PERFORMANCE DEMONSTRATION INITIATIVE: US IMPLEMENTATION OF ASME B&PV CODE SECTION XI APPENDIX VIII

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ABSTRACT

New requirements have now been added to Section XI as mandatory Appendix VIII, "Performance Demonstration Requirements for Ultrasonic Examination systems". The appendix was recently published and incorporates performance demonstration requirements for ultrasonic examination equipment, procedures, and personnel.

These new requirements will have far reaching and significant impact on the conduct of ISI at all nuclear power plants. For the first time since Section XI was issued in 1970, the effectiveness of ultrasonic examination procedures and the proficiency of examiners must be demonstrated on reactor pressure vessel (RPV), piping, and bolting mock-ups containing real flaws.

Recognizing the importance and complexity of Appendix VIII implementation, representatives from all US nuclear utilities have formed the Performance Demonstration Initiative (PDI) to implement Appendix VIII to provide for uniform implementation.

POTENTIAL BENEFITS OF PERFORMANCE DEMONSTRATION

Implementation of these new requirements is expected to substantially improve the effectiveness, capability, and credibility of ISI. With the implementation of Appendix VII, ISI results obtained from procedures that have been demonstrated to be effective can be more readily accepted by regulatory authorities when indications are detected and sized or if utilities are seeking license extension for older units. Appendix VIII qualified procedures are expected, therefore, to provide the benefit of avoiding expensive and unnecessary repeat or augmented examination. The financial implications alone are substantial. For example, Rochester Gas & Electric has already documented savings of over $8 million resulting from NRC acceptance of indication sizing results using specialized RPV examination procedures that were demonstrated to be accurate [2].

Participation in the unified, utility-directed PDI program will significantly lower the cost to utilities through economies of shared resources and will provide utilities with a strong voice in negotiations with regulators through NUMARC. Orderly implementation of a cost-effective and credible program without placing undue burden on those utilities that will be faced with early implementation is the most important objective of the PDI program.
PDI STEERING COMMITTEE FOR IMPLEMENTING PERFORMANCE DEMONSTRATION

The purpose of the PDI Steering Committee is to establish and operate a unified, utility-controlled implementation program. The Steering Committee is comprised of 16 members representing 16 different US utilities. All utilities owning nuclear plants in the US are participating in PDI.

To address the many difficult issues pertaining to implementation, PDI formed five working groups with members from the main committee and other key individuals from other utilities, ISI vendors, and the EPRI NDE Center. The Technical Group is evaluating the demonstration protocol, the matrix of intentional defects, methods of producing defects, number and type of samples, computer modeling and other related issues. The Code Liaison Group has the responsibility to work with the ASME Section XI Committee to keep them informed of PDI activities and to recommend potential changes and clarifications to the Code. The Finance Group is responsible for recommending methods of raising the needed funding, developing budgets, and overseeing program expenditures. The Special Projects Group is addressing issues such as the timing for implementation, organizing industry information meetings, scheduling, and long-term administration of the demonstration program. A Quality Assurance working group developed guidance for the QA program in PDI and monitors the quality assurance aspects of the program. EPRI and the EPRI NDE Center are providing support as requested by the committee and will administer the demonstration program for PDI.

The timing of implementation is a critical issue considering the complexity and cost of the program and its impact on utility ISI programs. The PDI Steering Committee meets periodically with the NRC staff for the purpose of discussing implementation of Appendix VIII. PDI will continue to work through NUMARC to facilitate reasonable implementation dates.

OVERVIEW OF PERFORMANCE DEMONSTRATION PLAN

The PDI implementation program addresses the sample fabrication and operational requirements for a unified performance demonstration program operated by EPRI for the PDI Steering Committee. PDI will establish the requirements for the demonstration test blocks as well as the rules and protocol for the operation of the program. The PDI implementation plan consists of RPV and non-RPV (piping and bolting) programs. The major features of the implementation plans are described below. Rules for performance demonstration for dissimilar metal welds, overlays, and cast stainless steel are not yet contained in Appendix VIII. Accordingly, the PDI plan does not currently address these components.

A thorough evaluation showed that the most cost-effective option for the RPV demonstrations featured portable samples that could be shipped to vendor locations for performance demonstrations. The piping and bolting options studied included regional and mobile centers, individual utilities, and ISI vendors. After careful consideration of the workload and the operational cost, the PDI steering committee has concluded that the piping and bolting qualification program could be effectively and economically accomplished through one mobile and one fixed site (the EPRI NDE Center).

For both the RPV and piping programs, uniformity of approach is important to credibility and acceptability and to ensure that qualifications earned at one location can be applied at another, avoiding the substantial cost of repeating qualification demonstrations.

Some key features of the proposed program are still under consideration by the PDI Steering Committee. Many difficult decisions were required to implement a program with significant technical value at minimum cost. The cost and schedule estimates currently under consideration are based on a program which includes the following features:

1. A unified industry approach of high credibility
2. A generic program that minimizes the need for site-specific demonstrations
3. Regional and mobile centers unified by a common protocol and sample sets
4. A basis for negotiating implementation approaches and dates.

Samples. The samples are a critical ingredient of the program and represent a substantial portion of the total cost. A thorough investigation of existing samples has been completed to minimize the number of samples that must be fabricated. Field-removed piping samples currently used for wrought austenitic piping examinations for IGSCC at the NDE Center can fulfill a portion of the requirements for piping qualifications but will require substantial augmentation to meet the size range specifications of Appendix VII. Samples suitable for RPV qualifications are not available.

PDI has developing a detailed general design specification that contains requirements for sample design and fabrication, including requirements for introduction and characterization of intentional flaws. Each sample, in addition, is described in a specific design specification.

RPV Samples. The RPV samples address the needs of automated and manual ISI and PSI for both BWRs and PWRs. Practice blocks which can be used for skill improvement and technique development are also included. Separate portable test blocks are provided for PWR and BWR performance demonstrations due to major differences in configurations and examination approaches as well as the number of qualifications expected in the initial stages of the program. Both BWR and PWR samples are designed to be used in ISI vendor facilities. It is expected that PWR and BWR demonstrations can be carried out simultaneously at two different sites, if necessary.

The PWR sample set includes four large curved plates and two nozzles. The test samples will contain under-clad and embedded flaws. One nozzle will simulate the thickest inlet nozzle currently in service and will be installed in an 11.25-inch thick plate. The outlet nozzle will be used both for nozzle-to-shell weld and nozzle inner-radius examination demonstrations. The second nozzle will simulate the smallest diameter inlet nozzle and will be used for nozzle inner-radius examination demonstrations. The size and configuration of the samples and number of flaws were selected to satisfy the requirements of Appendix VIII, provide flexibility in the demonstration, and allow retesting of individuals as necessary.

The BWR sample set will consist of five curved plates and five nozzle mock-ups. The samples will contain under-clad and imbedded flaws. The nozzle mock-ups will include a BWR recirculation system outlet and inlet and three smaller nozzle mock-ups to satisfy the nozzle-to-shell thickness ratio requirements of Appendix VIII. These mock-ups are primarily intended for BWR examination demonstrations from the outside surface but will also be suitable for demonstrations from the inside. It is expected that the BWR sample set will also be used extensively for manual examination demonstrations which are applicable to both BWR and PWR vessels.

Practice samples are an integral part of the PDI program and are being provided to assist ISI vendors to improve their procedures and skills to a level that will maximize the potential for meeting Appendix VIII requirements. The current inventory of EPRI NDE Center RPV test specimens has been made available to the industry for immediate use. These specimens include PWR plate specimens with imbedded defects and smaller plates with under clad cracks. The proposed practice samples, to be fabricated, include: a PWR nozzle-to-shell mockup, a BWR nozzle-to-shell mockup, three BWR nozzle inner radius mockups (20", 12" and 4"), a BWR plate, and a multipurpose nozzle-to-shell simulation of a small diameter nozzle. It is expected that the majority of these practice mockups will be available by mid 1993.

Appendix VIII allows considerable flexibility in the selection of flaw types and locations. The Technical Committee has established rules for
selecting a matrix of flaws for the PWR and BWR sample sets which will be both realistic and representative. Fabrication techniques which provide accurate knowledge of the flaw size will be used in accordance with PDI specifications.

Non-RPV Samples. In addition to the RPV, Appendix VIII addresses wrought austenitic and ferritic piping as well as bolting 2 inches or greater in diameter. The program includes sufficient samples to supply one regional center and one mobile demonstration facility. The primary piping sample sets will be wrought austenitic pipe supplemented with ferritic piping samples as required. The sample sets will also address PWR clad ferritic and wrought stainless steel main coolant loop piping. Requirements for cast austenitic, dissimilar metal welds, and overlays are not yet included in Appendix VIII. The sample set as presently envisioned will contain 64 wrought austenitic detection and length sizing samples in the size ranges appropriate to both BWR and PWR application and 48 depth sizing samples. Sixteen detection and 24 depth sizing ferritic piping samples in the range of 4 inch to 24 inches in diameter are also included as are 16 samples, each of ferritic and wrought stainless steel PWR main coolant loop piping.

The quantity of samples will help to maintain sample security. The field-removed samples currently used for IGSCC qualifications at the NDE Center would be available for use as required.

Samples which will be used for depth sizing demonstrations will be fabricated using flaw implantation techniques which provide a precise knowledge of the true flaw depth.

LIAISON WITH ASME CODE COMMITTEES

The Steering Committee has identified feedback to the ASME Code Committees on Appendix VIII issues as an important part of their charter. As implementation of Appendix VIII evolves, clarifications and modifications are inevitable, and feedback to the Code committee will be a useful way to provide industry input to changes considered for Appendix VIII.

Two proposed Code revisions have been introduced and accepted by the Code. The first of these allows the use of demonstration samples with thickness within 90 percent of the maximum component thickness to be examined. This change will allow the PDI program to use existing surplus vessel plate material rather than being required to fabricate material to the absolute maximum thickness of the thickest vessel currently in service. This change provides a program savings of approximately two million dollars. The second change to the Code involves the characteristics of the ultrasonic system. The current code requirement places stringent tolerances on each component of the system. The proposed change allows characterization of the system as a whole. Demonstrations and characterizations at the NDE Center showed that this revision would allow considerably more flexibility in the selection of ultrasonic instruments, provide equivalent quality levels and substantially reduce the number of essential variable requalifications which would be required. The cost savings have not been estimated but are expected to be substantial.

Even though dissimilar metal welds, overlays, and cast stainless steel demonstration requirements are not incorporated as yet into Appendix VIII, PDI is actively reviewing appropriate requirements for these components. The Technical and Code Liaison working groups, together with the EPRI NDE Center, have developed candidate demonstration rules and have initiated Code revisions with Code committees to provide input for formulation of realistic requirements in Appendix VIII.

ADMINISTRATION

PDI is developing guidelines for organizing and operating the performance demonstration program. These guidelines describe the scope and purpose of
the PDI program; the roles and responsibilities of PDI, utilities, and program administrator; and contain the basic elements of the PDI performance demonstration program.

Administration of the program includes sample design and procurement, sample documentation, administering demonstrations, QA activities and audit support, and maintaining qualification records. It is expected that utility personnel may also participate in administering performance demonstrations.

Documentation that must be maintained to show compliance with the requirements of Appendix VIII includes: the list of qualified essential variables for each procedure-vendor combination, sample set descriptions, and the results of the qualification demonstrations.

**TECHNICAL CONSIDERATIONS OF PERFORMANCE DEMONSTRATION**

**Sample Design.** A comprehensive survey of U.S nuclear utilities was made to determine the range of RPV component, piping, and bolting sizes and configurations that must be addressed in the program. This was done with the objective of including the majority of configurations in the sample matrix. PDI is now reviewing this data to select the sample matrix.

The committee is also reviewing how to determine whether a particular component that may be specific to only a few plants should be in the matrix. The samples are designed to cover the widest practicable range of components in US plants. Nonetheless, if some particular component configuration is not covered by the PDI samples, the affected utility may have to develop a special mock-up or investigate the use of computer modelling to cover qualification for that case.

Detailed dimensional information was obtained and reviewed to design a sample set that spans the maximum range according to the rules in Appendix VIII that govern the range of qualifications. For example, for nozzle inner radius examinations performed from the vessel outer surface, Appendix VIII allows a variation of ± 30% in the ratio of nozzle thickness to shell thickness between the demonstration sample and the actual plant component. By considering the range of this ratio that exists in plants and using the ± 30% rule, it is possible to cover most of this range with 5 or 6 nozzle mock-ups.

The RPV weld samples for BWR and PWR applications are designed with the maximum wall thickness expected to be encountered. Candidates demonstrating on this one set of samples will, therefore, be qualified for all vessels with this thickness or less.

Similarly, the piping sample set was designed to accommodate the widest practical range of wall thickness and diameter. Appendix VIII requires demonstration on the minimum and maximum wall thickness and diameter that is to be examined, with the additional requirement that at least 4 samples with different diameters and thicknesses be used.

The bolting matrix was designed to cover the range of lengths and diameters that was determined from the plant surveys.

**Role of Computer Modeling.** The wide diversity of component configurations in US power plants and the high cost of well characterized samples make it difficult to include a mock-up of every plant-specific feature in the sample matrix. Computer modelling of ultrasonic examination procedures is being investigated as a possible way to minimize the number and cost of required samples and the number of demonstrations that each organization must perform.

Computer modelling of examination procedures has the potential to determine the equivalence of different procedures on the same component and, similarly, the performance of minor procedure variations on different configurations. In this way, it may be possible to establish the
equivalence of procedures even though some of the essential variables, such as beam angle, vary more than the tolerances allowed in Appendix VIII. Establishing equivalence would eliminate the need for an expensive and time consuming re-qualification of the procedure when a change in essential variable is required.

Another important application for modelling is examination of nozzle inner radius regions from the outside of the RPV. In addition to determining procedure equivalence, modelling may offer a way to establish the technical basis for procedure design criteria such as beam angle selection and aiming directions that would eliminate the need to re-qualify procedures or personnel for each component configuration.

Computer modeling has the potential to significantly enhance the performance demonstration program and reduce costs in the following ways:

1. Evaluate sample designs to determine the minimum number of samples needed to cover the range of existing configurations
2. Establish the equivalency of procedures that may have slightly different essential variables
3. Evaluate the capability of procedures before performance demonstration to assist in optimizing effectiveness.

**Flaw Fabrication.** The characteristics of the intentional flaws in the samples is a major consideration for a valid performance demonstration. A considerable portion of the sample fabrication cost is associated with flaw fabrication and verification.

The PDI Technical Working Group has developed technical criteria for constructing samples and introducing intentional flaws. The criteria describe:

1. Accuracy of flaw sizes and locations
2. Flaw characteristics
3. Use of clean base material
4. Sample security

**Essential Variable Demonstration.** Appendix VIII lists 10 essential variables that must be specified as part of the procedure qualification. Procedures with the same essential variables, within given tolerance limits, are considered equivalent. Procedure demonstration, therefore, requires documentation of the essential variables actually used in each demonstration. This data will become part of the qualification record.

**CONCLUSION**

PDI has developed a comprehensive, five-year program for implementing Appendix VIII in a timely, credible, and cost-effective way. All U.S. nuclear units have joined the program, confirming the importance placed by utilities on NDE performance demonstration. The PDI program is organized and led by the utilities with technical and administrative support being provided by EPRI and the EPRI NDE Center. Strong utility leadership was a key reason behind the formation of the PDI program and will continue to be the operating principle of the program.

**REFERENCES**


2. "Accurate Flaw Sizing Technique Eliminates need for Augmented Reactor Pressure Vessel Examination at RG&E". EPRI First Use Number F-126.