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ULTRASONIC TESTING OF REACTOR VESSEL WELDS DURING PRESERVICE AND INSERVICE EXAMINATIONS

A. INTRODUCTION

Criterion 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires, in part, that components important to safety be tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, these codes and standards must be evaluated to determine their adequacy and sufficiency and must be supplemented or modified as necessary to ensure a quality product in keeping with the required safety function. Criterion 1 further requires that a quality assurance program be implemented in order to provide adequate assurance that these components will satisfactorily perform their safety functions and that appropriate records of the testing of components important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

Section 50.55a, "Codes and Standards," of 10 CFR Part 50 requires, in part, that structures, systems, and components be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed. Section 50.55a further requires that American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV Code) Class 1 components meet the requirements set forth in Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," of the ASME Code.

Criterion XII, "Control of Measuring and Test Equipment," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires, in part, that measures be established to ensure that instruments used in activities affecting quality are properly controlled, calibrated, and adjusted at specified periods to maintain accuracy within necessary limits.

Criterion XVII, "Quality Assurance Records," of Appendix B requires, in part, that sufficient records be maintained to furnish evidence of activities affecting quality. Consistent with applicable regulatory requirements, the applicant is required to establish such requirements concerning record retention as duration, location, and assigned responsibility.

This guide describes procedures acceptable to the NRC staff for implementing the above requirements with regard to the preservice and inservice examinations of reactor vessel welds in light-water-cooled nuclear power plants by ultrasonic testing (UT). The scope of this guide is limited to reactor vessel welds and does not apply to other structures and components such as piping.

B. DISCUSSION

Reactor vessels must periodically be volumetrically examined according to Section XI of the ASME Code, which is incorporated by reference, with NRC staff modifications, in §50.55a of 10 CFR Part 50. The rules of Section XI require a program of examinations, testing, and inspections to evidence adequate safety. To ensure the continued structural integrity of reactor vessels, it is essential that flaws be reliably detected and evaluated. It is desirable that results from prior UT examinations be compared to results from subsequent examinations so that flaw growth rates may be estimated. Lack of reliability of UT examination results is partly due to the reporting of ambiguous results, such as reporting the length of flaws to be shorter during subsequent examinations. This lack of reproducibility arises because the Code requirements are not specific about many essential variables in the UT procedures. Recommendations of this guide provide guidance that would help to obtain reproducibility of results. Reporting of UT indications as recommended in this guide will help to provide a means for assessing the ambiguity of the reported data.

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Operating and licensing experience[1,2,3] and industry tests[4] have indicated that UT procedures that have been used for examination of reactor vessel welds may not be adequate to consistently detect and reliably characterize flaws during inservice examination of reactors. This lack of reproducibility of location and characterization of flaws has resulted in the need for additional examinations and evaluations with associated delays in the licensing process.

1. INSTRUMENT SYSTEM PERFORMANCE CHECKS

Instrument system performance checks to determine the characteristics of the UT system should be performed at intervals short enough to permit each UT examination to be correlated with particular system performance parameters to help compare results. These determinations will help make it possible to judge whether differences in observations made at different times are due to changes in the instrument system characteristics or are due to real changes in the flaw size and characteristics. Determinations for "Frequency-Amplitude Curve" and "Pulse Shape" recommended in regulatory positions 1.4 and 1.5 may be made by the licensee's examination agent by using any of the common industry methods for measuring these parameters as long as these methods are adequately documented in the examination record. These measurements may be performed in the laboratory before and after each examination, provided the identical equipment combination (i.e., instrumentation, cable, and search unit) is used during the examination.

These determinations are to aid third-party evaluations when different equipment is used to record indications on subsequent examinations and are not intended to qualify systems for use.

The intent of regulatory position 1.5 is to establish the instrument pulse shape in a way that actual values of pulse length and voltages can be observed on an oscilloscope. The calibrated time base does not necessarily have to follow the time base of the distance-amplitude correction (DAC) curve but may be chosen to suitably characterize the initial pulse. The pulse shape record will assist in analyzing potential differences in flaw response between successive examinations (i.e., is the difference due to flaw growth or system change).

Pulse shape is best determined by using a high-impedance oscilloscope with the transducer disconnected from the instrument.

2. CALIBRATION

According to Appendix I, Article I, I-4230, Section XI of the ASME Code, 1974 edition, instrument calibration for performance characteristics (amplitude linearity and amplitude control linearity) is to be verified at the beginning of each day of examination. Requirements in Article 4, Section V, 1977 edition, which is referenced by Section XI, for the periodic check of instrument characteristics (screen height linearity, amplitude control linearity, and beam spread measurements) for UT examination of reactor pressure vessels have been relaxed. The interval between periodic checks has been extended from a period of 1 day to a period of extended use or every 3 months, whichever is less. This change has not been justified on the basis of statistically significant field data. Performance stability of automated electronic equipment is dependent on system performance parameters (essential variables), and the ASME Code has no quality standards to control these performance parameters. Until the performance stability of UT systems can be ensured by the introduction of quality standards, it is not reasonable to increase the period between calibration checks. Therefore, recommendations have been made to check instrument performance parameters more frequently than is specified in the ASME Code.

Requirements of Appendix I, Article I, I-4230, Section XI of the ASME Code, 1974 edition, state:

> "System calibration shall be checked by verifying the distance-amplitude correction curve (I-4420 or I-4520) and the sweep range calibration (I-4410 or I-4510) at the start and finish of each examination, with any change in examination personnel, and at least every 4 hours during an examination."

In the 1977 edition, these requirements were changed. According to Article 4 (T-432.1.2), Section V of the ASME Code, 1977 edition, the following applies:

> "A calibration check on at least one of the basic reflectors in the basic calibration block or a check using a simulator shall be made at the finish of each examination, every 4 hours during the examination and when examination personnel are changed."

This requirement has several minor deficiencies, including the following:

a. One-Point Check

A calibration check is now required on only one of the basic reflectors. As a result, the accuracy of only one point on the DAC curve, and not the accuracy of three points as previously required, is checked. This alteration would permit the instrument drift for other metal path distances to go unnoticed, which is not desirable.

b. Secondary Reference

The change allows a one-point check by a mechanical or electronic simulator instead of a check against the basic calibration block. A mechanical simulator could be a plastic, steel, or aluminum block with a single reference reflector, which may be a hole or a notch. Without specified details, the electronic simulator could be any device that

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[1] "Ultrasonic Reinspection of Pilgrim 1 Reactor Vessel Nozzle N2B," John H. Gieske, NUREG-6502.

[2] "Summary Hatch Nuclear Plant Unit 1 Reactor Pressure Vessel Repair," 1972, Georgia Power Company.

[3] "Summary of the Detection and Evaluation of Ultrasonic Indications - Edwin Hatch Unit 1 Reactor Pressure Vessel," January 1972, Georgia Power Company.

[4] Round robin tests conducted by the Pressure Vessel Research Committee (PVRC) of the Welding Research Council for UT of thick section steels.

provides an electrical signal. With the resulting uncertainty, there may be errors in checking against the secondary reference (simulator), the magnitude of which is undefined and unknown.

c. Electronic Simulator

Subarticle T-432.1.3 of Article 4, Section V of the ASME Code, 1977 edition, allows the use of an electronic simulator and also permits the transducer sensitivity to be checked separatel·· Both these provisions may introduce errors that will be very difficult to detect.

To avoid the introduction of errors and to ensure repeatability of examinations at a later date, it would be advisable to check the calibration of the entire system rather than that of individual components. Checking system calibration without the transducer and the cable is not advisable because these tests do not detect possible leakage or resistance changes at the connectors. This is especially important when the UT examination is performed under conditions of high humidity or under water and the connectors may not be waterproof or moistureproof. Checking the transducer sensitivity separately (sometimes weeks in advance) also neglects the effects of possible damage due to transport or use. The transducer characteristics may change because of damage to or degradation of internal bonding agents or inadvertent damage to the transducer element. Further, the use of an electronic block simulator (EBS) as a secondary standard introduces an error band in the calibration process. The error band may depend on, among others, the following factors:

(1) Drift due to ambient temperature change.
(2) Drift due to high temperature storage.
(3) Drift due to high humidity storage.
(4) Drift due to vibration and shock loading during shipment.
(5) Degradation of the memory device used to store the reference signal information due to vibration, shock, aging, or heat effects.

To ensure stability, computer systems are generally kept in an air conditioned environment; however, EBS systems are not usually kept in a controlled environment.

Error band for one particular type of instrument[5] was determined to be in the range of ±6 percent. The error band for other instruments may be in a different range and may vary for the same instrument if memory devices or components of different quality are used at a later date. The error band is dependent on the temperature extremes, shock loadings, and vibrations suffered by the instrument. Since the error band value depends on these parameters, it would be advisable to ensure, through recording instruments, that the EBS was not subjected to higher temperatures (container lying in the sun) and greater shock (container dropped) during transport than those parameters that served as a basis for defining the error band.

Use of electronic simulators would be permissible if they can check the calibration of the UT system as a whole and the error band introduced by their use can be relied on and ta!:en into consideration.

d. Static Versus Dynamic Reflector Responses

With some automated systems, the DAC curve is manually established. In these cases, the signal is maximized by optimizing the transducer orientation toward the calibration holes. Subsequently, detection and sizing of flaws are based on signals received from a moving transducer where no attempt is made (or it is not possible) to maximize the signal even for significant flaws. This procedure neglects several sources of error introduced by the possible variation in signal strength caused by:

(1) Differences between the maximized signal and the unmaximized signal.

(2) Loss in signal strength due to the separation of the transducer from the metal surface because of the viscosity of the coupling medium (planing effects).

(3) Variation in contact force and transducer coupling efficiency.

(4) Loss in signal strength due to structural vibration effects in the moving transducer mount and other driving mechanisms.

(5) Loss in signal strength due to the tilting caused by the mounting arrangement in some transducer mounts.

Because of the above, it would be advisable to establish the DAC curve under the same conditions as those under which scanning is performed to obtain data for detection and sizing. It would be acceptable to establish a DAC curve by maximizing signal strength during manual scans when signals are also maximized for flaw sizing. However, it would not be advisable to use manually maximized signals to establish the DAC curve when data are obtained later by mechanized transducers (where signals cannot be maximized) for the detection and sizing of flaws without adjustment for the potential error introduced. In these situations, an acceptable method would be to establish DAC curves using moving transducers or to establish correction factors that may be used to adjust signal strength. It would be prudent to use care and planning in establishing correction factors. For example, establishing a ratio between a dynamic and static mode under laboratory conditions using a precision transducer drive and stiff mounting may have very little in common with the transducer mounting and traverse conditions of the actual examination setup. If correction factors are to be used, it would be worthwhile to build either full-scale mockups or consider the variation of all the important parameters in a suitable model taking into

[5] "Calibration Verification of Ultrasonic Examination Systems with the Electronic Block Simulator," D. J. Boomgard et al., August 1979, Report No. WCAP-9545, Westinghouse Electric Corporation, Nuclear Service Division, P.O. Box 2728, Pittsburgh, PA 15230.

consideration scaling laws on variables such as mass, vibration, and stiffness constants. It would be advisable to confirm the scaling law assumptions and predictions for vibration and viscosity effects before correction factors are used for setting scanning sensitivity levels.

Differences in the curvature and surface finish between calibration blocks and vessel areas could change the dynamic response, so it may be advisable to establish correction factors between dynamic and static responses from the indications that are found during examination. This would avoid the difficulties associated with establishing a dynamic response DAC curve and still take all the factors into consideration.

e. Secondary DAC

During some manual scans, the end point of the DAC curve may fall below 20 percent of the full screen height. When this happens, it is difficult to evaluate flaws on the 20 percent and 50 percent DAC basis in this region since the 20 percent and 50 percent DAC points may be too close to the baseline. To overcome this difficulty, it is advisable that a secondary DAC curve using a higher-gain setting be developed so that 20 percent and 50 percent DAC points may be easily evaluated. For this purpose, it is advisable that the gain be increased sufficiently to keep the lowest point of the secondary DAC curve above 20 percent of screen height.

The secondary DAC curves need not be generated unless they are required. If electronic DAC is used and amplitudes are maintained above 20 percent of full screen height, a secondary DAC would not be necessary.

f. Component Substitution

A calibration check should be made each time a component is put back into the system to ensure that such components as transducers, pulsers, and receivers were not damaged while they were in storage. This will ensure elimination of the error band and mistakes in resetting the various control knobs.

g. Calibration Holes

Comparison of results between examinations performed at different times may be facilitated if the same equipment is used and if the reflections from growing flaws can be compared to the same reference signal. Reference signals obtained from a calibration block depend on, among other things, the surface roughness of the block and the reflector holes. Therefore, these surfaces should be protected from corrosion and mechanical damage and also should not be altered by mechanical or chemical means between successive examinations. If the reference reflector holes or the block surface are given a high polish by any chemical or mechanical means, the amplitude of the reflections obtained from these reflector holes may be altered. Polishing the holes or the block surface is not forbidden by the ASME Code. However, this possibly altered amplitude could affect the sizing of indications found during any examination. At this time, no recommendations are being made to control the surface roughness of the block or the above-mentioned reflector holes; however, if the block or these holes are polished, this fact should be recorded for consideration if a review of the UT data becomes necessary at a later date.

3. NEAR-SURFACE EXAMINATION AND SURFACE RESOLUTION

Sound beam attenuation in any material follows a decaying curve (exponential function); however, in some cases the reflection from the nearest hole is smaller than the reflection from a farther hole. This makes it difficult to draw a proper DAC curve. In such cases, it may be desirable to use a lower frequency or a smaller transducer for flaw detection near the beam-entry surface to overcome the difficulty of marginal detectability.

Near-field effects, decay time of pulse reflections, shadow effects, restricted access, and other factors do not permit effective examination of certain volume areas in the component. To present a clear documentation and record of the volume of material that has not been effectively examined, these volume areas need to be identified. Recommendations are provided to best estimate the volume in the region of interest that has not been effectively examined, such as volumes of material near each surface (because of near-field effects of the transducer and ring-down effects of the pulse due to the contact surface), volumes near interfaces between cladding and parent metal, and volumes shadowed by laminar flaws.

4. BEAM PROFILE

Beam profile is one of the main characteristics of a transducer. It helps to show the three-dimensional distribution of beam strength for comparing results between examinations and also for characterizing flaws. The beam profile needs to be determined and recorded so that comparisons may be made with results of successive examinations.

5. SCANNING WELD-METAL INTERFACE

The amount of energy reflected back from a flaw is dependent on its surface characteristics, orientation, and size. The present ASME Code procedures rely on the amplitude of the reflected signal as a basis for judging flaws. This means that the size estimation of a defect depends on the proportion of the ultrasonic beam reflected back to the probe. The reflection behavior of a planar defect, which largely depends on the incident beam angle when a single search unit is used to characterize the flaw, is thus a decisive factor in flaw estimation. The larger the size of a planar defect, the narrower is the reflected sound beam. The narrow reflected sound beam makes the flaw very difficult to detect in most cases (unless the beam angle is right).[6,7]

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[6] "Probability of Detecting Planar Defects in Heavy Wall Welds by Ultrasonic Techniques According to Existing Codes," Dr. Ing. Hans-Jurgen Meyer, Quality Department of M.A.N., Nurnberg, D 8500 Nurnberg 115.

[7] "Reflection of Ultrasonic Pulses from Surfaces," Haines and Langston Central Electricity Generating Board, U.K. (CESB) Report Number RD 18/N4115.

Therefore, the beam angles used to scan welds should be optimized and should be based on the geometry of the weld/parent-metal interface. At least one of these angles should be such that the beam is almost perpendicular (±15 degrees to the perpendicular) to the weld/parent-metal interface, unless it can be demonstrated that large (Code-unacceptable) planar flaws unfavorably oriented, parallel to the weld-metal interface, can be detected by the UT technique being used. In vessel construction, some weld preps are essentially at right angles to the metal surface. In these cases, use of shear wave angles close to 75 degrees is not recommended. Two factors would make the use of shear wave angles close to 75 degrees inadvisable, – first, the test distances necessary become too large resulting in loss of signal, and second, the generation of surface waves tends to confuse the interpretation of results. In these cases, use of alternative volumetric nondestructive examination (NDE) techniques, as permitted by Subarticle IWA-2240, Section XI of the ASME Code, should be considered. Alternative NDE techniques to be considered may include high-intensity radiograph or tandem-probe ultrasonic examination of the weld-metal interface. To avoid the possibility of missing large flaws, particularly those that have an unfavorable orientation, it is desirable that the back reflection amplitude, while scanning with a straight beam, be monitored over the entire volume of the weld and adjacent base metal. Any area where a reduction of the normal back-surface reflection amplitude exceeds 50 percent should be examined by angle beams in increments of ±15 degrees until the reduction of signal is explained. Where this additional angle beam examination is not practical, it may be advisable to consider examining the weld by a supplementary volumetric NDE technique.

6. SIZING

The depth or through-wall dimension of flaws is more significant than the length dimension, according to fracture mechanics analysis criteria. Using the single-probe pulse-echo technique, it is possible, depending on flaw orientation, that some large flaws may not reflect much energy to the search unit.[6] Because of this possibility, the depth dimension of the flaw should be conservatively sized unless there is evidence to prove that the flaw orientation is at right angles to the beam. It is recommended that indications that are associated with through-thickness flaws and do not meet Code-allowable criteria or criteria recommended in this guide be sized at 20 percent DAC as well as at 50 percent DAC.

In certain cases, it is possible for various reasons that a flaw would not reflect enough energy to the search unit to make the indication height 50 percent of the DAC curve height. However, if such a flaw were large, a persistent signal could be obtained over a large area. It is therefore recommended that all continuous signals that are 20 percent of DAC with transducer travel movement of more than 1 inch plus the beam spread (as defined in Article 4, nonmandatory Appendix B, Section V of the ASME Code, 1977 edition) should be considered significant and should be recorded and investigated further. The beam spread effect in some cases can make very small flaws appear to be large when judged at 20 percent DAC; hence, beam spread has to be considered in judging the significance of flaws.[8] It is therefore recommended that only signals with a total transducer travel movement greater than the beam spread should be considered significant.

7. REPORTING OF RESULTS

This guide gives recommendations for recording the characteristics of the UT examination system. This information can be of significance in later analysis for determining the location, dimensions, orientation, and growth rate of flaws.

Records pertaining to UT examinations should be considered quality assurance records. Recommendations on the collection, storage, and maintenance of these records are given in Regulatory Guide 1.88, "Collection, Storage, and Maintenance of Nuclear Power Plant Quality Assurance Records." Availability of these records at a later date will permit a review of the UT results from the data gathered during previous ultrasonic examinations.

When ultrasonic examination is performed, certain volumes of material such as the following are not effectively examined:

a. Material volume near the front surface because of near-field effects, cladding disturbance, or electronic gating.

b. Material volume near the surface because of surface roughness or unfavorable flaw orientations.

c. Volumes shadowed by insulation or part geometry.

In some cases, as much as 1 inch (25.4 mm) or more below the surface is not examined because of the electronic gate setting. This means that the unexamined volume may contain flaws that would be unacceptable according to Section XI, ASME Code, as follows:

a. Without evaluation (deeper than approximately 0.2 inch).

b. Even after evaluation (deeper than approximately 0.85 inch).

Assuming an aspect ratio of 0.1, according to IWB-3510.1, Section XI, ASME Code, flaws 0.2 inch deep would be unacceptable for a 9-inch wall thickness.

Typically a BWR reactor pressure vessel (RPV) wall in the beltline region is 6 inches thick and a PWR-RPV wall is 8.5 inches thick. During flaw evaluation, where the wall temperature is high and the available toughness is high, and the calculated critical surface flaw depth (a_c) exceeds the wall thickness (t), a_c is taken[9] as the wall thickness. According to IWB-3600, Section XI, the allowable end-of-life size is $a_f = 0.1a_c$. Flaws exceeding this allowable value, which would

[8] "Ultrasonic Examination Comparison of Indication and Actual Flaw in RPV," Ishi Kawajima-Harima Industries Co., Ltd., January 1976.

[9] "Flaw Evaluation Procedures: ASME Section XI-EPRI," NP-719-SR, special report, August 1978.

be 0.85 inch for a PWR and 0.65 inch for a BWR, will have to be repaired. The above example illustrates the importance of blanking out the electronic indication signals and not examining the surface volume to a depth of 1 inch. Since the flaws that can be missed because of electronic gating may be larger than the flaws permitted with or without evaluation, this unexamined volume is important and needs to be identified.

In certain specific cases, areas were not examined because insulation was in the way and the transducer could not scan the volume of interest. NRC was not informed of this situation until much later. In view of the above and to avoid licensing delays, it is advisable that the volume of areas not examined for any or all of the above reasons be reported.

The volumes of material that are not effectively examined depend on the particular part geometry and unique situations associated with each RPV. During identification of the material volumes that have not been examined, consideration should be given to the types of flaws that are currently being reported in some of the operating plants. These include stress corrosion cracks in the heat-affected zone, fatigue cracks, and cracks that are close to the surface and sometimes penetrate the surface. These volumes of material should be identified and reported to NRC along with the report of welding and material defects in accordance with the recommendation of regulatory position 2.a(3) of Regulatory Guide 1.16, "Reporting of Operating Information–Appendix A Technical Specifications."

C. REGULATORY POSITION

Ultrasonic examination of reactor vessel welds should be performed according to the requirements of Section XI of the ASME B&PV Code, as referenced in the Safety Analysis Report (SAR) and its amendments, supplemented by the following:

1. INSTRUMENT PERFORMANCE CHECKS

The checks described in paragraphs 1.2 through 1.5 should be made for any UT system used for the recording and sizing of reflectors in accordance with regulatory position 6 and for reflectors that exceed the Code-allowable criteria.

1.1 Frequency of Checks

As a minimum, these checks should be verified within 1 day before and within 1 day after examining all the welds that need to be examined in a reactor pressure vessel during one outage. Pulse shape and noise suppression controls should remain at the same setting during examination and calibration.

1.2 Screen Height Linearity

Screen height linearity of the ultrasonic instrument should be determined according to the mandatory Appendix I to Article 4, Section V of the ASME Code, within the time limits specified in regulatory position 1.1.

1.3 Amplitude Control Linearity

Amplitude control linearity should be determined according to the mandatory Appendix II of Article 4, Section V of the ASME Code, 1977 edition, within the time limits specified in regulatory position 1.1.

1.4 Frequency-Amplitude Curve

A photographic record of the frequency-amplitude curve should be obtained. This record should be available for comparison at the inspection site for the next two successive inspections of the same volume. The reflector used in generating the frequency-amplitude curves as well as the electronic system (i.e., the basic ultrasonic instrument, gating, form of gated signal, and spectrum analysis equipment) and how it is used to capture the frequency-amplitude information should be documented.

1.5 Pulse Shape

A photographic record of the unloaded initial pulse against a calibrated time base should be obtained. The time base and voltage values should be identified and recorded on the horizontal and vertical axis of the above photographic record of the initial pulse. The method used in obtaining the pulse shape photograph, including the test point at which it is obtained, should be documented.

2. CALIBRATION

System calibration should be checked to verify the DAC curve and the sweep range calibration per nonmandatory Appendix B, Article 4, Section V of the ASME Code, as a minimum, before and after each RPV examination (or each week in which it is in use, whichever is less) or each time any component (e.g., transducer, cable, connector, pulser, or receiver) in the examination system is changed. Where possible, the same calibration block should be used for successive inservice examinations of the same RPV. The calibration side holes in the basic calibration block and the block surface should be protected so that their characteristics do not change during storage. These side holes or the block surface should not be modified in any way (e.g., by polishing) between successive examinations. If the block surface or the calibration reflector holes have been polished by any chemical or mechanical means, this fact should be recorded.

2.1 Calibration for Manual Scanning

For manual scanning for the sizing of flaws, static calibration may be used if sizing is performed using a static transducer. When signals are maximized during calibration, they should also be maximized during sizing. For manual scanning for the detection of flaws, reference hole detection should be shown at scanning speed and detection level set accordingly (from the dynamic DAC).

2.2 Calibration for Mechanized Scanning

When flaw detection and sizing are to be done by mechanized equipment, the calibration should be performed using the following guidelines:

a. Calibration speed should be at or higher than the scanning speed.

b. The direction of transducer movement during calibration should be the same as the direction during scanning unless (1) it can be shown that the change in scanning direction does not make a difference in the sensitivity and vibration background noise received from the search unit or (2) these differences are taken into account by a correction factor.

c. For mechanized scanning, signals should not be maximized during the establishment of the DAC curve.

d. One of the following alternative guidelines should be followed for establishing the DAC curve:

(1) The DAC curve should be established using a moving transducer mounted on the mechanism that will be used for examination of the component.

(2) Correction factors between dynamic and static response should be established using full-scale mockups.

(3) Correction factors should be established using models and taking scaling factors into consideration (assumed scaling relationship should be verified).

(4) Correction factors between dynamic and static response should be established from the indications that are found during examination for sizing. For detection of flaws during the initial scan, correction factors may be assumed based on engineering judgment. If assumed correction factors are used for detection, these factors should later be confirmed on indications from flaws in the vessel during the examination. Deviation from the assumed value may suggest reexamining the data.

2.3 Calibration Checks

If an EBS is used for calibration check, the following should apply:

a. The significant DAC percentage level used for the detection and sizing of indications should be reduced to take into account the maximum error that could be introduced in the system by the variation of resistance or leakage in the connectors or other causes.

b. Calibration checks should be performed on the complete connected system (e.g., transducer and cables should not be checked separately).

c. Measures should be taken to ensure that the different variables such as temperature, vibration, and shock limits for which the EBS error band is determined are not exceeded during transport, use, storage, etc.

d. When a universal calibration block is used and some or all of the reference holes are larger than the reflector holes at comparable depths recommended by Article 4, Section V, of the ASME Code, 1980 edition, a correction factor should be used to adjust the DAC level to compensate for the larger reflector holes. Also, if the reactor pressure vessel has been previously examined by using a conventional block, a ratio between the DAC curves obtained from the two blocks should be noted (for reference) with the significant indications data.

3. NEAR-SURFACE EXAMINATION AND SURFACE RESOLUTION

The capability to effectively detect defects near the front and back surfaces of the actual component should be estimated. The results should be reported with the report of abnormal degradation of reactor pressure boundary in accordance with the recommendation of regulatory position 2.a(3) of Regulatory Guide 1.16. In determining this capability, the effect of the following factors should also be considered:

a. If an electronic gate is used, the time of start and stop of the control points of the electronic gate should be related to the volume of material near each surface that is not being examined.

b. The decay time, in terms of metal path distance, of the initial pulse and of the pulse reflections at the front and back surface should be considered.

c. The disturbance created by the clad-weld-metal interface with the parent metal at the front or the back surface should be related to the volume of material near the interface that is not being examined.

d. The disturbance created by front and back metal surface roughness should be related to the volume of material near each surface that is not being examined.

4. BEAM PROFILE

The beam profile should be determined if any recordable flaws are detected. This should be done for each search unit used during the examination by a procedure similar to that outlined in the nonmandatory Appendix B (B-60), Article 4, Section V of the ASME Code, 1980 edition, for determining beam spread. Beam profile curves should be determined for each of the holes in the basic calibration block. Interpolation may be used to obtain beam profile correction for assessing flaws at intermediate depths for which the beam profile has not been determined.

5. SCANNING WELD-METAL INTERFACE

The beam angles used to scan welds should be based on the geometry of the weld/parent-metal interface. At least one of these angles should be such that the beam is almost perpendicular (±15 degrees to the perpendicular) to the weld/parent-metal interface unless it can be demonstrated that unfavorably oriented planar flaws can be detected by the UT technique being used. Otherwise, use of alternative volumetric NDE techniques, as permitted by the ASME Code, should be considered. Alternative NDE techniques may be considered to include high-intensity radiography or tandem-probe ultrasonic examination of the weld-metal interface.

6. SIZING

Indications from geometric sources need not be recorded.

6.1 Traveling Indications

Indications that travel on the horizontal baseline of the scope for a distance greater than indications from the calibration holes (at 20 percent DAC amplitude) should be recorded. Indications that travel should be recorded and sized at 20 percent DAC. Where the indication is sized at 20 percent DAC, this size may be corrected by subtracting for the beam width in the through-thickness direction obtained from the calibration hole (between 20 percent DAC points) that is at a depth similar to the flaw depth. If the indication exceeds 50 percent DAC, the size should be recorded by measuring the distance between 50 percent DAC levels without using the beam-width correction. The determined size should be the larger of the two.

6.2 Nontraveling Indications

Nontraveling indications above 20 percent DAC level that persist for a scanning distance of more than 1 inch plus the beam spread between 20 percent DAC points (as defined by nonmandatory Appendix B, Article 4, Section V of the ASME Code, 1977 edition) should be considered significant. The size of these flaws should be determined by measuring the distance between points at 50 percent DAC and between points at 20 percent DAC where the beam-width correction is made only for the 20 percent DAC size. The recorded size of the flaw would be the larger of the two determinations. If it can be adequately demonstrated that a nontraveling indication is from a geometric source (and not a flaw), there is no need to record that indication.

The following information should also be recorded for indications that are reportable according to this regulatory position:

a. Indications should be recorded at scan intervals no greater than one-fourth inch.

b. The recorded information should include the indication travel (metal path length) and the transducer position for 10 percent, 20 percent, 50 percent, and 100 percent DAC and the maximum amplitude of the signal.

7. REPORTING OF RESULTS

Records obtained while following the recommendations of regulatory positions 1.2, 3, 5, and 6, along with discussions and explanations, if any, should be kept available at the site for examination by the NRC staff. If the size of an indication, as determined in regulatory positions 6.1 or 6.2, equals or exceeds the allowable limits of Section XI of the ASME Code, the indications should be reported as abnormal degradation of reactor pressure boundary in accordance with the recommendation of regulatory position 2.a(3) of Regulatory Guide 1.16.

Along with the report of ultrasonic examination test results, the following information should also be included:

a. The best estimate of the error band in sizing the flaws and the basis for this estimate should be given.

b. The best estimate of the portion of the volume required to be examined by the ASME Code that has not been effectively examined such as volumes of material near each surface because of near-field or other effects, volumes near interfaces between cladding and parent metal, volumes shadowed by laminar material defects, volumes shadowed by part geometry, volumes inaccessible to the transducer, volumes affected by electronic gating, and volumes near the surface opposite the transducer.[10]

c. The material volume that has not been effectively examined by the use of the above procedures may be examined by alternative effective volumetric NDE techniques. If one of these alternative NDE techniques is a variation of UT, recommendations of regulatory positions 1 and 3 should apply. A description of the techniques used should be included in the report. If other volumetric techniques or variations of UT are used as indicated in regulatory position 5, the effectiveness of these techniques should be demonstrated and the procedures reported for review by the NRC staff.

D. IMPLEMENTATION

Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of (1) the results of inservice examination programs of all operating reactors after July 15, 1981, and (2) the results of preservice examination programs of all reactors under construction performed after January 15, 1982.

The recommendations of this guide are not intended to apply to preservice examinations that have already been completed.

The NRC staff intends to recommend that all licensees modify their technical specifications to make them consistent with the recommendations contained herein.

[10]It should be noted that the licensee is required to apply for relief from impractical ASME Code requirements according to § 50.55a of 10 CFR. If the licensee is committed to examine a weld as per the inspection plan in the plant SAR, the licensee is required to file an amendment when the commitments made in the SAR cannot be met.