Replacement of Radiography with Ultrasonic Phased Array for Feeder Tubes in CANDU Reactors using ASME Code Case N- 659-2

Robert SIMMONS[1], Quintin BOWER[2], Shawn ARSENEAU[3]

[123]Metalogic Inspection Services, Edmonton, Canada
Phone: +1 780 469 6161, Fax: +1 780 469 6152; e-mail[1]: bsimmons@metalogicinspection.com, e-mail[2] qbower@metalogicinspection.com, e-mail[3] sarseneau@metalogicinspection.com

ABSTRACT

In this paper we will discuss Phased Array technology for the replacement of radiography on new construction projects in the nuclear industry. Specifically, through the implementation of A.S.M.E. code N-659-2 and MetaPhase™ phased array services. Phased Array is not considered a new technique on in service welds in the nuclear industry; however it was unprecedented on new construction welds and required significant investment in regulatory approval (C.N.S.C.), technology research and development, regulatory, client and technician training for successful service implementation. This paper will illustrate the abilities and limitations associated in replacing radiography with MetaPhase™, as well as the substantial benefits relative to increased production, improved weld quality, enhanced safety and overall project cost savings.

Keywords: Ultrasonic Testing (UT), MetaPhase ™, New construction welds, ASME Code Case N659-2, Phased Array, Radiography, Feeder Tubes, Nuclear, CANDU.

HISTORY

Metalogic Inspection Services specializes in phased array ultrasonic inspection on new construction welds. MetaPhase™, is the complete service package required to replace radiography for weld inspection on all diameters and thicknesses of piping, vessels and storage tanks. In 2007, ASME code case N-659-2 allowing ultrasonics in lieu of radiography was approved and Metalogic was approached by AECL and N.B. Power to discuss the replacement of radiography on their upcoming PLGS CANDU 600 PHWR refurbishment project. Understanding that this was an industry first, there were several hurdles to overcome.

Although phased array had been implemented for the detection of “in service anomalies” such as wall thinning and cracking, Code Case N-659-2 on new construction welds was unprecedented and considered by the Canadian Nuclear Safety Commission (C.N.S.C.) as a special nondestructive inspection application under Clause 11.2.2 of CSA N285.0 [2]. As a special inspection process, the methods of examination must be fully demonstrated and accepted by the regulatory authority (CNSC).

In addition to the C.N.S.C, a demonstration and approval was required by the local authorized area inspector (A.I.) and requiring final acceptance by the licensee.

The C.N.S.C. considered Code Case N-659-2 too general to accept unconditionally. A set of requirements over and above CC N-659-2 were implemented to demonstrate the capabilities of the MetaPhase™ technique, MetaPhase™ technician training, qualification standards, flaw sizes and flaw acceptance standards. Additionally the procedure performance demonstration also needed to meet the intent of ASME section XI appendix VIII and the rules and requirements were adopted by the technical specification to enhance and counter the perceived limitations of CC N659-2.

PROJECT REQUIREMENTS

Comparisons between Radiography and Phased Array have been widespread, with significant amounts of documentation showing that phased array allows for improvements in P.O.D. on critical defects, inspection speeds, auditability, safety and cost savings. However there were concerns expressed by the CNSC on some aspects of Code Case N659-2 specific to the types of fabrication flaws, performance demonstration, flaw discrimination and acceptance criteria.

To negate these concerns and strengthen the technical specification and procedure, the qualification, procedure, personnel and equipment requirements were significantly enhanced beyond code and industry standards.

1. Defined Demonstration requirements

- Number of flaw specimens - set to demonstrate a reasonable sample size of all 5 different diameters. 17 individual coupons (welds) in total.
- Types of flaws – Typical defects inherent to new construction welds such as lack of fusion, incomplete penetration, cracks, undercut and “other” which was set to describe porosity and tungsten inclusions.
- Number of flaws – a reasonable sample size to demonstrate sensitivity over a wide range of similar defects. In total there were 45 flaws.
- Grading units - Defined areas around the circumference of the weld that were either flawed or unflawed.
- Target flaw sizes – Sizes of indications deemed to be detrimental to the integrity of the welds based on their type and location within the weld. *NOTE: Flaw sizes were reduced in size relative to code requirements to provide a more sensitive inspection.*

2. Defined Personnel Demonstration requirements

- Number of flaw specimens – the amount of test specimens required to accurately demonstrate all possible weld defects while also covering all material size ranges.
- Number of flawed grading units – In addition to the number of flaw specimens each technician must scan a minimum number of flawed grading units.
- Number of unflawed grading units – Each technician must also scan a defined set of unflawed grading units. This would ensure proper locations and test for improper characterization.

- Types of flaws - Each technician must be tested for all of types of indications determined inherent to the particular welding process.
- RMS sizing error – Technicians must properly size indications within acceptable limits set out in the code compliant procedure. NOTE: *RMS requirements were tightened relative to code to ensure more a stricter tolerance on sizing.*
- Numbers of false calls – Technicians must successfully differentiate between relevant and non-relevant indications.

3. Technician requirements

Although the minimum standards are defined in the code, it was requested that a much higher technician qualification standard be used for this project. The regulator, client and A.I requested in depth training records for qualified technicians with additional audits performed. Some of the qualifications were as follows:

- CAN/CGSB 48.9712-2006 Ultrasonic Level 2 or 3
- MetaPhase™ Certified (3 week MetaPhase™ training course).
- Technicians required 720 field hrs as a level II Metaphase™ Technician, both operating and interpreting new construction welds.
- Three days of procedure specific training relative to Code Case N-659-2, equipment operation, accept/reject criteria and reporting.
- Each technician was required to pass a performance qualification based on anomaly detection, characterization and sizing.

4. Equipment Requirements

The design and installation of the feeder tubes posed some hurdles relative to the nuclear environment. The following modifications were made to MetaPhase™ equipment.

- Scanners were specifically designed and constructed to ensure accessibility, efficiencies and repeatability.
- Scanners were optimized and simplified for quick diameter changes and probe change outs in a nuclear environment (Rubber Suits).
- Project specific probes and wedges were designed to optimize P.O.D and sizing for specific diameters and thicknesses.
- Loose parts and tooling were reduced to minimize any probability of Foreign Material Exclusion (F.M.E).

5. Procedures

Procedures were submitted for approval to the CNSC and accepted on an application specific basis. Although the regulator had accepted the technical specification and procedure, they retained the right to request changes if required and noted that each project and licensee must re-apply for conditional acceptance to use code case N-659-2.

6. Additional CIQB Certification

In 2010 Metalogic was requested to qualify the procedure through the CANDU Qualification Inspection Bureau (CIQB). The purpose was twofold:

- Give the project team further reassurance and confidence that the procedures and technical specification would deliver a high level inspection through a review by industry peers.
- The CIQB is the approving body reporting to both the C.O.G. and C.N.S.C. for all inspection procedures. Any technical specification/procedure registered through CIQB would be accepted by the C.N.S.C. This served to minimize costs associated with development and need to demonstrate technical procedures to the regulator should revisions be required. The procedure was certified by the CIQB in June 2011.

PROJECT SUMMARY (POINT LEPREAU, WOLSONG, BRUCE)

Scope of Work

Each of the 3 refurbishment projects had significant variances relative to work scope and duration. In total greater than 5000 new welds were inspected with MetaPhase™, totaling more than 50,000 scans. Each refurbishment phase was approx. 3-4 months in duration depending on the amount of welds present, averaging between 7500-10000 scans during that time frame.

- PLGS upper feeder install of 760 welds and 5320 scans between July 2009 – May 2010; Lower feeder install of 760 welds and 8360 scans between Dec 2011 – March 2012; Totaling 1520 new field welds and 13680 scans.
- Wolsong upper feeder install of 760 welds and 7840 scans between November 2009 – June 2010; Lower Feeder install of 760 welds and 8360 scans between Jan 2011 – March 2011; Totaling 1520 new field welds and 16200 scans.
- Bruce feeder welding (Unit 1 & 2) 960 welds and 10560 scans per Unit between Jan 2011 – Oct; Totaling 1920 new field welds and 21120 scans.

1. Project Impacts – Summarized

A detailed process analysis is required to identify and measure all areas affected by the elimination of radiography. The following are a few general examples and should be noted that some impacts were not realized on all projects.

- **A.L.A.R.A:** Dosage levels were substantially reduced by eliminating unproductive time spent entering and exiting the vault for all tradespersons during “xray windows”. Reducing inspection times, not only minimized the radiation dosage for inspection personnel, but all other working tradesmen in the vault. As no radioactive isotopes were introduced into the work area, the risk of secondary exposure from radiographic isotopes was eliminated.

- **Increased Production**: Several, significant production increases were realized by eliminating radiography. The most obvious was eliminating “radiography windows” allowing full production to continue in parallel with the inspection process. Other examples were, quicker reporting reduced unnecessary welder and equipment movement or rework. More accurate repair location and sizing (3D) reduced repair times and re repairs, as well as eliminating the need to cut out the weld (Additional repair procedure was developed) eliminating the need for re-fit, re-tack, and purging.

- **Higher Quality Weld:** Superior detection of the more critical defects rendering a higher quality of weld. In addition, by working alongside welders and providing quicker feedback on potential weld quality, welding issues were quickly dealt with, leading to quicker pattern recognition and faster resolutions. Inspection during welder training and qualification aided the processes and procedures before field implementation, thus increasing the potential for success.

- **Cost Savings:** Tangibles; Elimination of radiography windows, increased overall production, reduced repair times, reduced repairs, faster inspection times,
Intangible; Reduced radiation exposure/dosages to tradespersons, reduced re repairs, Reduced risk of weld failure and increased Safety.

2. Project Quality Improvements – Summarized

Procedure, Training and Equipment improvements were realized during each of the 3 projects. The following are brief examples;

- Data transfer and storage procedures and processes were scrutinized and resulted in enhanced processes to reduce the potential of human error.
- MetaPhase™ reporting software evolved to aid both internal and external client data auditing and allow for a more simplistic audit of inspection results.
- Scanners were modified based on continuous feedback from field operations, minimizing diameter changeovers and reduced clearance requirements, resulting in increased production.
- Wedge and probe designs were modified to decrease set up times in a nuclear environment.
- Technician training program was developed specific to CANDU refurbishment and the CNSC, CIQB procedure.
- Enhancements were made to client MetaPhase™ training “Implementing and Auditing Phased Array”.
- New equipment and software (under development) to further decrease scans and simplify reporting.

FUTURE REFURBISHMENT CONSIDERATIONS

- Considerable enhancements to both welding and inspection procedures/processes were identified over all 3 projects. It is suggested a thorough review of individual project successes to date, relative to welding and inspection is implemented, to further leverage and optimize the benefits Phased Array.
- Although the code case allows PAUT in lieu of radiography, the code has not been modified to allow PAUT for welder qualification. The process of using one inspection technique during qualification and then another during production minimizes the opportunity for welder training and further enhancement to weld quality.
- Implementation of Phased Array during the welding procedure development to ensure welding quality is optimized.
- Additional Phased Array training for welders prior to production relative to inspection technique and accept reject criteria, will optimize weld quality and reduce welding repairs.
- Modifications to the accept/reject criteria (ECA) through the CIQB, based on new code cases and industry experience, to further enhance weld quality while reducing repairs.
- Additional Phased Array “Auditing Training” to key project personnel to enhance the understanding and confidence of inspection results.