# THE STATUS OF PERFORMANCE DEMONSTRATION IN TAIWAN

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**Abstract**

The Institute of Nuclear Energy Research (INER) in Taiwan is holding an ultrasonic testing performance demonstration (PD) program for the nondestructive testing crew in Taiwan's nuclear power plants. This program is for qualifying personnel's ultrasonic testing (UT) skills on stainless steel piping welds, carbon steel piping welds and bolts. For stainless steel and carbon steel piping welds, artificial flaws embedded in welds comprise two types of circumferential and axial ones. Examinees are required to detect and size flaw lengths. For the PD of bolt, circumferential EDM notches were designed and machined on the threaded sections of bolts. Examinees are required to detect and indicate the location of all the flaws on tested bolts. The PD passing rates for piping weld and bolt are 62.5% and 33.3% respectively.

## 1. Introduction

The performance demonstration (PD) program held by INER follows the ASME Boiler and Pressure Vessel Code Section XI, Appendix VIII for nuclear power plant (NPP) nondestructive testing (NDT) workers. At the moment three PD items are available for UT workers, including stainless steel piping welds, carbon steel piping welds and bolts. For stainless steel and carbon steel piping welds, artificial flaws embedded in welds comprise two types of circumferential and axial ones. Examinees are required to detect and size flaw lengths. For the PD of bolting, circumferential EDM notches were designed and machined on the threaded sections of bolts. Examinees are required to detect and indicate the location of all the flaws. The details about design and ultrasonic response of bolting notches, and the experiences of the three PD items are reported in this paper.

## 2. Piping Weld Performance Demonstration

### *2.1 PD Examination Rules and Experiences*

During the 4-day PD section, the examinees perform UT skill on steel piping specimens to detect and size artificial flaws (Figure 1). The test pieces are made of carbon steel and stainless steel with both circumferential and axial thermal fatigue cracks. Each examinee should decide if the designated region contains flaws first, and then evaluate flaw orientation and length. A corner of test pieces storage room is shown as Figure 2. Each examinee is given 6 stainless steel piping specimens and 3 carbon steel piping specimens of different diameters and artificial flaws. There are 18 designated testing regions on 6 stainless steel piping specimens, including 6 regions that contain flaws while the others contain no flaw. There are 9 designated testing regions on 3 carbon steel piping specimens, including 3 regions that contain flaws while the others contain no flaw.

*Figure 1. Piping weld performance demonstration*

*Figure 2. A corner of test-pieces storage room*

The qualification criterion is to find out all flaws in stainless steel piping welds with at most one erroneous call in no-flaw region, subjecting to the condition that the difference between the actual and estimated flaw length cannot exceed 1 inch. The examinees who pass the stainless steel piping welds UT PD had to also give all correct calls on carbon steel piping welds to qualify.

Until August 2006, INER has held 8 PD sections since October 2002 for totally 24 NPP workers with 3 workers each time. Fifteen out of twenty four examines were qualified, resulting in 62.5% qualification rate.

*2.2 Statistical Analyses of Flaw Detection*

Statistical analyses, including accuracy rates and detection rates are made over examinees' detection data [1]. The definition of accuracy rate is the probability of judging correctly the existence or non-existence of flaws and the existing flaw's orientation (circumferential or axial), even though the sizing error exceeds 1 inch. Based upon examinees' output in the passed 4 years' PD sessions, the overall accuracy rate is about 90%, with stainless steel and carbon steel piping yielding similar results.

The definition of detection rate is the probability that finds out the existing flaws, regardless of sizing error or misjudgment in flawless regions. For stainless steel, the detection rates of circumferential and axial flaws are 90.5% (i.e. out of 10 existing circumferential flaws 9 are found) and 75.0% respectively. For carbon steel, the detection rates of circumferential and axial flaws are 90.5% and 77.8% respectively. The detection rates of circumferential and axial flaws regardless of piping material are 90.5% and 76.2% respectively. The detection rate is 86.9% as a whole.

## 3. Bolt Performance Demonstration

*3.1 Test pieces preparation*

There are many types of bolt in NPPs. Among them, reactor pressure vessel (RPV) head bolting, reactor cooling pump (RCP) bolting, recirculation pump bolting and main steam isolation valve (MSIV) bolting are more critical. The diameters of these bolts are greater then 5cm. The biggest bolt, with 15 cm diameter and 141 cm length, in all three operating NPPs in Taiwan is the RPV head bolting of Kuosheng NPP, as shown in Figure 3.

*Figure 3. Bolts for PD*

These bolts have to be inspected during the outage of a NPP. The major inspection method is using a straight beam ultrasonic probe to scan on the top end surface of a bolt. The ultrasound propagating along axial direction can detect circumferential flaws of a bolt.

This project obtained several spare bolts for each kind of the mentioned bolting, from three NPPs. Each bolt was designed to make some circumferential notches on the surface of different locations by electrical discharge machining (EDM). In order to assure the accuracy of notch size and obtain desired efficiency of sound reflection, ultrasonic inspection was performed during machining. The real depth of each notch was measured by mechanical probe after machining, to assure the depth and quality of notch.

*3.2 Development of ultrasonic software and instrumentation system*

In order to evaluate the inspection efficiency for different bolt cracks, this project set up a ultrasonic testing system with a home-made data acquisition and analysis software for the convenience of data storage and post analysis, as shown in Figure 4. This portable system included a digital ultrasonic instrument, data acquisition card and transducers. Many experiments were performed, during notch machining, to detect and analysis the signals from different depth and distance notches. With the help of these experiments, the influence from the shape of a bolt was understood more and the correctness of notch design and machining was also confirmed.

*3.3 PD Examination Rules and Experiences*

The bolting PD system was developed in 2005. The examinee uses straight beam UT probes to inspect 4 different bolts within one day (Figure 5).

Each bolt has several notches. All the notches on these bolts has to be detected, and the tolerance for the measured axial location of detected notch shall be within ±5% of the bolt length.

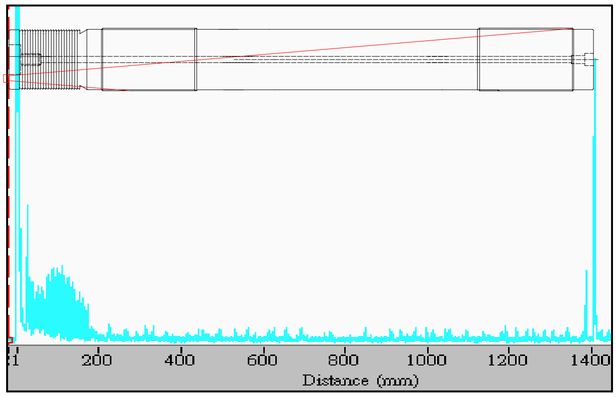


*Figure 4. Display of UT system*

*Figure 5. Bolting performance demonstration*

Although inspecting bolts from the top surface with straight beam probe seems to be simpler than the piping weld inspection by angle beam, it still has much interference affecting the inspection. The interference include delay echoes due to the slender shape of bolt, phantom echoes usually happened during fogging inspection, teeth echoes (at left side of Figure 4), roughness of bolt top surface, and the poor resolution between tooth and crack located at tooth root. The interference makes the bolting inspection difficult.

Until August 2006, only 2 bolting PD sections have been held since 2005 with 3 workers each time. Due to the mentioned difficulty and lack of training bolts, only 1/3 of the examinees passed. Therefore this project suggests NPPs to design and prepare more bolts with notches to train their UT people. The passing rate should rise after sufficient training.

## 4. Conclusion and Future Works

After the preparation for several years, the domestic PD system in Taiwan has grown up and been approved by the authority, Atomic Energy Council. It is providing stainless steel piping weld, carbon steel piping weld and bolting PD services conveniently and effectively for the NPP UT inspectors.

The statistical results can provide both regulatory authorities and utilities with a conservative evaluation of the confidence level of realistic UT results, especially in piping weld inspection.

The IGSCC (inter granular stress corrosion crack) PD is also expected to set up for several years. However due to lack of field cut IGSCC test pieces, this item is still idle. This project is looking for the organizations that can provide, sell or rent IGSCC samples for this purpose.

Dissimilar metal (DM) weld is the next PD item preparing by this project. Some of the required test pieces are available, others are manufacturing. The procedures are preparing and reviewing. The first AUT and MUT PD for DM weld are scheduled around the end of this year. It will strongly enhance the achievement of this PD program.

## 5. Reference


[1] Shyu, H.F. and Shong, W.J., “Statistical Analysis Results of Performance Demonstration for Piping Welds”, *Insight* 47(11):688-690, 2005.