RPV and Primary Circuit Inspection

The Introduction of Phased Array Technology and the Advanced Nozzle Tool for the Inspection of their Nuclear Reactor Vessels
C.M. Barrera, IHI Southwest Technologies, USA; K-H. Park, SEA-AN Engineering Co., USA

ABSTRACT

IHI Southwest Technologies, Inc. (ISwT) and Saean Engineering Corporation (Saean) recently joined forces and introduced ultrasonic phased array technology and the Advanced Nozzle Tool (ANT) to Korean Hydro and Nuclear Power Company (KHNP) for the inspection of their nuclear reactor vessels (Figure 1).

ISwT and Saean used equipment and tooling that requires minimal use of the polar crane and has minimum critical path impact to perform these examinations. The ISwT developed ANT and phased array systems are unique systems which consist of a remotely operated swimming scanning tool that is specifically designed for nozzle bore ultrasonic examinations and is used to deliver the latest fully Performance Demonstration Initiative (PDI) qualified phased array ultrasonic examination techniques.

ISwT/Saean TEAM

ISwT and Saean established a teaming arrangement (Figure 2) several years ago. The teaming arrangement has allowed both organizations to exchange and share technologies, equipment, and technical expertise. Through this teaming arrangement, ISwT and Saean have primarily focused on using the PDI platform to jointly demonstrate and qualify advanced phased array techniques, procedures, and personnel.
Under the auspices of the PDI program, ISwT qualified phased array techniques and procedures for the examination of nozzle-to-shell (NTS) welds and dissimilar welds (DM) from the inside surface of the reactor pressure vessel (RPV). This was followed by training and henceforth the qualification of both ISwT and SaeAn personnel.

WORK SCOPE

KHNP requested hot leg inside surface NTS weld and hot and cold leg inside surface DM weld remote ultrasonic examination services at the Kori Unit 3 and 4 Nuclear Power Stations. The nozzle-to-shell (Appendix VIII, Supplement 7) examinations and the elbow-to-safe end, safe end-to-nozzle, and the nozzle-to-safe end (Appendix VIII, Supplements 2 and 10) examinations (Figure 3) were all performed using fully qualified ISwT PDI phased array procedures.

Figure 3 - Supplement 2 and Supplement 10 Examination Areas
AUTOMATED NOZZLE TOOL SYSTEM (ANTS)

SaeAn acquired an ANT (Figure 4) from ISwT which was first used by ISwT, previously SwRI, at Watts Bar Unit 1. The ANT uses floatation and thrusters to allow it to maneuver freely in the water and perform as a remotely operated vehicle. It uses two centering tripod mechanisms that are activated once the tool is installed into a nozzle to center and grasp the nozzle bore. A movable axial drive provides movement along the nozzle centerline and a rotary drive provides circular movement. Either movement can be used for scanning or incrementing the ultrasonic search unit package.

The ANT is shipped fully assembled and weighs less than 250 lbs. (in air). This allows for an easy and cost effective mobilization and de-mobilization of the tool. The ANT provides benefits in terms of move-in simplicity and logistics support. Due to its small size it requires minimal plant support, crane usage, and real estate for set-up and checkout activities. The only crane support needed is for installation and removal of the ANT into the nozzles, and that can be provided by a small jib crane or the refuel bridge hoist.

The ANT can be configured to examine outlet or inlet nozzles with the core barrel removed or just the outlet nozzles with the core barrel in place. The ANT can provide coverage of the nozzle-to-piping and the NTS weld from the nozzle bore inside surface. Its small, light weight, completely submersible design allows examinations to be performed without obstructing the center of the reactor vessel, therefore, allowing other in-vessel operations to be performed while the nozzle examinations are ongoing.

![Figure 4 - Lower Head Examinations Performed While ANT is Being Lowered into the RPV](image)

PHASED ARRAY UT

The NTS and DM examinations were all conducted using PDI qualified phased array techniques. The phased array techniques provide beam focusing, beam steering, and greatly improved resolution over conventional techniques. The phased array techniques utilized allow the use of multiple element examination angles generated by a single search unit (Figure 5) which helps to improve detection and sizing capabilities and efficiency simultaneously.
ISwT and SaeAn use the TomoView analysis software as the data analysis platform. The TomoView software uses a Windows Operating System for easy import, export, and transfer of data images and data for second opinion or confirmation. It also provides high density data without having to partition examination areas.

The TomoView software provides the data analyst a flexible platform with a variety of confirmation and characterization features which can be utilized to enhance the data analysis process. In addition to single angle views of each angle generated during an examination, the analyst can merge all or selected angles to assist in the sometimes complex decision making process. Additionally, the data analyst can use volume corrected or non-corrected A-Scan, B-Scan (ref. figure 6), C-Scan, D-Scan, Polar, and/or Sectorial presentations to aide in the data analysis process. The TomoView analysis software also allows for the insertion of CADD-based drawings like geometric conditions or the search units themselves right onto the data images. Hysteresis correction is another tool that the TomoView software offers. It can be used to correct for any unplanned hysteresis of the scanner itself.
The Kori 3 and Kori 4 DM weld examinations were conducted using PDI phased array qualified techniques and a 0-degree immersion technique which was used in order to obtain butt weld profile information. The examinations were performed from the inside surface of the nozzle bore looking in four directions for the detection of flaws both parallel and transverse to the weld. A single phased array 1.5 MHz probe with beam ranges of 60-88 degrees was used for the examinations. This probe was specifically chosen for this application to allow efficient detection of flaws in the inner 1/3 T examination volume of the weld (Figure 7).

The Kori 3 and Kori 4 NTS weld examinations were also conducted using PDI phased array qualified techniques. The examinations were also performed from the inside surface of the nozzle bore looking perpendicular to the weld for the detection of flaws parallel to the weld. A single phased array 2.0 MHz probe with beam ranges of 5-40 degrees was used for the examinations. This probe was specifically chosen for this application to allow efficient detection of the entire examination volume of the weld including the clad-to-base metal interface and the OD surface.
OVERALL SYSTEM BENEFITS

The combination of the T-III and the ANT allowed ISwT and SaeAn to achieve the following:

- Minimized DM and NTS scan time
- Allowed the utility to schedule parallel activities during the nozzle inspections
- Quickly mobilized and de-mobilized for the performance of the examinations at both Kori 3 and Kori 4
- Used single search units for each examination
- Utilized State-of-the-Art phased array equipment
- Acquired versatile, easy to manipulate, very high quality data
- Used a simple and straightforward delivery system (the ANT)
- Achieved higher equipment reliability due to the use of less complicated equipment
- Required minimal utility support

ISwT and SaeAn RPV INSPECTION CAPABILITIES

ISwT recently (Spring 2009) completed a successful procedure demonstration satisfying the requirements of Section XI of the ASME Boiler and Pressure Vessel Code, Appendix VIII, Supplement 4 and 6 as implemented by PDI. This demonstration represents the only fully phased array ultrasonic option for performing automated ultrasonic (AUT) in-service or pre-service examinations of nuclear reactor pressure vessels from the inside surface. That was followed by ISwT and SaeAn personnel qualifications.

ISwT’s latest qualification of reactor vessel procedures uses the new ZETEC DynaRay phased array system. The DynaRay system is ZETEC’s latest phased array unit and will someday replace ZETEC’s T-III phased array system that ISwT and SaeAn have used for some time. The DynaRay system is capable of handling 256 PA channels, up to 4096 focal laws, and the data throughput is approximately four times faster than previous systems.

This newly qualified procedure for reactor vessel shell weld examinations allows for the faster collection of data thus saving time. This phased array technique improves examination times significantly and provides the latest phased array technology in the industry.

Presently, ISwT and SaeAn are in a unique situation because they are the only two organizations which can examine 100% of a reactor vessel from either the outside surface or from the inside surface using PDI qualified phased array techniques. ISwT and SaeAn use the ZETEC developed T-III and the DynaRay systems to accomplish this.

ISwT’s and SaeAn’s capabilities include the following reactor pressure vessel PDI phased array qualified techniques using a T-III system (ref. figure 8).

- OD RPV (Sup 4 / 6)
- ID NTS Hot / Cold Legs (Sup 7)
- ID NTS SI From the Bore (Sup 7)
- ID Hot / Cold Legs DM (Sup 2 / 10)
- ID SI DM (Sup 2 / 10)
ISwT’s and SaeAn’s capabilities also include the following reactor pressure vessel PDI phased array qualified techniques using a DynaRay system (ref. figure 9).

- ID RPV (Sup 4 / 6)
- ID Piping (Sup 3)

SUMMARY

The joint forces of ISwT and SaeAn were able to successfully introduce state-of-art PDI qualified phased array technology and a simple and straightforward delivery system to KHNP for the inspection of their hot let and cold leg DM and NTS welds at the Kori 3 and Kori 4 Units. ISwT and SaeAn used unique equipment and tooling that requires minimal use of the polar crane and has minimum critical path impact to perform these examinations. This resulted in not only cost savings, but more importantly, to a very high confidence level in the examination results.

The joint forces of ISwT and SaeAn have continued to push the NDE technology envelope by being the only two organizations which have successfully qualified reactor pressure vessel phased
array techniques and procedures under the auspices of PDI, therefore being able to virtually examine 100% of a reactor pressure vessel from either surface using phased array techniques.

CONFERENCE THANKS

Coordinating Bodies:
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