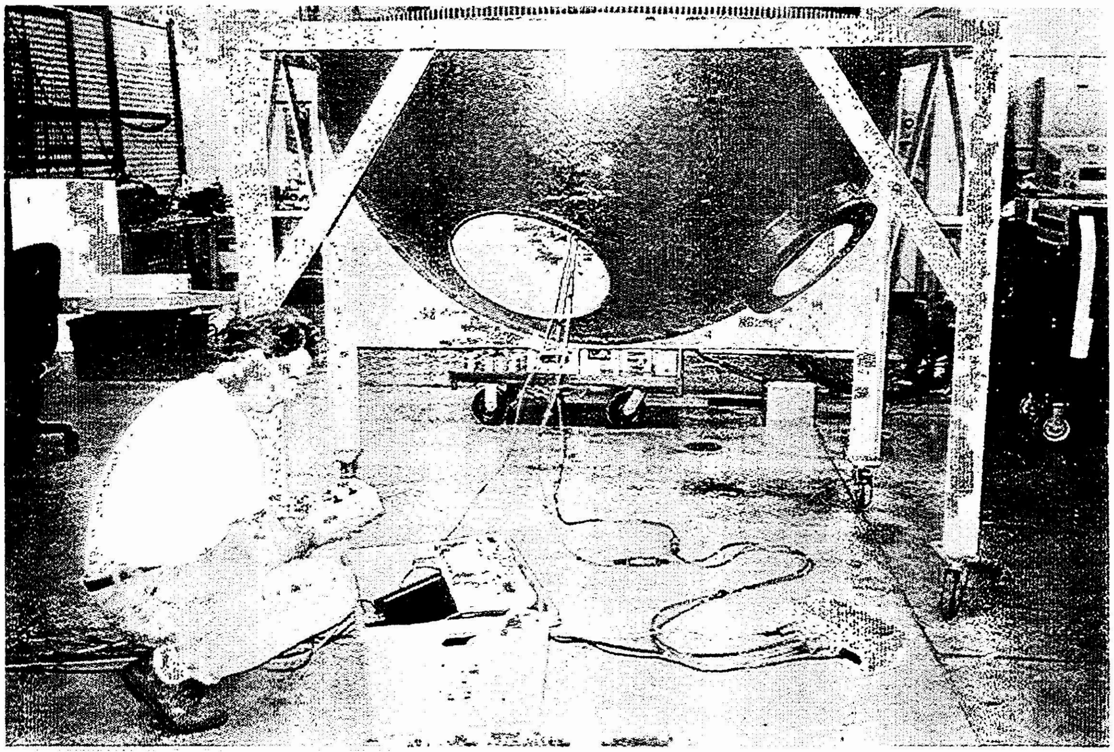

Figure 3
Operator Performing a Simulation of Divider Plate Leakage Inspection Using ALIS

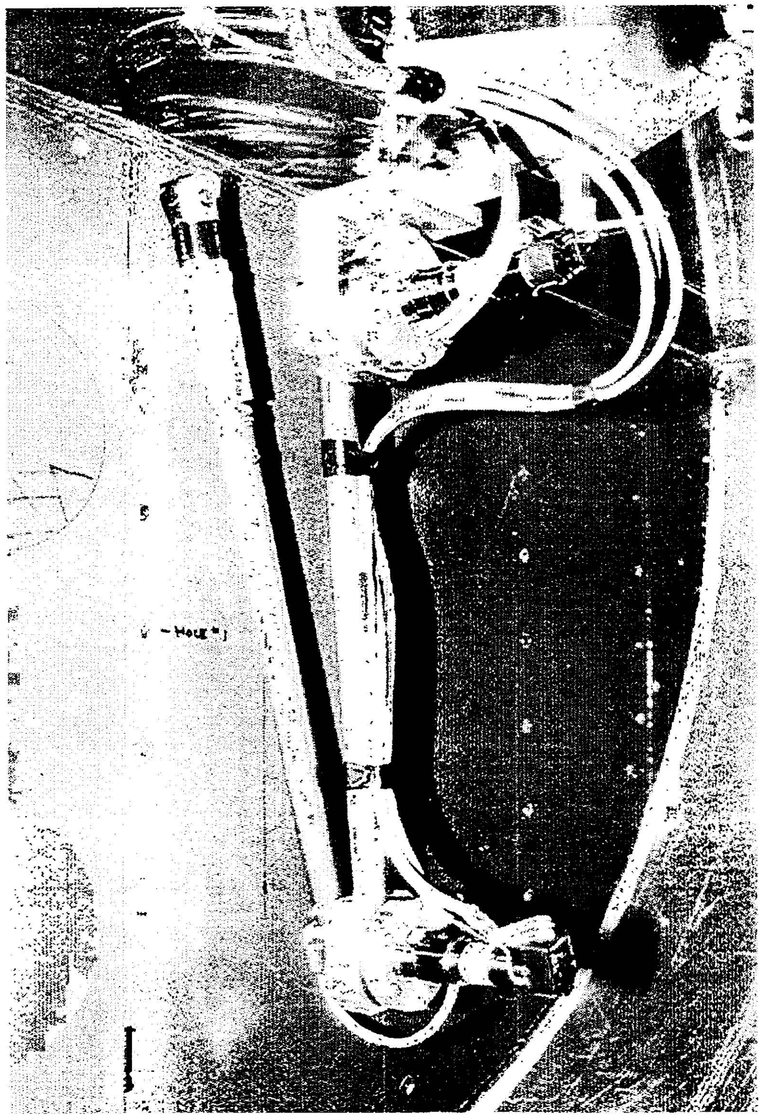

Figure 4
Acoustic Probe and Clamp Attachment Inside a Primary Head Mock-up

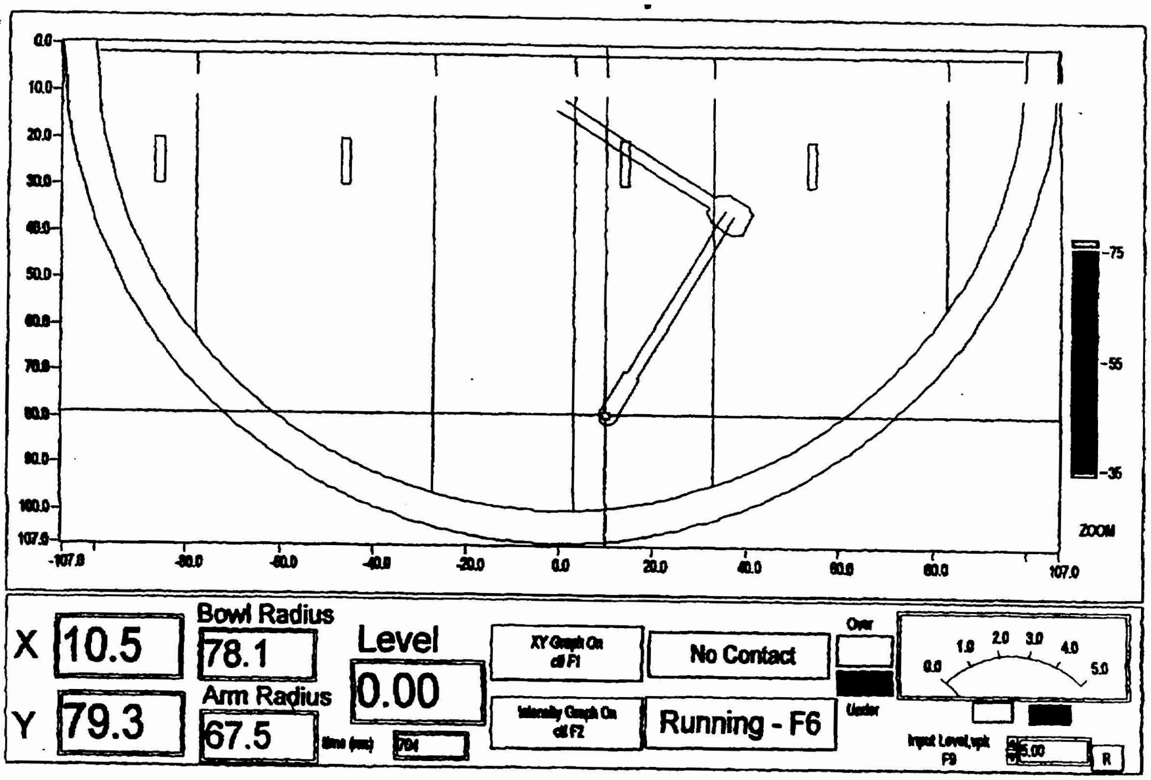

Figure 5
Panel Display During Manual Scanning Operation
Probe Location is Shown by the XY Coordinates

Estimated Total Leakage Area: 60 cm^2.
Red coloured (or darker) areas indicate leakage paths.

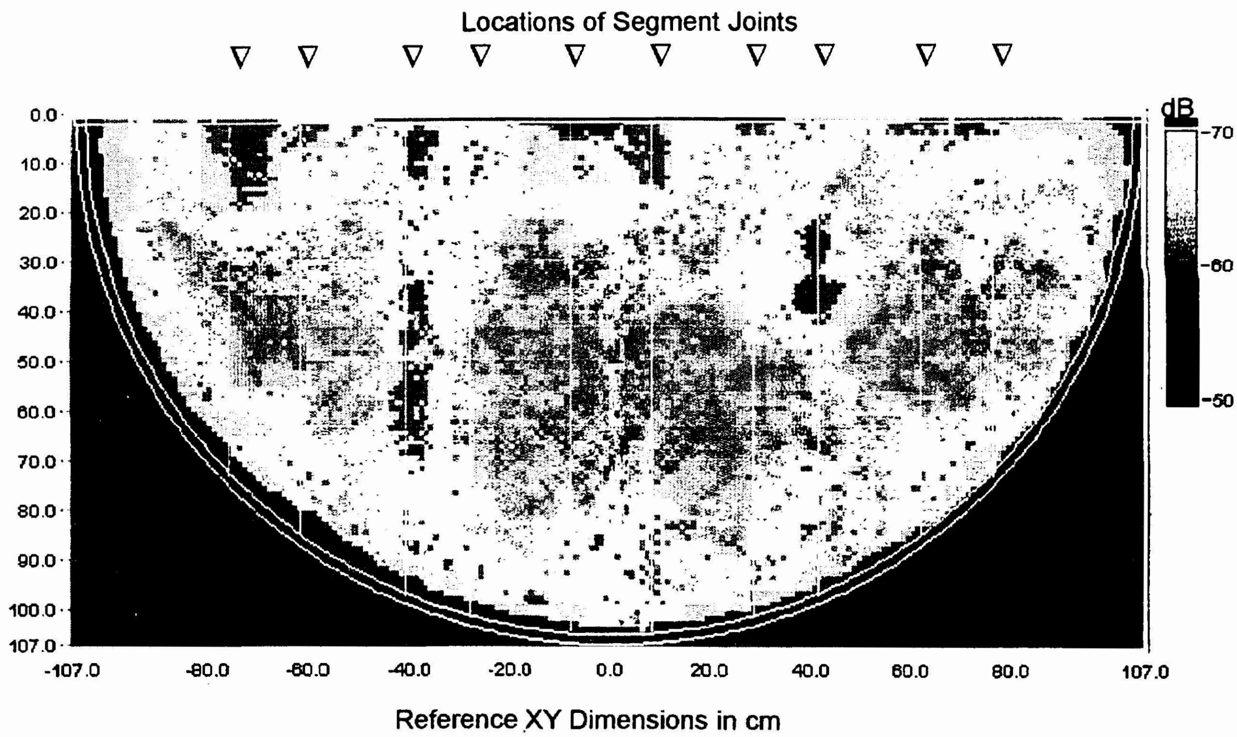

Figure 6
Sample of Results from a Bruce NGS B Divider Plate Inspection Using ALIS