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State-of-Practice Review of Ultrasonic In-Service Inspection of Class I System Piping in Commercial Nuclear Power Plants

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Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory
Commission

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ABSTRACT

The Pacific Northwest Laboratory conducted a survey to determine the state of practice of ultrasonic in-service inspection of primary system piping in light water reactors. Personnel at four utilities, five inspection organizations, and three domestic reactor manufacturers were interviewed. The intention of the study was to provide a better understanding of the actual practices employed in in-service inspection of primary system piping and of the difficulties encountered.

Among the principal findings of this state-of-practice review are:

1. Test procedures are very similar among the different organizations and are in general designed to meet only minimum requirements of Section XI of the ASME Boiler and Pressure Vessel Code. Supplemental tests (after a defect indication has been located) are substantially different.
2. Selection of ultrasonic search units is highly variable.
3. Confidence in the ability to detect defects was highest for ferritic piping and lowest for cast stainless steel.
4. Recording of geometrical indications during baseline preservice inspection or in-service inspection is not consistent and, therefore, of limited value.

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GLOSSARY OF ABBREVIATED TERMS

ASME Code	Boiler and Pressure Vessel Code published by the American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
BWR	boiling water reactor
CB	counterbore
CCSS	centrifugally cast stainless steel
DAC	distance amplitude correction
EPRI	Electric Power Research Institute
ID	inner diameter
IGSCC	intergranular stress corrosion cracking
IIW	International Institute of Welding
ISI	inservice inspection
KB	Krautkramer Branson
L-wave	longitudinal wave
LWR	light water reactor
MT	magnetic particle test
NA	not applicable
NDE	nondestructive evaluation
OD	outer diameter
PNL	Pacific Northwest Laboratory
PSI	preservice inspection
PT	dye penetrant testing
PVRC	Pressure Vessel Research Committee
PWR	pressurized water reactor

RF	radio frequency
rms	root mean square
RT	radiographic testing
SDH	side drilled hole
SS	stainless steel
T	pipe wall thickness
UT	ultrasonic testing
V	full V metal path

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EXECUTIVE SUMMARY

The Pacific Northwest Laboratory conducted a survey to determine the state of practice of ultrasonic in-service inspection of primary system piping in light water reactors. This state-of-practice review was conducted to define the actual procedures and practices applied in the field. Personnel at four utilities, five inspection organizations, and three domestic reactor manufacturers were interviewed.

- The principal findings of this review are:
 1. Test procedures are very similar among the different organizations and are in general designed to meet only minimum requirements of Section XI of the ASME Boiler and Pressure Vessel Code. Supplemental tests (after a defect indication has been located) are substantially different.
 2. Selection of ultrasonic search units is highly variable.
 3. Only one organization measures and periodically verifies the operating characteristics of their search units.
 4. Confidence in the ability to detect defects was highest for ferritic piping and lowest for cast stainless steel.
 5. Recording of geometrical indications during baseline preservice inspection or in-service inspection is not consistent and, therefore, of limited value.
 6. Nominal and worst-case counterbore conditions described by the inspectors provide an insight into the inspection difficulties produced by this condition.

This document is intended to provide the reader with a better understanding of the actual practices employed in in-service inspection of primary system piping as well as the difficulties encountered. Areas of concern listed in this document are currently under investigation to determine their impact on inspection reliability. Results of these investigations will be reported separately.

STATE-OF-PRACTICE REVIEW OF ULTRASONIC IN-SERVICE INSPECTION OF CLASS I SYSTEM PIPING IN COMMERCIAL NUCLEAR POWER PLANTS

1.0 INTRODUCTION

In-service inspection of the primary piping systems in commercial light water reactors is performed to meet the requirements of Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereafter referred to as Code) and Appendix III of Section XI (ASME 1977a). Periodic inspections of a sampling of pipe joints are made 1) to assure that cracks are not growing while pipes are in service and 2) to identify generic defects that may be present in the remainder of the system or in similar systems.

The adequacy of ASME Section XI requirements for assuring continued operating safety has not been conclusively established. Safety analyses therefore give little credence to the ability of in-service inspection (ISI) to detect defects that may result in pipe failure. The U.S. Nuclear Regulatory Commission (NRC) is sponsoring several programs directed at establishing the credibility of ISI and identifying the requirements necessary to assure light water reactor (LWR) operating safety. The Pacific Northwest Laboratory (PNL) was selected by the NRC to conduct a five-year program, "Integration of Nondestructive Evaluation Reliability and Fracture Mechanics," (Becker 1981).

Early in the program it was recognized that there was a lack of information regarding the procedures practiced by organizations performing ISI of primary system piping at commercial LWRs. Uncertainty existed as to the specific techniques, procedures, equipment, transducers, methods of signal evaluation, etc. in use for ISI at nuclear power plants. Research staff at PNL felt that current practices were highly variable and that the procedures should be documented for reference and for guidance in future research. This report documents one task of the program: a state-of-practice review of the available technology, procedures, and practices employed for ASME Code Section XI inspection of Class I system piping and components at commercial nuclear power plants.

This state-of-practice review was accomplished by literature review, personal interviews, and a survey of personnel at several utilities, private inspection organizations, and domestic reactor manufacturers. The objectives of the review (and definitions of terms important to the review) are discussed in Section 1.1.

The personal interviews and survey, which were the major part of the state-of-practice review, are discussed in Section 1.2.

The results of the survey are presented in Section 2 with subsequent conclusions in Section 3. An appendix supplies details of responses obtained in the survey.

1.1 OBJECTIVES AND DEFINITIONS

The first objective of the review was to define current ultrasonic inspection technology as practiced in the field, including procedures and practices used for the required ASME Code volumetric examination of Class I piping and components in commercial LWRs. Section XI of the Code defines the in-service inspection requirements for nuclear power plant components. Specific to this study, Subsection IWB-2500 of Section XI (Categories B-F and B-J) defines those areas subject to examinations and the extent and frequency of examinations for Class I pressure-retaining welds. Subsection IWB-2500 requires volumetric examination of these important Class I pipe welds with ultrasonic inspection being the preferred method of examination. Figure 1 shows a cross section of a typical welded pipe joint.

A second objective was to define a combination of test procedure and equipment that is most typical of field practice and that could be used as a basis for determining the capability and reliability of current ultrasonic inspection practices for detecting and sizing flaws in Class I piping.

The state of practice is the technology which is commonly applied in the field. The state of the art is (by our definition) the technology that has been proven in use and is generally accepted but not necessarily by code-writing organizations. A third category is advanced technology, techniques that are under laboratory study but which have not been demonstrated in the field.

FIGURE 1. Cross Section of a Typical Welded Pipe Joint

1.2 STATE-OF-PRACTICE SURVEY

This report discusses the information received as a result of personal interviews with four utilities, five private inspection organizations, and three domestic reactor manufacturers. Information furnished to PNL described ultrasonic inspection techniques, test procedures specific to materials examined, equipment and transducers, standards, confidence limits, and problem areas such as pipe counterbore geometry.

Interviews were made with key personnel who were knowledgeable of the ISI field practices of their organization. The individual responses to the survey (as presented in the Appendix) are limited in that they are often the opinions of one or two persons in a large organization. However, efforts were made to assure that these were well-informed opinions: together the interviewed organizations encompass the major portion of domestic ISI experience in ultrasonic inspection of Class I piping in nuclear power plants.

The next section covers the results of the survey.

2.0 STATE-OF-PRACTICE SURVEY RESULTS

The results of the state-of-practice survey are summarized by topic in the following sections. Specific responses to the survey interviews are included in the Appendix for reference. A glossary of terms at the front of this document presents acronyms and abbreviations that may be helpful in reading this summary or the detailed responses in the Appendix.

The interviews covered 10 topics specific to ultrasonic in-service inspection:

- 2.1 Utility, Inspection Organization, and Reactor Vendor Experience
- 2.2 Selection and Performance Verification of Transducers
- 2.3 Manual Piping Inspection Practices
- 2.4 Inspection Practices for Ferritic and Stainless Steel Pipe
- 2.5 Experience with Centrifugally Cast Stainless Steel Pipe
- 2.6 Automated Inspection Practices
- 2.7 Pipe Outer Diameter Geometry Conditions
- 2.8 Pipe Inner Diameter Geometry Conditions
- 2.9 Calibration, Inspection, and Flaw Evaluation
- 2.10 Experience with Dissimilar Metal Welds.

2.1 UTILITY, INSPECTION ORGANIZATION, AND REACTOR VENDOR EXPERIENCE

This topic covered questions about the number of in-service inspections that a company typically performs per year. Utilities were asked as to their degree of participation in the ISI program. Pacific Northwest Laboratory was interested in determining where the majority of inspection experience is being accumulated and to what extent utility personnel actually participate. In addition, PNL was interested in the inspection philosophy of these organizations and possible suggestions for improving in-service programs based on their experience.

Recognizing current inspection problems with intergranular stress corrosion cracking (IGSCC) in the austenitic stainless steels, PNL asked respondents about the number of inspections in which they had participated, looking specifically for IGSCC. Respondents were also asked about their experience and

confidence in the inspection of centrifugally cast stainless steel (CCSS) welds. The large grain structure characteristic of CCSS creates uncertainty in the inspectability of CCSS welds. Responses to these questions are detailed in Section 2.5, Experience with Centrifugally Cast Stainless Steel Pipe.

To date no in-service cracks have been found in the main loop coolant piping at domestic pressurized-water reactors (PWRs). Private ISI organizations and reactor vendor organizations perform about 95% of the domestic ISI programs at commercial nuclear power plants, of which there are currently 72 operating units. Utility personnel generally plan and oversee the ISI program with inspections by utilities themselves generally limited to special problem areas. However, the trend at some of the larger nuclear utilities is to increase utility inspection staff, thereby improving in-house inspection capability in addition to having broader versatility to plan, conduct, and execute their in-service inspection, testing, and maintenance programs. One utility estimated that 20% to 30% of ISI would be performed by in-house staff.

The survey respondents had different levels of inspection experience with IGSCC. Because of the incidence of IGSCC at certain domestic plants, the experience of utility and inspection personnel at these affected plants appears substantial. By comparison, one respondent from an inspection organization that participates in 30 to 40 ISI programs yearly stated that, to his knowledge, their people were not involved with any inspections looking specifically for IGSCC. Another respondent indicated that his company had been contracted specifically to look for IGSCC in certain piping systems at four plants; although he found no strong evidence of IGSCC, there was uncertainty at two plants concerning ultrasonic indications in the sensitized area of some welds. Respondents' answers also indicated differences in IGSCC test procedures, examination techniques, transducers, data recording levels, training, and standards. These differences are discussed further in Section 2.4, Inspection Practices for Ferritic and Stainless Steel Pipe.

The Electric Power Research Institute and the U.S. Nuclear Regulatory Commission are funding several research programs concerning IGSCC in piping systems.

2.2 SELECTION AND PERFORMANCE VERIFICATION OF TRANSDUCERS

Several studies (Buchanan 1976; ASNT 1977; Serabian and Lawrie 1977; Birks and Lawrie 1978) have shown the dramatic variability in measurement accuracy and repeatability that result when transducers are not properly characterized but randomly selected for use. This topic covered questions concerning the criteria for selecting transducers and the methods used to verify the operation and performance of transducers. Respondents were asked if certain parameters (such as center frequency, radio frequency (RF), waveform, sensitivity, or frequency bandwidth) were routinely measured to verify transducer performance. Respondents were also asked about methods used to periodically check transducer performance. Numerous technical studies now under way under the auspices of the U.S. Naval Research Laboratory, National Bureau of Standards, ASTM, PVRC committees, and other organizations are emphasizing the development of appropriate specifications and testing procedures for the evaluation of ultrasonic system components.

Inspectors select transducers based on inspection experience and the demands of a given test procedure. A typical test procedure states the nominal operating frequency and transducer size range that can be used. For shear wave examination, beam spread and exit point are measured.

In order to verify initial transducer performance, most companies request manufacturer's certification (RF waveform and frequency spectrum) and the results of a standard calibration. Center frequency is generally assumed from manufacturer's certification; two respondents check center frequency themselves, and one respondent checks the beam profile. Others feel that taking a beam profile has little merit.

The industry makes no checks of near-surface resolution. One company checks transducers on an inner-diameter reflector (notch) if they are going to inspect thin-wall pipe. Calibration blocks with side-drilled holes (SDH) are used to calibrate for distance amplitude correction (DAC) and to establish a sensitivity level. Resolution is checked using SDH. Almost half the respondents use International Institute of Welding (IIW) blocks for verification of beam angle and exit point. One respondent uses an IIW design modified to closer tolerances (1° measurements added).

Records of transducer certification are often kept, and all DAC curves are recorded and documented as required by test procedures. The philosophy of several respondents was that a successful DAC calibration (within a few decibels of typical values for a specific pipe standard) indicates that the transducer is good. Any need for a significant increase in gain to maintain a given DAC curve is often perceived as a sign of transducer problems. Only one respondent indicated the use of periodic (biannual) checks on transducer performance (RF waveform frequency spectrum and distance-versus-amplitude plot).

All respondents estimated that the typical lifetime of an angle-beam transducer is two to three years for inspection organizations. Special units may last up to five years.

2.3 MANUAL PIPING INSPECTION PRACTICES

This series of questions was intended to identify the ultrasonic flaw detection instruments used in practice: the make, model, modifications (if any), and reasons for modifications. The use of electronic DAC, external recording devices, requirements on warm-up time, and periodic calibration or measurement requirements not specified by Code were also covered in the survey.

Although companies use many different instruments for manual piping inspection, the most common is a Sonic Mark I. The Nortec 131D, Krautkramer-Branson USIP II, and Branson 301 and 303 instruments are also widely used. These instruments are usually unmodified with no particular requirements other than manufacturer specifications for instrument pulser or receiver bandwidth. Electronic DAC is not used for manual pipe inspection. Only one respondent uses an external recording device (a strip chart) to record all analog data (metal path and amplitude) for each weld inspection.

Standard practice is to completely wrap the instrument in a plastic bag to protect it from contamination. The bag is taped, and the instrument-transducer system is then calibrated. The most common practice is to recalibrate the instrument before it is removed from the reactor containment area before decontamination. All respondents indicated that wrapping the instrument

does not alter instrument performance. However, there was concern about instability problems that occur in containment at temperatures of 125°F and higher.

Less than half of the respondents apply periodic calibration or measurement requirements more frequently than specified by Code.

The requirements for instrument warm-up time vary from no warm-up to thirty minutes for manual systems and one hour for automated systems. Although several companies have no requirements for warm-up time, the instrument is usually on two to five minutes before the operators are ready to begin inspection. Two companies that recommended a specific time for instrument warm-up indicated that their test procedure did not call for it. One respondent observed a three-decibel difference between instrument calibration after warmup and calibration immediately after the instrument is turned on. A few companies noted problems with instrument stability that were related to instrument warm-up time, battery charge, or line voltage fluctuation. One respondent noted that portable instruments are generally sensitive to line voltage and temperature changes. Another respondent found line voltage fluctuations to be a problem when a generator was used for automatic inspection at some sites; he also found that using new batteries for each major inspection alleviates problems that occur with battery-powered units.

2.4 INSPECTION PRACTICES FOR FERRITIC AND STAINLESS STEEL PIPE

Questions were intended to identify the specific transducers and any special procedures used for testing and detecting cracks in ferritic steel and austenitic stainless steel (SS) piping. Respondents were asked to indicate what confidence they had in detecting cracks.

The industry uses transducers of many different sizes with transducer selection dependent on pipe wall thickness—generally the thicker the wall, the larger the transducer. Typically, minimum Code inspection requirements are performed: on ferritic pipe, a 45° shear wave examination at 2.25 MHz. Standard Code procedures are used without exception; no special procedures are used. Inspection confidence for crack detection with ferritic pipe was very high.

Many respondents use the same transducers for austenitic SS pipe inspection as those used for ferritic pipe inspection: 2.25-MHz, single-element transducers at 45° shear wave examinations. Several companies use transducers of the same size but with a 1.5-MHz nominal frequency. Special test procedures with more extensive examination techniques are required by some companies.

All respondents have evaluated or have experience in using a dual-element transducer for inspection of austenitic SS pipe. The reported advantages of the dual-element transducer are "less noise," "cleaner recording," and "seems to work well with thin-wall material." Other respondents are considering use of the dual-element units but have no specific plans for using them.

Most companies use the same pipe test standards for IGSCC inspection of austenitic SS pipe as they use for ferritic pipe inspection (i.e., 10%T notch) per ASME Code Section XI, Appendix III. Two companies use a 5% T notch standard, and one company uses actual IGSCC pipe samples. Several respondents indicated that it would be most beneficial to make available to inspection personnel the many IGSCC samples that are stored at several sites in the U.S. Several companies concerned with ultrasonic examination of pipe welds for IGSCC have developed written procedures similar to those documented by Serabian and Lawrie (1977).

Confidence in detecting IGSCC in austenitic SS with depths from 10% to 25% of wall thickness (T) ranged between 50% to 85%. One respondent indicated that confidence in detecting cracks at 10% T is "borderline." At 25% to 50% T inspection confidence averaged about 78%. At greater than 50% T, inspection confidence averaged about 95%. These confidence estimates are based on the experience of the individual respondents and have little statistical significance; however, they indicate the relative degree of difficulty associated with detection of flaws in austenitic SS compared to ferritic material.

2.5 EXPERIENCE WITH CENTRIFUGALLY CAST STAINLESS STEEL PIPE

Respondents were asked several questions concerning their experience with the inspection of CCSS pipe. Use of specific transducers, procedures, instruments, standards, and test confidence estimates were discussed.

Respondents estimated that 8 to 10 domestic plants contain primary reactor coolant piping of CCSS. At least half of the respondents indicated some experience with CCSS pipe. The preferred method of examination is with a 1.0- or 1.5-MHz single-element or dual-element transducer using a refracted longitudinal wave incident at 40° to 45°. Standard field flaw detector instruments are used in conducting the examination. Because of the characteristically large, finger-like grains of this material (see Figure 2), examination of the weld using 45° refracted shear waves is impractical.

Most of the inspection experience with CCSS seems to be with one inspection organization. This respondent felt confident that one could detect any significant flaws using a 40° to 45° refracted longitudinal technique. Other respondents with experience in inspection of this material were more pessimistic about the detection capability and reliability of this ultrasonic inspection technique and showed a wide range of inspection-detection confidence. Some specific comments were: "difficult", "not very confident in test", "fair-good", "pretty good", "can see Code-size reflectors; however, there are many metallurgical reflectors in this cast material."

Current standards are pipe sections with 5% T Code notches and/or side-drilled holes. Several respondents indicated the need for better standards.

All respondents agreed that there is a need for additional study on inspection practices for CCSS pipe, and one reactor vendor is conducting a substantial program on the inspection of CCSS pipe.

2.6 AUTOMATED INSPECTION PRACTICES

This topic details the industry use of automated ultrasonic inspection systems: frequency of use, estimates of relative efficiency, data recording standards, couplants used, and special requirements.

Most respondents had used automated inspection systems but only to inspect nozzle-to-safe-end and safe-end-to-pipe welds. Respondents indicated that automated inspection accounts for 5% to 25% of the inspection program. The respondent who quoted a 25% use of automated systems indicated that this is only used during the preservice (baseline) inspection program.

FIGURE 2. Pipe Cross Section of Centrifugally Cast Stainless Steel

All respondents stated that manual inspection is superior to automatic inspection. Manual inspection is always preferred for critical problems. One respondent criticized the equipment design. Automated systems are unproven, require specific access conditions, and seem to break down at the most inappropriate times. Automated systems typically require as much time as manual systems (or more) to set up, calibrate, and conduct an inspection. Automated systems are less versatile but do offer improvements in measurement repeatability.

No industry standard exists for recording automatic inspection data. Strip charts, analog magnetic tape recording, analog-to-digital conversion with magnetic tape recording, and videotapes are current methods of recording ultrasonic data.

Water is the sound couplant for these automated systems. Systems are calibrated statically using pipe standards supplied by the utility, and then placed on the pipe for the dynamic inspection of the welds.

Weld preparation is important when employing automated systems. In practice these systems do require certain access limits. Typical access requirements (e.g., safe-end) are 18 in. on either side of the weld. Weld crown height should be flush or have a smooth taper.

2.7 PIPE OUTER DIAMETER GEOMETRY CONDITIONS

The survey discussion of pipe outer diameter (OD) geometry included information on single-side access, weld crown height, diametrical shrink, surface finish, overground conditions, and pipe-to-component OD conditions (see Figure 3).

Respondents estimated that typically 20% of the welds for Class I reactor coolant piping have single-side inspection access. However, one company replied that 90% of the welds for their PWR units have single-side access and 60% to 70% of the welds for their boiling water reactors (BWRs) have single-side access. Further, a reactor vendor spokesman stated that 90% to 100% of the primary reactor coolant system welds have single-side access. Respondents indicated that single-side access results because of pipe-to-valve and pipe-to-elbow conditions. Most respondents indicated that no special test procedures exist for single-side inspection access; one can usually perform a 1/2 V

a) Single-Side Access

b) Excessive Crown

c) Diametral Shrinkage

d) Overground

e) Unknown Centerline

FIGURE 3. Outer Diameter Geometry Conditions

path weld root examination, or a $3/2$ V path weld root examination when $1/2$ V path examination is impossible. Full V path examination is used for inspection of the upper weld crown area. Figure 4 shows $1/2$ V and full V path ultrasonic weld examination. Respondents estimated that essentially 80% to 100% of the primary reactor coolant system welds were ground. New plants under construction have welds that are blended. Older operating PWR and BWR plants have a variety of conditions; the most common reported condition is with the crown ground flat with an edge height of approximately 0.03 in.

Typically, there are no special procedures used to compensate for severe diametrical shrinkage. Respondents indicated that shrinkage is usually not a problem in thick-wall pipe, but occurs more often in thin-wall (0.5-in. wall thickness or less) pipe.

Respondents indicated that pipe surface finish is of good quality (e.g., 125 to 250 rms).

2.8 PIPE INNER DIAMETER GEOMETRY CONDITIONS

The survey discussion of pipe inner diameter (ID) geometry included information on pipe counterbore conditions and problems resulting from counterbore geometry.

FIGURE 4. $1/2$ V and Full V Path Ultrasonic Weld Examination

Figure 5 indicates the range of welded pipe counterbore conditions as sketched by the survey respondents. These sketches represent estimated worst-case and nominal-case conditions. As-built information on the counterbore is rarely available to the surveyed companies. Respondents indicated that design specification drawings are usually available; however, they questioned the usefulness of this information because of the optional methods currently allowed for pipe joint fabrication at commercial plants. In older operating plants, the design specification drawings are often unavailable.

In general, the survey respondents felt that their capability for accurately measuring counterbore geometry ranged from "poor" to "very poor." Most companies use a single-element transducer with a 0° examination (thickness measurement) at 2.25 MHz to 5 MHz. However, one respondent uses a dual-element, line-focused transducer. On occasion radiography is used where possible.

The availability of baseline information on geometric reflectors varies from "not very often", to, "40% to 50% of the time" and "frequently available." Respondents indicated that the baseline information on geometric reflectors is generally correct. However, in one case where destructive analysis had been performed, one respondent reported that stress corrosion cracking was labeled as a geometric reflector. Counterbore geometry, weld root suck-up, and weld root drop-through were mentioned as key pipe ID concerns (see Figure 6). One respondent indicated that sometimes geometric indications are reported and sometimes they are not: if indications are not reported on the data sheet but are noted by plant inspection personnel, the reporting of the geometric indication in future in-service inspections is used as a check on the inspector.

Respondents were asked if they thought there was a need for a standard format for recording geometric indications. Several respondents saw no need for a standard format for recording geometric indications. Other respondents believed that a standard format is needed and that it should be a Code requirement.

FIGURE 5. Pipe Counterbore Geometry Conditions

FIGURE 6. Pipe Inner Diameter Suck-Up and Drop-Through Conditions

Those respondents that did not feel the need for a standard format stated that the recording of geometric reflectors is essentially a Code requirement: the Code specifies recording of all defect-like indications which exceed a reference level. One respondent felt that all tests should be strip chart recorded for a permanent record of each examination.

Opinions varied concerning the value of baseline data gathered by different organizations. Responses ranged from "It should be valid if procedures and calibration blocks are the same," to "often very little value, since levels of recording and test procedure can be different," to "do not record geometry reflector for baseline."

Respondents were asked how they evaluate $3/2$ V signal indications when the beam is incident on the conical section of the counterbore (see Figure 7). Respondents indicated that they can get a $1/2$ V examination of the weld root for the majority of primary system welds.

2.9 CALIBRATION, INSPECTION, AND FLAW EVALUATION

Calibration verification and inspection practices were discussed in the survey, and a series of questions were asked concerning flaw evaluation and recording methods.

Typical industry practice is to verify initial instrument calibration by recalibrating at least every four hours and/or at every operator change. Scan overlap during calibration/inspection is 10% to 25%. Some skew is usually used

FIGURE 7. 3/2 V Examination with the Beam Incident on the Conical Section of the Counterbore (mode conversion of shear to longitudinal wave at conical section of counterbore)

during calibration/inspection, but the amount is neither mandatory nor recommended. One company uses a 45° skew for IGSCC inspection. The skew for ferritic pipe inspection ranges from 0° to 20°.

In-practice flaw evaluation and recording methods were determined with the following questions.

1. What is the data recording procedure?

Most respondents record signal indications that are 50% of DAC or greater and evaluate indications at 100% of DAC. Several respondents investigate and note signals 20% and 25% of DAC. One procedure called for the recording of indications down to 20% of the maximum indicated amplitude. Taylor and Selby (1980) evaluated the change in inspection sensitivity and data recording requirements resulting in major changes of the ASME Boiler and Pressure Vessel Code Section XI between the 1974 and 1977 Editions. Also discussed are the U.S. Nuclear Regulatory criteria in effect at several plants.

2. What is the position accuracy on the pipe ID surface?

Estimated positional accuracy on the pipe surface during inspection varied from 0.02 to 0.2 in.

3. What is the time metal path accuracy for 1/2 V and 3/2 V inspections?

Estimates of time metal path accuracy for 1/2 V examination were as small as 0.01 in. and as large as 0.125 in. Estimates of time metal path accuracy for 3/2 V examination ranged from 0.02 to 0.2 in.

4. Are there supplemental tests? other angles, frequencies? Two-side evaluation? Finger damping?

Standard practice is to use a 45° examination of each side of the weld. When a flaw is suspect, companies use 60° and 70° supplemental examinations. Finger damping is a common practice used to check on extraneous signals.

5. What methods do you use to call ID geometry? OD geometry?

For ID geometry, inspectors use reflector position (i.e., proximity to weld root) and the extent of indication (e.g., a 360° single reflector often indicates geometry conditions). Signal shape and characteristics, plotting methods, and refracted angle conversion charts are also used. Inspectors use many of these techniques to determine DD geometry. Finger damping is a key test for OD geometry.

6. When and how often do you call for radiography? How useful is radiography?

Inspectors call for radiography if they think that the ultrasonic test is inadequate for making a reliable inspection. The utility usually requests a radiograph if a flaw is called. One respondent calls for radiography if other radiographs are already on file (for comparison). Another calls for radiography if the inspector suspects IGSCC, which was estimated to occur about once per site inspection. The radiographs may then show weld spatter or can sometimes detect IGSCC. One inspector noted that radiography is not usually used for in-service inspection, while others indicated that radiography is used quite often. Most respondents judged radiography to be useful in some cases, but they varied in their estimate of its effectiveness.

7. When do you call for penetrant?

Most inspectors call for penetrant when ultrasonic inspection indicates suspect surface anomalies or through-wall indications. One company calls for penetrant when the weld has only single-side access.

8. What supplemental information do you call for and what is your confidence in them?

A variety of supplemental information is used but not necessarily all the time: design drawings, radiographic testing records, welding procedures, weld specifications, weld preparation data, previous ultrasonic inspection data, contour gauge measurements, as-built drawings, or other information may be available. The consensus seems to be that such information can be helpful although its reliability must be suspect, especially with older plants.

2.10 EXPERIENCE WITH DISSIMILAR METAL WELDS

Respondents were asked about their experience with dissimilar metal welds (bimetallic and trimetallic). Companies indicated that the bimetallic (e.g., carbon to stainless) and trimetallic welds (e.g., carbon to Inconel to stainless) produce many indications (particularly along the weld fusion zone interface) that complicate ultrasonic examination. Respondents try to use the most attenuative material for standards, but standards vary. One respondent indicated that it is not uncommon to experience a 20- or 30-decibel loss in signal amplitude when looking through the weld zone at known artificial reflectors positioned in the heat-affected zone. Training with dissimilar metal weld standards is a common practice. Test confidence in detection of flaws was estimated at 50% to 60%.

3.0 CONCLUSIONS

The ultrasonic examination procedures used for in-service inspection and evaluation of Class 1 reactor coolant system pressure-retaining welds are essentially the minimum requirements documented in the 1974 edition of the ASME Code, Section XI. Special ultrasonic examination procedures for the detection of inter-granular stress corrosion cracking and flaws in centrifugally cast stainless steel are more variable. Major differences occur in the examination techniques, the methods and procedures used for evaluating indications after detection, and the method and extent of data recording.

A major difference of opinion exists as to the need for recording geometric reflectors during preservice inspection (PSI). Some organizations do not record geometric indications during PSI. When geometric indications are recorded, their usefulness for ISI is sometimes questioned because there is no standard format for data recording. Researchers at PNL believe that a well-documented PSI would substantially improve the reliability of in-service inspections.

A wide range of nominal and worst-case counterbore geometry conditions was reported. Many of these conditions are unacceptable according to Section III of the ASME Code (ASME 1977b) and could lead to highly variable inspection results. As-built information on counterbore geometry is seldom available and is difficult to determine by nondestructive evaluation methods.

Only one company performs periodic evaluations on search units used for ISI. Few organizations make any search unit characterization other than the manufacturer's test report (RF waveform and frequency spectrum). Many respondents feel that extensive search unit or instrument characterization has no substantial benefit. Research efforts at PNL have indicated substantial differences in the performance of ultrasonic instruments and search units. Researchers at PNL believe that repeatable test results can be obtained only with well-characterized search units and instruments. Evaluations are in progress to determine the magnitude of these test variables.

The respondents uniformly agree to a high-confidence level (greater than 90) in their ability to detect flaws in ferritic steel piping. For flaws in austenitic stainless steel piping the confidence estimate is lower--60 to 85 for flaws from 10 to 25 of through-wall thickness and approximately 90 for flaws greater than 25 of through-wall thickness. Confidence for dissimilar metal weld joints ranges from 50 to 60 because of the high attenuation and spurious reflectors common to these welds. Confidence levels for centrifugally cast stainless steel are highly variable with one organization expressing a relatively high confidence (due to their independent research) compared to others who expressed no confidence. These levels of confidence should not be construed to have any statistical basis because they are personal opinions based on individual experiences. However, these opinions do give a realistic indication of the relative degrees of difficulty associated with inspection of these materials.

Over the last several years the utilities, the U.S. Nuclear Regulatory Commission, the Electric Power Research Institute, and other private non-destructive testing organizations have been increasingly aware of the need to improve both qualitative and quantitative nondestructive measurement capabilities for inspection of Class I piping systems at commercial nuclear power plants. Several of the more difficult areas of pipe weld inspection have been noted here. The review showed that there are noted differences in the as-practiced ultrasonic inspection methods and procedures used at commercial nuclear power plants. Researchers at PNL believe that further documentation of these practices will substantially benefit both NDE practitioners and regulatory personnel by providing technical information that will increase and improve the understanding of current Code inspection practices.

4.0 RECENT EXPERIENCES

The preponderance of data compiled in this report was collected during 1979 and 1980. Since that time, the state of practice has progressed, particularly in the areas of IGSCC detection and the inspection of centrifugally cast stainless steel (CCSS). Recent evaluations of the state of practice in the areas of IGSCC and CCSS are reported below.

• 4.1 IGSCC DETECTION

Recent developments in the area of IGSCC detection and characterization include: increased sensitivity, better transducer selection, improved training and experience, and improved "rule-of-thumb" techniques for separating IGSCC from geometric responses. Many organizations have lowered their threshold for evaluation to 50% of a side-drilled-hole DAC or 20% of a 10% notch DAC. These are approximately the same sensitivities for 0.5-in. wall thickness (Taylor and Selby 1980). Others, however, are still using 100% of a 10% notch DAC; this is a 14-dB difference in sensitivity. It is our understanding that the 20% of a side-drilled-hole DAC is the required evaluation threshold in Japan. A 5% notch is used by some companies. The 5% notch yields a DAC approximately 2 to 3 dB more sensitive than a 10% notch.

There is still considerable diversity of opinion as to which transducer is most appropriate for the detection of IGSCC. Those most favored include: a dual 1.5-MHz transducer; a 0.375-in.-dia., 1.5-MHz single-element transducer; a 0.25-in.-dia., 2.25-MHz transducer; and 0.5-in.-dia., 2.25-MHz transducer. Of the two available types of dual units, the one with broader bandwidth is most popular. Stated reasons for these choices include:

- "1.5 MHz yields a larger response relative to DAC."
- "2.25 MHz yields higher flaw response amplitude relative to geometric root responses."

These are contradictory statements. Due to the rough and branched nature of IGSCC, it is expected that the 1.5-MHz units will yield higher responses than the 2.25-MHz units, as the roughness represents a smaller fraction of the wave

length. Better discrimination against geometric reflectors (root) might be expected as the 2.25-MHz sound beam is more highly collimated and will experience more attenuation passing through the cast structure of the weld metal. The most appropriate transducer will depend on application, i.e., wall thickness, geometrical conditions, and reporting threshold.

The development of the graphite wool technique (Kawamoto 1980) has allowed the fabrication of test samples which cracks similar to those found in-service. The availability of these samples for training and test development should substantially improve the reliability of IGSCC flaw detection.

Over the past five years considerable experience has been gained in evaluating IGSCC flaws. The principal difficulty in evaluating IGSCC flaw indications is separating them from geometrical indications (primarily root reflections). There is general agreement that the most appropriate method for evaluating indications is very careful plotting of the indications. This requires precise location of the root as well as counterbore by normal-beam measurements. Any indication that plots on the near side of the root centerline should be highly important in this determination. Most organizations claim axial plotting accuracy of less than 0.1 in.

It has been stated that "IGSCC will occur 1/4 to 1/2 in. from the fusion line, depending on thickness." Exceptions have been observed, i.e., cracks located directly adjacent to the root. The applicability of the 1/4 in. "rule of thumb" is questionable. Other characteristics of IGSCC that aid in its identification include:

- Orientation: it can occur in any orientation from circumferential to axial.
- Flaws are generally discontinuous but not always.
- The search may be skewed $\pm 10^\circ$ with relatively little loss in amplitude compared to geometric reflectors (however, this is not always true).
- Sixty-degree inspections using a higher frequency (4 or 5 MHz) are often helpful in evaluating indications.

4.2 CENTRIFUGALLY CAST STAINLESS STEEL

Cast stainless pipe presents a major unresolved problem area because of its high attenuation and anisotropic grain structure. However, recent advances in search unit design promise improved inspection performance. Characteristics of these units include:

- dual units mounted on a plastic shoe
- 1 MHz operating frequency with 40 to 45° longitudinal wave
- high damping, i.e., short pulse.

The dual-element design minimizes near-surface ringdown. The short pulse allows better visual discrimination between flaw signals and grain noise. One-MHz longitudinal is about the only wave mode and frequency that can penetrate (2- to 3-in. wall thickness pipe) and still see flaws.

In using longitudinal waves for detection of surface-connected cracks, it should be understood that approximately 85% of the incoming signal is mode converted to shear waves and lost. Calibrations using side-drilled holes do not represent this condition as no mode conversion takes place. On the other hand, it is often not possible to detect a 10% calibration notch (or for that matter, a corner reflection from the end of the block), because of the high noise level. However, fatigue flaws in test blocks can often be detected. The roughness of the fatigue flaws aid in their detection. Since neither the side-drilled hole or 10% notch are entirely appropriate, it may be advisable to turn up the gain to 20 or 30% screen height for general structural noise and to look for back-surface-traveling indications. Operator training on real crack samples is highly advisable in this case.

4.3 FUTURE TRENDS

The single most often stated desire of inspectors was to be able to train on real cracks in realistic mock-up samples. The technology for fabricating crack samples is available and a limited number of samples are available through the Electric Power Research Institute and PNL. Wider distribution of these types of samples in the future could substantially improve inspection performance.

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APPENDIX

TABLES OF DETAILED SURVEY RESPONSES

APPENDIX

TABLES OF DETAILED SURVEY RESPONSES

The following pages present detailed information gathered in the state-of-practice survey. Representatives of four utilities, five private inspection organizations, and three domestic reactor manufacturers were interviewed and their responses recorded. The interviews included questions about ultrasonic in-service inspection of Class I system piping in nine subject categories:

1. Utility, Inspection Organization, and Reactor Vendor Experience
2. Selection and Performance Verification of Transducers
3. Manual Piping Inspection Practices
4. Inspection Practices for Ferritic and Stainless Steel Pipe
5. Experience with Centrifugally Cast Stainless Steel Pipe
6. Automated Inspection Practices
7. Pipe Outer Diameter Geometry Conditions
8. Pipe Inner Diameter Geometry Conditions
9. Calibration, Inspection, and Flaw Evaluation

The names of the survey respondents and their respective organizations are not included here. Within each of the ten subject categories survey respondents are designated by letter (A, B, and so on). These letter designations are consistent within subject categories but do not necessarily correspond between categories. The purpose of reporting these individual responses is not to identify certain inspection practices with specific organizations but rather to show the range of experience and practices: instances where opinions agree or diverge, where procedures are similar or vary widely, where problems are recognized or uncertain.

The trends of the responses are summarized and interpreted in Section 2, State of Practice Survey Results, and Section 3, Conclusions, of the main document.

1. Utility, Organization, Inspection and Reactor Vendor Experience

<u>Survey Respondent</u>	<u>Number of Units Inspected, (Operating/Under Construction)</u>	<u>Percent Inspected by Outside Agency?</u>	<u>Inspection mode Utility?</u>
A	PWR (2/4), BWR (7/0)	yes ~95%	only for special problems
B	20 BWRs/Year	NA	NA
C	PWR (0/2), BWR (1/0)	<40%	only for special problems and followup to PSI and ISI
D	30 to 40 inspections/year	NA	NA
E	PWR (0/8), BWR (3/6)	95%	only for special problems
F	20 to 30 PWRs/year	NA	NA
G	PWR (2/2), BWR (1/0)	95%	usually participates with special problems

<u>Survey Respondent</u>	<u>Inspections with Centrifugally Cast Stainless Steel (CCSS) Piping</u>	
	<u>Has ISI been performed by UT?</u>	<u>Is UT Inspection Planned?</u>
A	no	yes
B	NA	NA
C	--	--
D	NA	NA
E	no	yes
F	yes	yes
G	yes	yes

1. Utility, Organization, Inspection and Reactor Vendor Experience (contd)

<u>Survey Respondent</u>	<u>Number of plants inspected with CCSS Primary Coolant Piping</u>	<u>Number of Inspections for Intergranular Stress Corrosion Cracking (IGSCC) in 1978</u>
A	unknown	--
B	none	All tests on stainless pipe are done to detect stress corrosion.
C	none	--
D	none	no specific IGSCC inspections
E	4	--
F	8 to 10	Inspections at 4 plants found nothing; some evidence of stress corrosion in the sensitized area was found at two plants.
G	1	extensive experience with piping IGSCC

2. Selection and Performance Verification of Transducers

<u>Survey Respondent</u>	<u>What are your general criteria for selecting transducers?</u>	<u>What methods are used initially to verify transducer performance? a) center frequency, beam profile</u>
A	past experience; response; signal-to-noise ratio	certification data from manufacturer
B	past experience; response; signal-to-noise ratio	certification data from manufacturer
C	past experience; signal-to-noise ratio; resolution	certification data from manufacturer
D	past experience; procedures	certification data from manufacturer
E	past experience; response; signal-to-noise ratio	certification data from manufacturer
F	Criteria are determined by procedure during procedure development tests; if tests are limited or non-existent, then criteria are determined by liason with experienced fieldinspectors.	in-house laboratory certification
G	past experience	certification data from manufacturer
H	past experience; recommendation of procedure development engineer	none
I	past experience; response; signal-to-noise ratio	A transducer that gives a good calibration is assumed good. There is not much merit in requiring a beam profile, and the inspection frequency is not critical. "We are trying to make a science out of an art."

2. Selection and Performance Verification of Transducers (contd)

<u>Survey Respondent</u>	<u>What methods are used initially to verify transducer performance?</u> <u>b) near-field, distance amplitude correction (DAC)</u>	<u>c) Sensitivity</u>
A	For thin-wall pipe the transducer is checked on ID notch; side-drilled holes (SDH) on calibration blocks are used for DAC.	SDHs are used.
B	There is no near-field check; DAC uses SDH.	SDHs are used.
C	There is no near-field check; DAC uses SDH.	SDHs are used.
D	There is no near-field check; DAC uses SDH.	SDHs are used.
E	There is no near-field check; DAC uses SDH.	SDHs are used.
F	DAC uses SDH; a 7- to 9-point calibration curve is used.	SDHs are used.
G	DAC uses SDH; a 7- to 9-point calibration curve is used.	SDHs are used.
H	There is no near-field check; DAC uses SDH.	SDHs are used.
I	There is no near-field check; DAC uses SDH.	SDHs are used.

<u>Survey Respondent</u>	<u>What methods are used initially to verify transducer performance?</u> <u>d) resolution</u>	<u>e) angle</u>	<u>f) others</u>
A	SDHs are used.	IIW	Beam spread is checked with SDH. Tests are made on surface notches to get some feel for SDH versus notches.
B	SDHs are used.	IIW	none
C	SDHs are used.	IIW	none
D	SDHs are used.	IIW	none
E	SDHs are used.	IIW	none
F	SDHs are used.	IIW	none
G	SDHs are used.	IIW	none
H	none	IIW	none
I	--	--	--

2. Selection and Performance Verification of Transducers (contd)

<u>Survey Respondent</u>	<u>What is used to control and monitor transducer performance?</u>	<u>What is the estimated useful lifetime for an angle-beam transducer?</u>
A	Although there are no periodic checks, records of all transducer certifications are kept. Transducers usually "deteriorate rapidly" as noted by the need for significant increase in gain.	Utility use: 4 to 5 years; ISI company: 2 years
B	Each successful calibration monitors performance. Usually a significant increase in gain indicates problems. There are no periodic checks.	4 years. Dropped transducers are the biggest problem.
C	Although there are no periodic checks, records of all transducer certifications are kept.	Utility use: 4 or 5 years; ISI company: 2 years
D	In 1976, 15 transducers were sent back to the manufacturer for checking. All tests confirmed transducers OK.	2 years. Special units may last 4 or 5 years.
E	Calibration block checks performance.	2 to 3 years
F	Certifications are kept with each transducer. They are recertified every six months.	2 years
G	Experience tells them when transducer is about to fail; they are using a 7- to 9-point calibration block.	2 years
H	Each time a transducer is used, it is checked on a calibration block.	2 years
I	Calibration block checks performance.	2 to 3 years

3. Manual Piping Inspection Practices

<u>Survey Respondent</u>	<u>What make and model instrument is used for manual piping inspection?</u>	<u>Is the unit modified?</u>
A	mostly Sonic Mark I; some Branson 301; Nortec 131 D	no
B	6 Nortec 131D; 1 Sonic Mark I	no
C	Sonic Mark I; KB USM-2; Nortec 131D	modified Sonic Mark I
D	mostly Sonic Mark I; Sonic Mark IV; Nortec 131D; KB USM-2; Branson 303	no
E	Sonic Mark I; Sperry UJ; KB USL 31 and 32	yes
F	Magnaflux PS-710; KB USM-2; KB USIP-11; Magnaflux PS-702A	no
G	Sonic Mark I is vast majority; 1 each of a few other makes	no
H	KB USM-2	no
I	Branson 303; KB USIP-11; Sonic Mark I	no
J	KB USM-2; Branson 303	no
K	Nortec 131; Sonic Mark I; Branson 303; Sonic Mark IV	no

<u>Survey Respondent</u>	<u>If modified, what are the modifications?</u>	<u>How do you protect the instrument from contamination?</u>
A	--	plastic bag; tape sealed
B	--	plastic bag; tape sealed
C	20-inch range gate added for thick-wall inspection	plastic bag; tape sealed
D	--	plastic bag; tape sealed
E	The KB USL 31 and 32 has additional filter circuitry and vertical control adjustment changes	plastic bag; tape sealed
F	--	plastic bag; tape sealed
G	--	plastic bag; tape sealed
H	--	plastic bag; tape sealed
I	--	wrap in plastic, except for control and instrument screen
J	--	plastic bag; tape sealed
K	--	plastic bag; tape sealed

3. Manual Piping Inspection Practices (contd)

<u>Survey Respondent</u>	<u>Have these precautions for preventing instrument contamination resulted in any change in instrument performance? Has this been checked?</u>	<u>Is the performance of the instrument checked after decontamination or after an accident such as dropping or rough handling?</u>
A	No; calibration is completed with the instrument in the bag.	yes
B	--	
C	no	Yes, for rough handling or after dropping; the instrument is checked before decontamination.
D	No; calibration is completed with the instrument in the bag.	The instrument is checked after dropping and before it leaves the inspection area.
E	No; older units are more affected by thermal changes.	Yes; vertical and horizontal linearity are rechecked.
F	no	yes
G	no	Yes; the instrument is checked after rough handling. The instrument is calibrated before and after examination.
H	Generally no; higher temperatures can cause problems.	The instrument is checked after rough handling but not after decontamination.
I	No; calibration is completed with the instrument in the bag	The instrument is checked after rough handling but not after decontamination.
J	no	Operational performance checkout is required before inspection; the instrument is then calibrated before it leaves the inspection area.
K	no	yes

3. Manual Piping Inspection Practices (contd)

<u>Survey Respondent</u>	<u>Is electronic DAC used for manual inspection? Automatic inspection?</u>	<u>Do you follow periodic calibration or measurement requirements not specified by Code?</u>
A	no/no	Code only
B	--	Code only
C	no/yes	Code only
D	no/no	Code only
E	no/yes (vessel only)	Code only
F	no/no	Code only
G	no/yes	Code only
H	no/yes and no	Code only (once/year)
I	no/yes	Code only
J	no/no	Code only
K	no/yes	There is a transfer requirement on every weld or adjacent to every weld. If the back echo stays between 4 db of the pipe to pipe, and pipe to standard, then "you're okay"; Usually the instrument is recalibrated every 1 to 2 hours. If the operator sees something that he thinks is a flaw, then he repeats his calibration. Prior to ISI use, the instrument is qualified according to ASTM-317.

3. Manual Piping Inspection Practices (contd)

<u>Survey Respondent</u>	<u>Are there requirements on pulser or receiver bandwidth?</u>	<u>If an external recording device is used, how is it calibrated?</u>
A	no	none used
B		
C	No; only the manufacturer's specs and recommendations are used.	none used
D	No; a narrow band is used for weld exam; a wide band is used for thickness.	none used
E	no	none used
F	no	none used
G	No; only the manufacturer's specs and recommendations are used.	None used for manual inspection; Strip charts and a computer are used to record amplitude and time for automated inspections.
H	No; only the manufacturer's specs and recommendations are used.	none used
I	No; only the manufacturer's specs and recommendations are used.	--
J	no	none used
K	no	--

3. Manual Piping Inspection Practices (contd)

<u>Survey Respondent</u>	<u>Does your instrument require warm-up time?</u>	<u>Have you noted any problems with instrument stability, sensitivity, etc., due to warm-up time, battery charge, or line voltage fluctuation?</u>
A	No warm-up time is required by written procedure; however several minutes is a typical warm-up time.	Yes; there is a 3-dB difference between initial calibration (just after turning instrument on) and later calibration check. The instrument always runs on batteries.
B	--	--
C	no	None; batteries are used.
D	None, although the instrument is on 2 to 5 minutes before the operators are ready.	none
E	No warm-up is required by the written procedure; however, 5 or 10 minutes is typical warm-up time.	none
F	No warm-up is required by the written procedure; however, 10 to 15 minutes is typical warm-up time.	none
G	yes: 30 minutes	Initially some problems occurred with batteries; new batteries for each major inspection eliminated the problem. Line voltage changes did cause problems; inspectors had to use a generator for automatic inspection at some sites.
H	yes: 15 minutes	None; batteries are used.
I	yes: 30 minutes for manual inspection, 1 hour for automated inspection.	Not after warm-up; usually there are no line voltage problems.
J	yes: 4 to 5 minutes	none
K	no	none

4. Inspection Practices for Ferritic and Stainless Steel Pipe

Survey Respondent	What search units do you use for ferritic pipe inspection?	
	a) up to 10-in. dia	b) 10- to 20-in. dia
A	1/4 in. to 1/2 in., 2.25 MHz, 45°	1/2 in. dia or 1/2 in. x 1 in., 2.25 MHz, 45°
B	1/4 in. x 1/4 in., 2.25 MHz, 45°	1 in. x 1/2 in., 2.25 MHz, 45°
C	1/2 in. dia, 2.25 MHz, 45°	--
D	--	--
E	1/4 or 1/2 in. dia, 2.25 MHz, 45°	1/2 in. dia, 2.25 MHz, 45°
F	1/4 in. to 3/8 in. to 1/2 in. dia, 2.25 MHz, 45°	1/2 in. to 3/4 in. dia. 2.25 MHz, 45°
G	1/4 in. dia, 2.25 MHz, 45°	1/2 in. dia, 2.25 MHz, 45°
H	1/4 in. dia, or 1/4 x 1/4 in., 2.25 MHz, 45° and 60°	1/2 in. x 1/2 in., 2.25 MHz, 45° and 60°

Survey Respondent	What search units do you use for ferritic pipe inspection?	
	c) over 20-in. dia	Are there special procedures for ferritic pipe?
A	1/2 in. x 1 in., 2.25 MHz, 45°	none
B	1 in. x 1/2 in., 2.25 MHz, 45°	none
C	--	none
D	--	none
E	1/2 in. dia, 1/2 x 1/2 in., or 1/2 x 1 in., 2.25 MHz, 45°	none
F	3/4 in. to 1 in. dia, 2.25 MHz, 45°	none
G	--	none
H	1/2 in. dia, 1 in. x 1/2 in. (1.0 MHz permitted if lack of penetration noted)	none

4. Inspection Practices for Ferritic and Stainless Steel Pipe (contd)

Survey Respondent	What confidence do you have in ferritic inspection?	What search units do you use for austenitic stainless steel pipe? a) up to 10-in. dia
A	high	1/4 in. to 1/2 in. dia, 2.25 MHz, 45°; generally prefers smaller transducers sometimes 1/4 in. x 1/4 in. on small pipe
B	75% to 80%	1/4 in. x 1/4 in., 2.25 MHz, 45° (5.0 MHz used on small pipe)
C	high for fatigue cracks	1/2 in. dia, 2.25 MHz, 45°
D	very high	--
E	very high	--
F	good, no problems	3/8 in. to 1/2 in., 1.5 MHz
G	good	1/4 in. dia, 2.25 MHz, 45°
H	good	1/4 in. dia, or 1/4 x 1/4 in., 2.25 MHz, 45° and 60°; for piping greater than 0.75 in. thick, a dual-element (1.5-MHz) search unit is used.

Survey Respondent	What search units do you use for austenitic stainless steel pipe? b) 10- to 20-in. dia.	c) over 20-in. dia.
A	1/2 in. dia or 1/2 in. x 1 in., 2.25 MHz, 45°	1/2 in. x 1 in., 2.25 MHz, 45°
B	(don't use 60° except for evaluation)	1 in. x 1/2 in., 2.25 MHz, 45°
C	1/2 in. dia, 2.25 MHz, 45°	1/2 in. dia, 2.25 MHz, 45°
D	--	--
E	1/2 in. dia, 1.6 MHz as of 1/1/78 using dual units (1.6 MHz)	1/2 in. dia, 1.6 MHz as of 1/1/78 using dual units (1.6 MHz)
F	3/8 in. to 1/2 in. dia, 1.5 MHz	1/2 in. x 1 in., 1/2 in. x 3/4 in., 1.5 MHz
G	1/2 in. dia, 2.25 MHz, 45°	--
H	1/2 in. x 1/2 in., 2.25 MHz, 45° and 60°; for piping greater than 0.750 in. thick, a dual-element (1.5-MHz) search unit is used.	1/2 in. dia, 1 in. x 1/2 in. (1.0 MHz permitted if lack of penetration noted)

4. Inspection Practices for Ferritic and Stainless Steel Pipe (contd)

Survey Respondent	Have you used, evaluated, or considered using a dual-element search unit? What is your opinion of their usefulness?	What do you use for an austenitic SS stainless steel standard? Any other calibration aide?
A	We have two dual-element search units (1.5 MHz) and are considering using them; they seem to work well for thin-wall pipe inspections.	ASME Section XI, Appendix III standards
B	We have used one; it does not make much of an improvement. We used it on centrifugally cast pipe.	pipe standard 5% notches
C	We use a dual line-focused search unit for geometry. We are looking at IGSCC applications for this search unit.	Pipe standard has ID and OD notches. We also use IGSCC samples.
D	Sometimes a dual-element search unit is used; it has a better signal-to-noise characteristic.	ASME Section XI, Appendix III standards
E	We are using dual-element units.	pipe standard 5% notch
F	We have looked at them but have none in general use. They were used on a control rod drive inspection. Selection of 1.5 MHz was the result of an EPRI program. ^(a) We may use them in the future.	ASME Section XI, Appendix III standards
G	Yes. They have shown good performance.	ASME Section XI, Appendix III standards
H	Yes, but they have only been looked at in the lab, not for field service yet. There is no move to use them.	ASME Section XI, Appendix III standards

(a) Reinhart, E. R. 1979. Workshop On In-Service Inspection of Stainless Steel Piping in Nuclear Systems. Electric Power Research Institute Project 892, Palo Alto, California.

4. Inspection Practices for Ferritic and Stainless Steel Pipe (contd)

Survey Respondent	Austenitic stainless steel special procedure, skew, recording level, scan pattern, etc.?	What confidence do you have in austenitic stainless steel pipe inspection? a) For flaws 10% to 25% of wall thickness (T) in depth.
A	none	80% at 25% T; borderline at 10% T
B	no, same as ASME Section V	85%
C	special procedure and training of personnel for extreme skew; lower recording level; procedure close to EPRI workshop procedure(a)	reliably detect IGSCC at 50% T
D	none	--
E	We record anything over 20% DAC. The procedure is close to the EPRI workshop procedure.(a)	50%
F	We record anything at or over 50% DAC	60% to 70%
G	Special procedures are used only if looking for IGSCC; then the skew is greater. We used a dual-element transducer.	70%

Survey Respondent	What confidence do you have in austenitic stainless steel pipe inspection? b) at 25% to 50% T?	c) at over 50% T?
A	100%	100%
B	100%	100%
C	100%	100%
D	--	--
E	75%	75%
F	80%	90% to 100%
G	90%	95%
H	100%	100%
H	None 70%	

(a) Reinhardt, E. R. 1979. Workshop On In-Service Inspection of Stainless Steel Piping in Nuclear Systems. Electric Power Research Institute Project 892, Palo Alto, California.

4. Inspection Practices for Ferritic and Stainless Steel Pipe (contd)

Survey Respondent	Comments on inspection experience with austentic stainless steel
A	Most indications are 25% amplitude and over. Inspection performance improved due to round robin sponsored by EPRI. We now place less emphasis on signal amplitude and take more time to perform a detailed inspection.
B	no IGSCC on major piping sections
C	Our approach for IGSCC is to look at high-stress components with conventional techniques at 2.25 MHz. No geometric calls are allowed for piping that is susceptible to stress corrosion. One should consider an ISI program based on critical components and high-stress welds. Sutar instrumentation should help time and exposure problems; one approach we have used to reduce personnel exposure is to drain and flush the lines to be tested, if possible. This seems to save substantial time for radiography and ultrasonic testing of the weld by reducing radiation exposure.
D	Data must be automatically recorded.
E	Current inspection technique is good. Need another workshop. Need more IGSCC samples available with smaller cracks.
F	It is our experience that there has been only one leaker that ISI did not find first.
G	limited experience with IGSCC
H	Performance depends on highly skilled operator and training for special problems like IGSCC.

5. Experience with Centrifugally Cast Stainless Steel

<u>Survey Respondent</u>	<u>Have you inspected centrifugally cast pipe?</u>	<u>What search units and inspection conditions were used? a) frequency</u>
A	yes	1 MHz
B	yes	1.5 MHz
C	--	1.5 MHz
D	yes	1.0 MHz
E	yes	1.5 MHz, 2.25 MHz
<u>Survey Respondent</u>	<u>What search units and inspection conditions were used? b) transducer size</u>	<u>c) longitudinal (L) or shear</u>
A	1/2 in. dia	45°, shear; also some refracted L-wave
B	dual unit	45°, refracted L-wave
C	1 in. dia	40°, refracted L-wave
D	1 in. dia	45°, refracted L-wave
E	1/2 in. dia, (1.5 MHz) 1/2 in. x 1 in. (2.25 MHz)	45°, refracted L-wave
<u>Survey Respondent</u>	<u>What instrument was used?</u>	<u>Are there special procedures or evaluation techniques?</u>
A	Sonic MK-1	Nothing yet; we are studying the problem.
B	Sonic MK-1	no
C	KB USM-2	yes
D	--	We did use special preamp at one time, but this practice was recently dropped.
E	Sperry UJ	no

5. Experience with Centrifugally Cast Stainless Steel (contd)

<u>Survey Respondent</u>	<u>What confidence do you have in inspection of centrifugally cast pipe?</u>	<u>What type of standard was used?</u>
A	Inspection is difficult.	--
B	not very confident	pipe section with 5% T notches
C	pretty good confidence	We started with a welded pipe standard but went to a base metal standard since the base metal is more attenuative.
D	Good to fair; we can see code-size reflectors; however, there are many metallurgical reflectors.	Side-drilled holes in centrifugally cast parts were used; cracked specimens are needed.
E	20% confidence in the 1.5-MHz inspection; no confidence in the 2.25-MHz inspection	Side-drilled holes and an ID notch were used. At one plant we could not detect the notch in the standard; likewise at another plant we could not detect either the notch or side-drilled holes.

6. Automated Inspection Practices

<u>Survey Respondent</u>	<u>Do you perform automated pipe weld inspection?</u>	<u>Approximately what percentage does automated testing represent?</u>
A	--	--
B	--	--
C	No, we have not seen the need yet, but we may have to in the future, because of radiation levels.	--
D	Yes, only from the nozzle to safe end, and safe end to pipe; we have done base-line inspections using automated equipment but no ISI.	25%
E	Yes, only from the nozzle to safe end and safe end to pipe.	5%
F	Yes, only from the nozzle to safe end and safe end to pipe.	--
G	no	0%
H	no	2%

<u>Survey Respondent</u>	<u>Equipment description</u>	<u>Access Requirement</u>
A	--	--
B	--	--
C	--	--
D	trace-type scanner	--
E	pipe weld inspection "bug," track chain, etc.	8-in. annular clearance around pipe
F	--	--
G	--	--
H	--	18 in. either side of weld

6. Automated Inspection Practices (contd)

<u>Survey Respondent</u>	<u>Crown height requirement</u>	<u>Data recording equipment</u>
A	--	--
B	--	--
C	--	--
D	1/32 in.	minicomputer; magnetic tape
E	flush or smooth taper	strip chart, analog tape, and video-tape; data is played back 100% and reviewed.
F	--	--
G	--	--
H	Flush is best; flat would be the minimum.	manual or strip chart

<u>Survey Respondent</u>	<u>Do you use static or dynamic calibration?</u>
A	--
B	--
C	--
D	static
E	static
F	--
G	--
H	static

6. Automated Inspection Practices (contd)

<u>Survey Respondent</u>	<u>What coupling method is used and how is coupling verified?</u>	<u>What is your opinion of the relative merits of manual versus automated testing?</u>
A	--	Manual is superior; designs of automatic equipment are poor, and they will never replace manual scan by an experienced operator. For critical problems we use manual over automated systems every time. Automated inspection is too complicated, too time consuming.
B	--	Manual inspection takes about the same time as automated inspection. Automated inspection takes too much time to set up.
C	--	No difference in relative merit; manual inspection is more versatile but suffers in repeatability.
D	water, --	Manual inspection with experienced people is better. Automated systems are "unproven."
E	water, --	Manual is better but automated inspection results in lower personnel radiation exposure.
F	--	--
G	--	--
H	water with ethylene glycol; O monitor for couplant verification	Automated inspection is effective for certain inspections such as the safe-ends.

7. Pipe Outer Diameter Geometry Conditions

Survey Respondent	What percent of Class I welds have single-side access?	PWR?	BWR?
A	--	unknown	~10%
B	--	10%	15%
C	--	~90%	~60 to 70%
D	--	~10%	~10%
E	--	10%	10%
F	--	10% to 20%	10% to 20%
G	--	10%	--
H	--	--	15%
I	20%	--	--
J	100%	--	--

Survey Respondent	What special test procedures and evaluation criteria are used for single-sided access?
A	L-wave inspection at top of weld; only shoot through weld if there is a reportable indication; usually uses 45°
B	include calibration L-wave on one side; sometimes change shear inspection angles
C	Always try to get 1/2 V exam. If weld crown is a problem, the crown is ground.
D	none
E	no special procedure
F	none; use 3/2 V through weld
G	none; use 3/2 V through weld
H	none
I	none
J	No special procedure or evaluation criteria exist for austentic welds. All austentic welds are ground for 1/2 V access.

7. Pipe Outer Diameter Geometry Conditions (contd)

Survey Respondent	Is the most attenuative material used for a standard? If not, is it available?
A	Standards are made from the same material used in the plant piping. If available, the most attenuative material will be used.
B	No attenuation measurements are made.
C	No; for example, cast valve material is difficult to obtain.
D	Standards are presumed to be from typical material.
E	We use what the plant supplies.
F	No; there is no good method of taking attenuation measurements.
G	yes; particularly with bimetallic welds such as Inconel to carbon steel
H	Inconel
I	No; standards are certainly variable. Standards could vary as much as 3 dB especially in the bimetallic and trimetallic standards.
J	--

Survey Respondent	What percent of weld crowns are ground for PWR primary coolant pipe welds?		
	% flush	% not ground	% ground flat not flush
A	100%	0%	0%
B	0%	0%	100%
C	--	--	~90%
D	(a)	--	--
E	(b)	--	--
F	40%	10%	50%
G	100%	0%	0%
H	--	--	--
I	--	--	--

- (a) It depends on the age of the plant. New plants coming on-line have welds blended. Older plants have welds ground flat.
 (b) All Class I primary and main coolant welds are ground flush or flat.

7. Pipe Outer Diameter Geometry Conditions (contd)

Survey Respondent	What percent of weld crowns are ground for BWR main coolant pipe welds?		
	% flush	% not ground	% ground flat not flush
A	0%	0%	100%
B	0%	0%	100%
C	--	~10%	~80%
D	--	--	--
E	--	--	--
F	20%	20%	60%
G	--	--	--
H	100% after 1977	90% prior to 1977	--
I	10%	10%	80%

Survey Respondent	What, if any, compensating procedures are used for severe diametrical shrinkage?
A	none
B	none
C	We have used a TIG filler wash weld for shrinkage problems.
D	--
E	none encountered
F	If search unit tilts, use profile gauge to measure angle for plotting of data.
G	none
H	none
I	This problem has occurred in thin-wall pipe; no special procedures used.

7. Pipe Outer Diameter Geometry Conditions (contd)

<u>Survey Respondent</u>	<u>What are typical surface finishes?</u>
A	~125 rms
B	~250 rms
C	250 rms
D	125 rms
E	125 rms
F	250 rms
G	250 rms
H	250 rms
I	125 rms

8. Pipe Inner Diameter Geometry Conditions

Survey Respondent	How well can the shape of the counterbore (C.B.) be measured?	How often is as-built information on counterbore available? Is this baseline informaton?
A	Given enough time, a fairly good job can be done. However, during normal inspection "you just make a quick judgement."	Usually some record can be found; however, many times it is ambiguous since optional ways of fabrication are allowed. No baseline ultrasonic inspection of the C.B. condition is made.
B	Not very well; normal beam inspection is used to see how the back wall changes.	Although design specifications are available, there are no as-built C.B. drawings.
C	We use a line-focused dual unit for thickness profile. Occasionally we call for a radiography (tangent shot).	There is no information on current operating units other than radiographs.
D	--	Seldom is there any as-built or baseline information.
E	not very well	Old plants never have this information. Sometimes even radiographs are unavailable. Generally baseline information is not recorded.
F	Normal-beam inspection is used to profile the C.B. Radiographs are taken when possible.	Design specifications are used all the time.
G	very poorly	A generalized drawing is usually available at most plants. This is not baseline information.
H	not very well	Very seldom; this is not baseline information.
I	Very poorly; you can only measure wall thickness and usually determine where the C.B. changes.	occasionally
J	A pulse-echo normal-beam inspection is used to profile the C.B. Radiography is used on occasion. "No idea how well they can measure the C.B. condition". We are more involved in the C.B. measurement if a crack is called.	--
K	We try to get a C.B. profile using a narrow beam thickness approach.	Sometimes as-built information is used; C.B. radiography is sometimes used to determine shape.

8. Pipe Inner Diameter Geometry Conditions (contd)

Survey Respondent	How often is baseline information on geometric reflectors available?	Is this geometric reflector information correct?
A	50%	If recorded, it is pretty accurate.
B	Most of the time we can get geometric reflector baseline information recorded at 20% DAC.	Yes, it is recorded on strip chart
C	We are concerned with suck up and counterbore inductions.	Information is generally correct. Some signal indications which were called geometric reflectors have actually turned out to be stress corrosion cracking.
D	Baseline data is usually limited to measurement of a few spots. Depending on the situation, it may be very helpful.	--
E	Geometric reflector baseline data is sometimes available but can be difficult to use; e.g., prior reference or metal path is sometimes undefined.	--
F	Baseline information is available 30 to 40% of the time; sometimes baseline information is not supplied when requested.	--
G	Correct information is frequently available.	yes
H	not very often	generally yes
I	--	yes
J	Sometimes geometric indications are reported, sometimes not; reporting of geometric indications would save Level II and Level III time. If they are not reported on the data sheet but are noted by plant inspection personnel, follow-on inspections can be a check on the contracting inspection agency. Experience with a lot of drop-through is reported.	--
K	--	

8. Pipe Inner Diameter Geometry Conditions (contd)

Survey Respondent	If the baseline inspection is performed by different organizations, of what value is it?	What are the difficulties?
A	All information is of value; past baselines have not been too good but baselines have improved in the last two years.	Location is difficult since pipes have no reference points.
B	Baselines should be valid if procedures and calibration blocks are the same.	no major problems
C	--	--
D	--	Summarizing these complex responses in a few words is difficult.
E	--	--
F	--	--
G	We do not record geometry; therefore, baseline inspection is lacking this information.	--
H	Baseline data is often of very little value, since procedure (or lack of it) and levels of recording can be different.	--
I	--	One difficulty is when the geometry condition is determined from UT but not recorded.
J	--	--
K	--	--

8. Pipe Inner Diameter Geometry Conditions (contd)

Survey Respondent	Is a standard format for recording geometric indications needed? Should this be a Code requirement? Or regulatory requirement?	How do you evaluate 3/2 V indications when the beam is incident on the conical section of the counterbore?
A	yes, no, no	With finger damping on surface and normal-beam to profile the C.B.; mode conversion is not calculated. Sound path is plotted.
B	yes, no, no	Look at RT film; look with UT at both sides; finger damp; look at design specs; plot sound path on x-section; don't usually consider ref. wave.
C	yes, yes, no	We try to get a 1/2 V exam; if there are problems, the crown is removed.
D	All tests should be recorded on strip chart. This should be a requirement for any examination repeated periodically.	All indications are evaluated on a case-by-case basis.
E	A standard format is needed, and a Code committee should do this. Even in-house formats change from year to year.	We request that welds be flush. If there are indications, we use finger damping.
F	Geometry indications are described on ISI data sheets.	We haven't had that problem with primary pipe. Two-side access for 1/2 V and V exams has been possible.
G	No; Code already says you shall record defect-like indications.	With great difficulty; hopefully the C.B. angle is known; finger damping.
H	A standard format is needed and we use one. It should be a Code requirement.	--
I	yes, yes, no	3/2 V information is not used.
J	No; geometry indications are reported on ISI data sheet.	A 1/2 V exam is used for most cases; for 3/2 V exam nothing special is done.
K	No, geometric indications can be plotted out on ISI data sheet.	We request that all welds are ground flat to allow a 1/2 V exam.

9. Calibration, Inspection, and Flaw Evaluation

Survey Respondent	Calibration and Inspection a) When do you verify calibration?	b) What transducer scan overlap do you use?
A	Recalibrate every 4 hours, and/or at change of operators.	10%
B	Recalibrate every 4 hours, and/or at change in operators or equipment.	10%
C	Recalibrate every 4 hours and/or at change of operators.	10% to 20%
D	Recalibrate before and after each component examination.	15%
E	Recalibrate every 4 hours and/or at operator change.	25%
F	Recalibrate every 4 hours or at operator change.	10%
G	Recalibrate every 4 hours and at the end of inspection.	10%
H	Recalibrate every 4 hours, or when operator is changed.	10%
I	Recalibrate every 4 hours.	20% manual; 10% automatic

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	Calibration and Inspection	Flaw Evaluation
	c) Is transducer skew used during the scan? How much? Is it mandatory or recommended?	a) What is the data recording procedure?
A	Yes; 20°; this is not mandatory or recommended, but it is practiced.	Procedure calls for recording down to 20% of maximum indicated amplitude.
B	Yes; the amount of skew is not specified, but the use of some skew is our recommended practice.	Note indications at 20% of DAC; record and evaluate at 50% of DAC.
C	Yes, 20°; skew is not mandatory or recommended but it is practiced.	Record at 50% of DAC; investigate at 20% of DAC.
D	--	Signal amplitude and range are recorded on strip charts continuously.
E	yes; 15° to 20° normally; 45° for IGSCC	Use Code Section XI criteria.
F	no skew	Investigate at 25% of DAC; record at 50% of DAC; evaluate at 100% of DAC.
G	Yes; up to 15°; the skew angle is recorded if important to define indication position. This practice is taught but is not a written procedure; however, it is practiced to achieve maximum signal amplitude by search unit manipulation.	Standard record sheet is used; amplitude (+6dB down) metal path, two-dimensional position.
H	yes, if looking for IGSCC, but this is not in written procedure.	Record at 50% DAC; evaluate at 100% of DAC.
I	Yes, up to 45°; the amount of skew is dependent on the operator.	Use Code Section XI criteria.

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	Flaw Evaluation	
	b) What is the position accuracy on the pipe surface?	c) What are the time metal path accuracies for 1/2 V and 3/2 V exams?
A	± 0.050 in.; ruler accuracy	± 0.10 for 1/2 V exam; drops considerably on for 3/2 V exam
B	± 0.20 in.	± 0.010 for 1/2 V exam; guess ± 0.020 for 3/2 V exam
C	ruler accuracy	good to within one minor division on scope; check with thickness gage
D	manual measurement to weld edge or reference line: 1/8 in.	Digital readout is usually within ± 0.10 in.
E	0.125 in.	± 0.06 in. 1/2 V exam; within 0.38 in. for 3/2 V exam
F	ruler accuracy	--
G	0.10 to 0.125 in.	± 0.125 in. for both 1/2 V and 3/2 V exam
H	± 0.10 to 0.20 in.	± 0.10 in. for 1/2 V exam; 0.20 in. for 3/2 V due to beamsread
I	0.06 in.	0.05 in. for 1/2 V exam; 0.075 to 0.10 in. for 3/2 V exam, but 3/2 V exam is not normally used.

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	Flow Evaluation	
	d) Do you use supplemental tests?	d1) Other angles, frequencies
A	yes	60°; higher frequency on L-wave
B	yes	35° to 70° at 2.25 to 5 MHz; hardly ever 1.0-MHz exam except for centrifugally cast pipe
C	yes; RT, PT, UT	60° and 70° at 2.25 MHz and higher frequency exam; full V with finger damping if no 1/2 V access
D	yes	--
E	yes; RT, MT, grinding	60° and 70° at 5 MHz; use of dual-element unit
F	--	60° and 70° exam; for single-side access we like to use a 70° exam; dual unit at 5 MHz used for normal profile
G	yes	45°, 60°, and 0° only; 60° for limited access; only use 2.25-MHz frequency
H	--	yes, different size transducers
I	not usually; maybe PT, but not usually RT	45°, 60°, and 70°; 1.0 to 2.25 MHz

9. Calibration, Inspection, and Flaw Evaluation (contd)

<u>Survey Respondent</u>	<u>Flaw Evaluation d2) Two-side evaluation</u>	<u>d3) Finger damping</u>
A	yes	yes
B	yes	yes
C	--	yes
D	yes, where possible	yes
E	yes	yes
F	yes, where possible	yes
G	yes	yes
H	yes	yes
I	yes, where possible	yes

<u>Survey Respondent</u>	<u>What methods do you use to call ID geometry?</u>	<u>What methods to you use to call OD geometry?</u>
A	360° signal indication, reference normal beam shot of counterbore	finger damping
B	plotting technique-position from weld root	finger damping
C	--	--
D	signal location, length, shape	signal location, length, shape
E	plotting technique	grinding, finger damping, MT, PT
F	--	--
G	plotting technique - position from weld root (close to root, IGSCC) use refracted angle conversion chart to determine mode conversion plotting technique	finger damping
H	plotting technique	plotting technique, finger dampening
I	plotting technique	finger damping

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	When do you call for radiography?	When do you call for penetrant?
A	always when an indication is called a cracked, or UT does not resolve indication	when UT indicates a large surface or near-surface flaw
B	when UT cannot be resolved and original RT is judged insufficient	not usually; only when the operator cannot get a complete scan in both directions
C	if a suspect indication is found, and after review of all prior radiographs	when needed for OD reflectors
D	only if prior radiographs are on file	when looking for small surface flaws; i.e., plating cracks
E	After UT indicates a defect is present; RT is used to confirm the defect indication.	--
F	Utilities will request RT when they feel UT is not adequate.	Utility will call for penetrant when needed.
G	"When I have made up my mind that it is IGSCC"; RT may show weld spatter and sometimes IGSCC	when you suspect OD cracking and always after you have cut out a suspect pipe section
H	when there are too many UT signals to interpret or check geometry	when UT data indicates surface or near-surface flaw
I	When one cannot make decision based on the UT results, RT is usually not called for during ISI.	when UT indicates a through-wall crack

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	How often do you call for radiography?	How useful is radiography?
A	very often	good for geometry, not very good for cracks
B	3% to 5%	adequate in many cases; provides backup to confirm UT exam 75% effective
C	on occasion	high confidence in good, controlled RT
D	seldom	shows weld characteristics, suckback, drop through, etc., which give rise to geometric reflections
E	about one per week during preservice inspection to confirm geometry; about 1 or 2 times per year for inservice inspection	depends on material, H ₂ O, radiation, generally useful
F	--	not good on cracks; time consuming; have to clear work area, often disrupting other workers on critical path; background radiation getting worse in many plants
G	every time IGSCC is indicated, about once every site	Sometimes it helps by verifying a borderline indication; about 50% effective.
H	5%	very, useful especially when trying to resolve many signal indications
I	seldom	not much

9. Calibration, Inspection, and Flaw Evaluation (contd)

Survey Respondent	What supplemental information do you call for?	What is your confidence in the supplemental information?
A	drawings, design specifications, etc., to eliminate one or more variables	fair
B	RT records, welding procedure, weld specifications and configuration	very useful
C	--	--
D	weld preparation drawings	generally representative of actual conditions but should not be considered accurate
E	ASME Section III radiographs, preservice records, and ISI records	good confidence in Section III radiographs; low confidence in preservice records
F	drawings or previous UT exam data	--
G	preservice inspection and previous ISIs	very helpful
H	contour gauge measurements, as built, preservice inspection information, weld preparation details	--
I	preservice inspection, ISI, and as-built drawings (Early reactors have very poor records.)	--

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16. ABSTRACT (200 words or less) The Pacific Northwest Laboratory conducted a survey to determine the state of practice of ultrasonic in-service inspection of primary system piping in light water reactors. Personnel at four utilities, five inspection organizations, and three domestic reactor manufacturers were interviewed. The intention of the study was to provide a better understanding of the actual practices employed in in-service inspection of primary system piping and of the difficulties encountered. Among the principal findings of this state-of-practice review are (1) Test procedures are very similar among the different organizations and are in general designed to meet only minimum requirements of Section XI of the ASME Boiler and Pressure Vessel Code. Supplemental tests (after a defect indication has been located) are substantially different. (2) Selection of ultrasonic search units is highly variable. (3) Confidence in the ability to detect defects was highest for ferritic piping and lowest for cast stainless steel. (4) Recording of geometrical indications during baseline preservice inspection or in-service inspection is not consistent and, therefore, of limited value.				10. PROJECT/TASK/WORK UNIT NO.	
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