

PHASED ARRAY ULTRASONIC TECHNOLOGY (PAUT) CONTRIBUTION TO DETECTION AND SIZING OF MICROBIALY INFLUENCED CORROSION (MIC) OF SERVICE WATER SYSTEMS AND SHUTDOWN COOLERS HEAT EXCHANGERS IN OPG CANDU STATIONS

Peter Ciorau

Lou Pullia*

Trek Hazelton

Wence Daks

– OPG-IMCS – Pickering –Canada – peter.ciorau@opg.com

- OPG-IMCS – Pickering –Canada – lou.pullia@opg.com

- OPG-IMCS – Pickering –Canada – trek.hazelton@opg.com

- CAD WIRE – Markham – Canada`- wence@cadwire.com

Abstract

Three PAUT techniques [linear scan – longitudinal waves, sector scan –longitudinal waves and sector scan-transverse waves] were developed and validated to assess the MIC attack in service water systems (SWS) and shutdown coolers heat-exchangers (SDC-HX) of Darlington and Pickering CANDU stations. PAUT employs linear array probes with a frequency between 4-12 MHz, depending on surface conditions, component geometry and MIC size/category to be detected. Examples from lab validation and field trials are presented. Based on field trials results, the techniques were optimized and new cal blocks were manufactured. It was demonstrated for mid-length pipes and for SDC-HX, the PAUT is the best technique compared with D-meter conventional UT and with guided waves. The expected field accuracy is about 0.5 mm (0.020”) for large MIC attack. The ligament evaluation is technically achievable for colonies / pin holes located 2 mm under the outer surface. Improvements were identified and implemented for the next outages.

Background

As service water systems within Electrical Utilities are supplied by Lake Water, there is a threat for MIC to occur within certain portions of the plant systems. These are generally isolated to service water systems where conditions of flow and temperature are conducive to MIC attacks. MIC generally occurs randomly with a tendency to attack the heat affected zone (HAZ) of welds (see Figure 1-left). The corrosion defects can take on a few different shapes but are principally conical in nature making it difficult to inspect with conventional ultrasonics. The MIC colonies could lead to forced outages, due to pin hole leaking (see Figure 1-right).

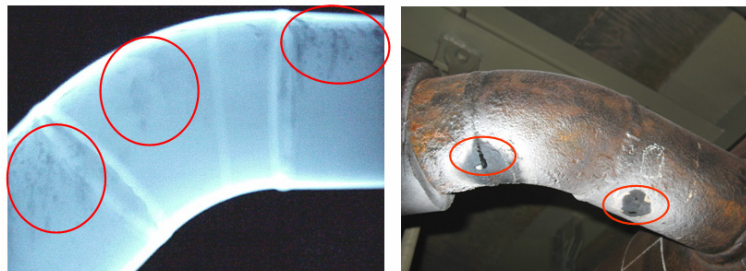


Figure 1: MIC attack on service water systems-elbows; left – radiography of random MIC; right – pi holes leaks detected in an elbow.

* Paper presenter

Heat exchangers of shut down coolers are attacked by MIC in HAZ of buffer plate weld (see Figure 2). The MIC attack produced costly forced outages.

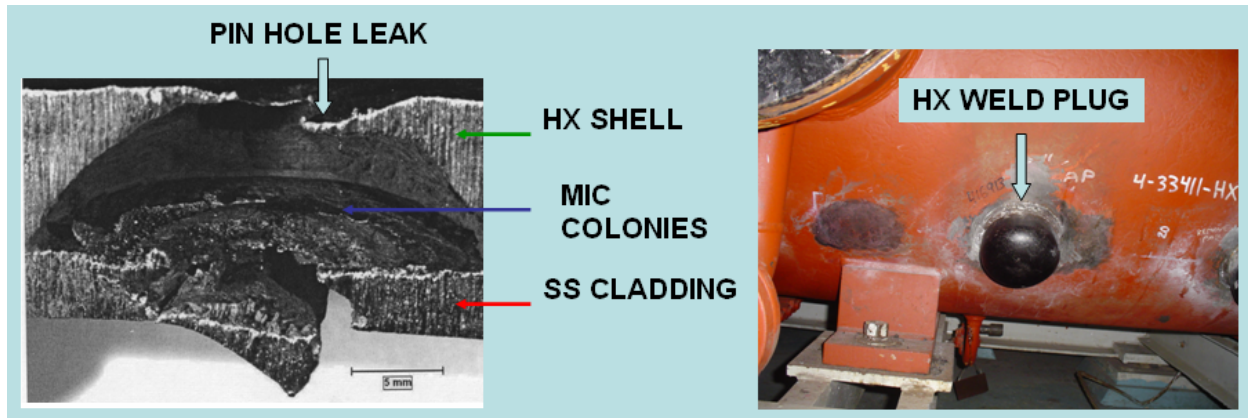


Figure 2: Examples of MIC attack on HX-SDC lower weld of the buffer plate.

In 2002-2003 OPG-IMCS developed conventional ultrasonic procedures for HX-SDC lower weld and SWS piping. These conventional procedures are time-consuming, have difficulty distinguishing inclusions and laminations from MIC attack, and could allow isolated small colonies and pin holes to be undetected. New techniques using PAUT were developed and commissioned for SWS piping and SDC-HX. The techniques were field-commissioned during two outages: Pickering Unit 4 in 2006 and Darlington Unit 2-3 in 2007. This paper presents the PAUT advantage in detecting and sizing MIC attack.

PAUT TECHNIQUES

PAUT could employ three techniques in detecting MIC attacks:

- *Electronic (linear) scan* using *longitudinal waves* with large probe: is used for a quick assessment of significant domes with height $> 1/3$ of pipe wall. Can't detect small colonies and pin holes. The wedge must be adapted to pipe curvature, and scan is performed axially.
- *Sectorial scan* using *longitudinal waves* with high frequency (8-10 MHz) small probes; this technique is capable to detect small MIC colonies with dome height > 2 mm. Could assess with mode-converted shear waves the pin holes up to 2 mm (0.080") to the outer surface.
- *Sectorial scan* using *shear waves* with frequency 4-10 MHz and small probes. This technique is very efficient for pin hole detection, but has errors in height evaluation, namely for shallow domes ($h < 2$ mm); however this technique can detect deep pin holes with ligaments of 1.2 mm (0.055") before piercing the outer surface.

The principle of three techniques is presented in Figure 3.

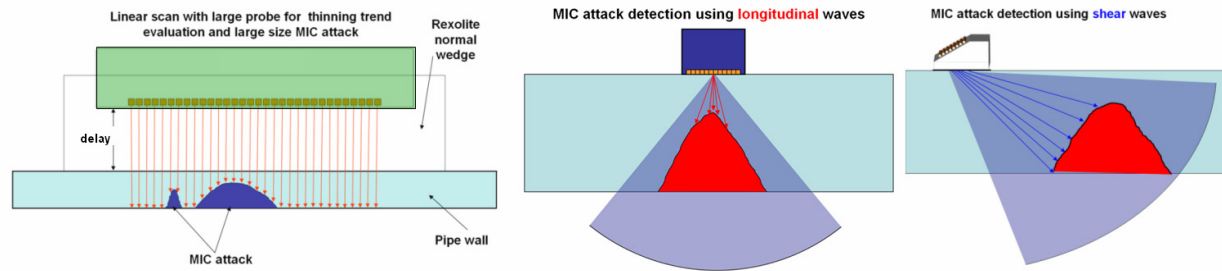


Figure 3: PAUT techniques for MIC attack detection: *left* - linear scan **L-waves; *middle* – sectorial scan **L-waves**; *right* – sectorial scan **T-waves**.**

The PAUT techniques were validated on retired-for-cause SDC-HX samples (see Figure 4) and on artificial-made MIC defects of different shapes (see Figure 5 to Figure 7).

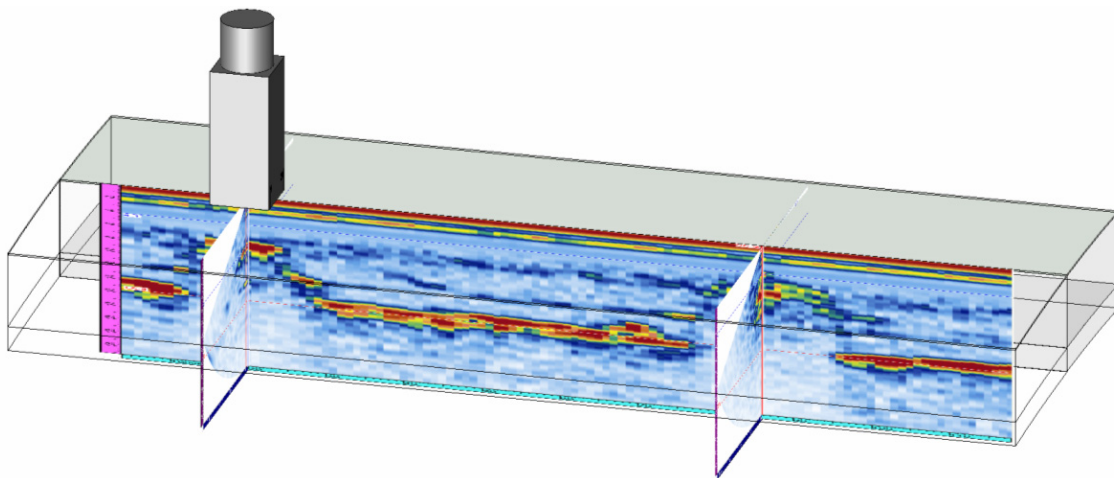


Figure 4: Detection of two MIC colonies in SDC-HX by S-scan L-waves.

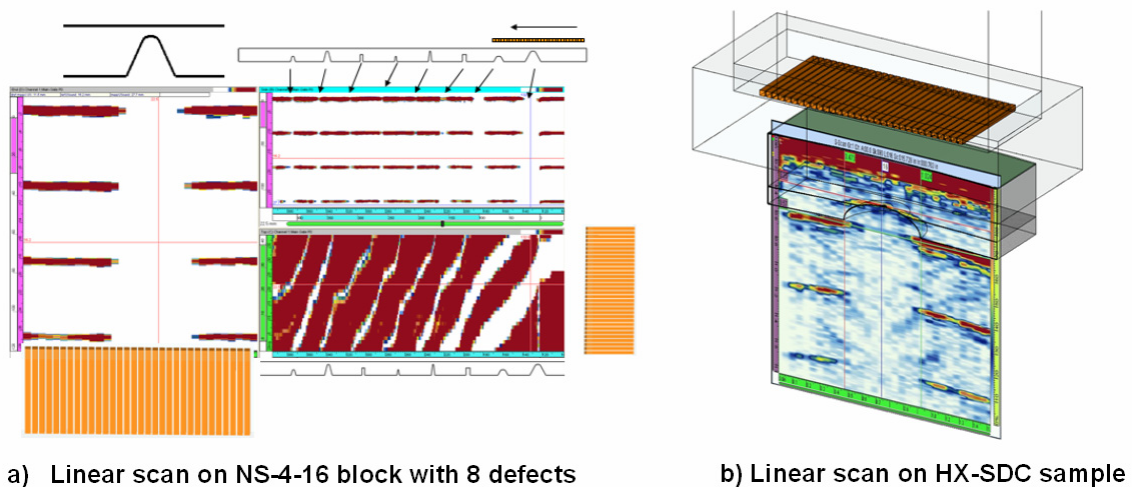


Figure 5: Linear scan on artificial defects (left) and on a MIC colony in HX sample (right).

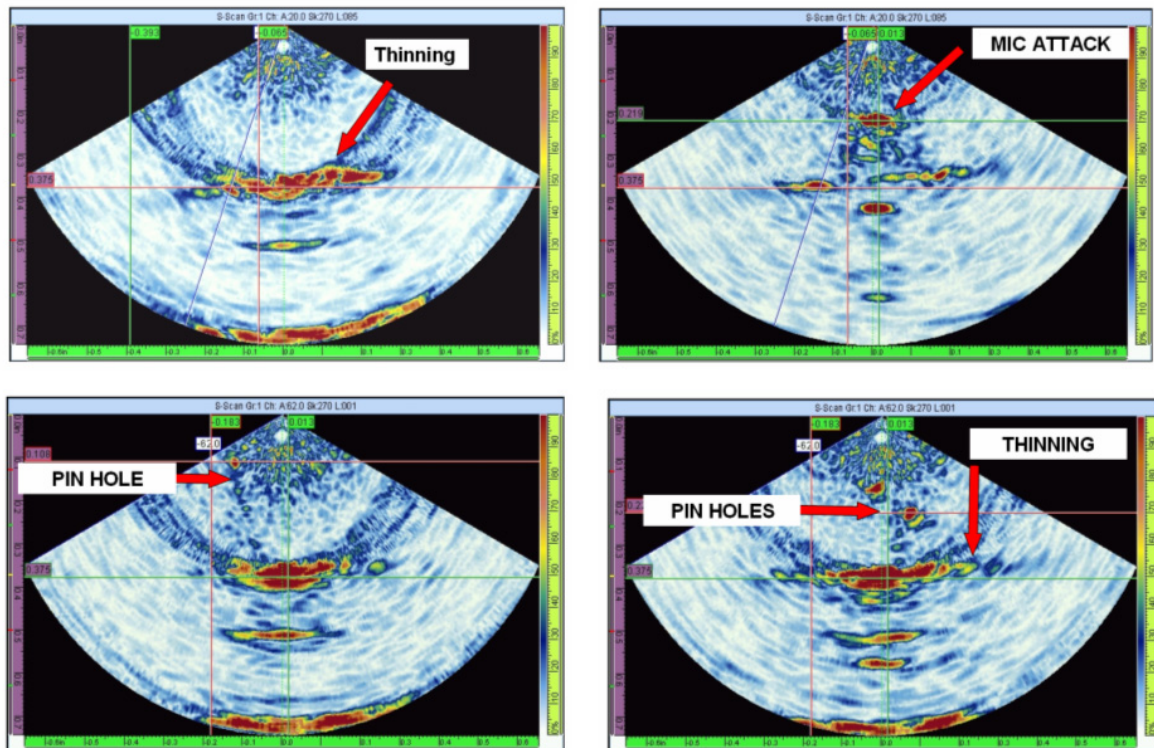


Figure 6: Different defect types detected by S-scan **L-waves**.

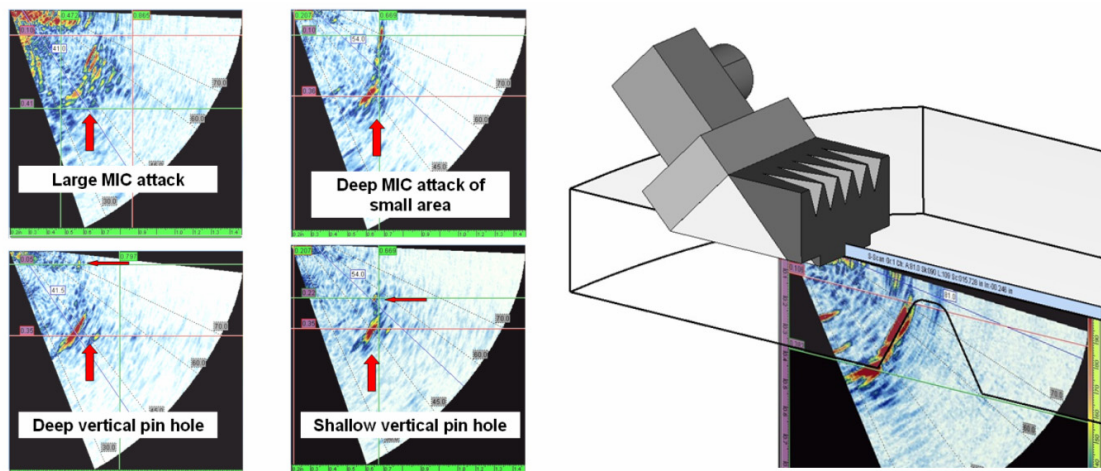


Figure 7: Different defect types detected by S-scan **T-waves**.

FIELD APPLICATIONS

Examples of field applications from Pickering SDC- HX inspections are presented in Figure 8 to Figure 10.



Figure 8: Example of PAUT inspection of SDC- HX with **L-waves**- PNGS U4.

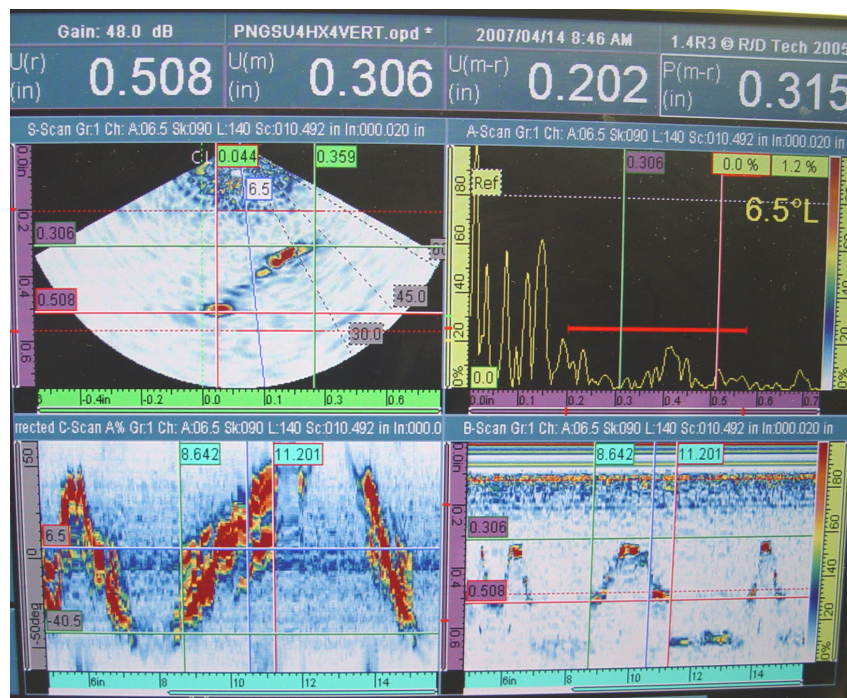


Figure 9: PAUT detection of a MIC attack with ligament of 0.306".



Figure 10: MIC attack location in HAZ of lower weld on HX 4.

Examples of field inspection of DNGS service water lines are presented in Figure 11 to Figure 13.



Figure 11: Examples of field inspection of secondary service water lines at DNGS.

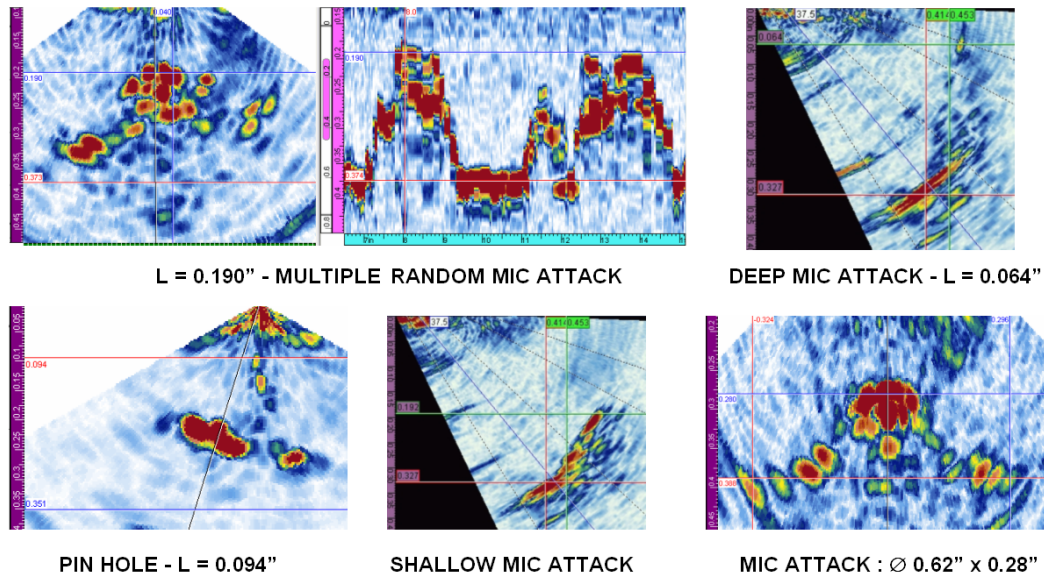


Figure 12: Examples of different MIC attack defects detected by PAUT at DNGS.

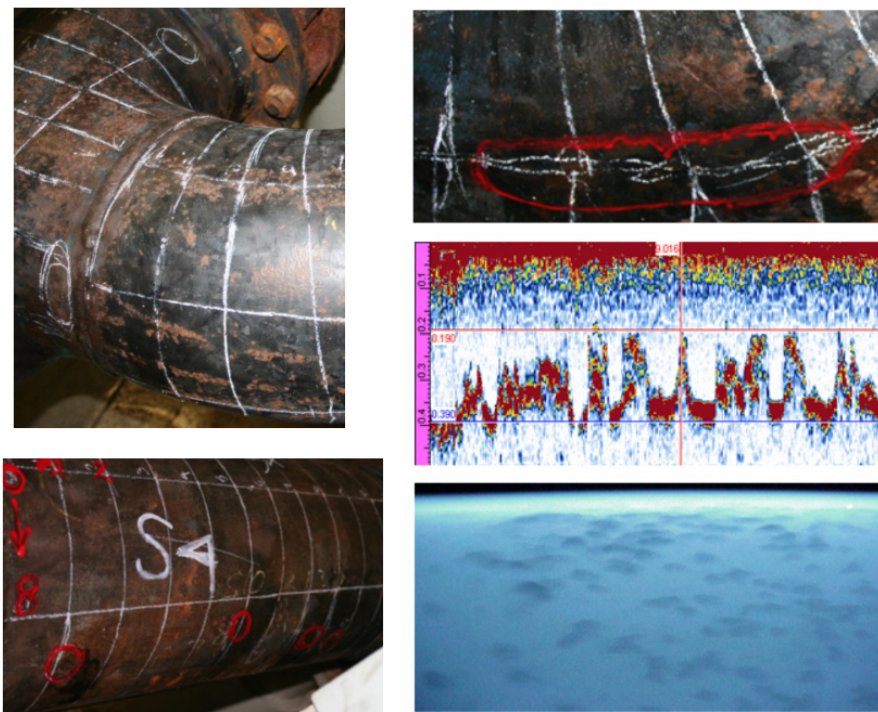


Figure 13: Examples of MIC location and data comparison with RT.

CONCLUDING REMARKS

PAUT techniques developed for MIC attack were validated during lab and field trials. PAUT is capable to detect and size different types of MIC attack, with ligaments up to 1.2 mm. The most productive technique is S-scan L-waves, with a direct reading of colony diameter and ligament. This PAUT

technique is also very visual, allowing easy interpretation of the data and has been well received from the inspection technicians.

The ligament measurement was improved for near-surface pin holes by using high-resolution filters and delay wedges. Measurements were compared to D-meter and RT and they were found in to be in good agreement. Improvements were identified, including cavitations evaluation near the weld or in the weld root area. PAUT method is efficient for short-range piping, between the valves and on elbows and Tees. PAUT contributed to dose reduction and reliable MIC attack detection on HX-SDC.

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