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50-413 Catawba Nuclear Station, Unit 1, Duke Power Co. 05000413
50-414 Catawba Nuclear Station, Unit 2, Duke Power Co. 05000414
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TUCKMAN,M.S. Duke Power Co.
RECIP.NAME RECIPIENT AFFILIATION
Records Management Branch (Document Control Desk)

SUBJECT: Requests approval to use alternative to requirements of ASME B&PV Code,Section XI,App I,I-2100/ASME Section V,Article 4 for Oconee,McGuire & Catawba Nuclear Stations.

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July 20, 1999

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

ATTENTION: Document Control Desk

SUBJECT: Duke Energy Corporation

Oconee Nuclear Station - Units 1, 2, & 3
Docket Nos. 50-269, 50-270, and 50-287

McGuire Nuclear Station - Units 1 & 2
Docket Nos. 50-369 and 50-370

Catawba Nuclear Station - Units 1 & 2
Docket Nos. 50-413 and 50-414

Request to use an Alternative to the ASME Boiler and Pressure Vessel Code, Section XI in accordance with 10CFR50.55a(a)(3)(i)
Duke Energy Corporation Serial Number 99-GO-01

Pursuant to 10CFR50.55a(a)(3)(i), Duke Energy Corporation requests NRC approval to use an alternative to the requirements of the ASME Boiler and Pressure Vessel Code, Section XI, Appendix I, I-2100/ASME Section V, Article 4 for Oconee Units 1, 2 and 3, McGuire Units 1 and 2, and Catawba Units 1 and 2.

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ASME Section XI, Appendix I, I-2100 references ASME Section V, Article 4 for the ultrasonic examination of welds in ferritic pressure vessels greater than 2 inches in thickness. Duke is proposing alternatives to several of the requirements of ASME, Section V, Article 4.

A detailed description of the proposed alternatives, including discussions of the basis and justification, are included in Attachment 1 to this letter. Attachment 2 contains a copy of Code Case N-662.

Duke Energy Corporation requests NRC review and approval of 99-GO-01 by March 1, 2000.

Inquiries on this matter should be directed to J. S. Warren at (704) 382-4986.

Very truly yours,

M. S. Tuckman

MST/JSW

Attachments

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DUKE ENERGY CORPORATION
McGuire Units 1 and 2
Catawba Units 1 and 2
Oconee Units 1, 2 and 3

10-YEAR INTERVAL REQUEST FOR ALTERNATIVE NO. 99-GO-01

Pursuant to 10CFR50.55a (a) (3) (i), Duke Energy Corporation proposes an alternative to the requirements of ASME Section XI. Accordingly, information is being submitted in support of our proposed alternative.

I. **System/Components for Which the Alternative Applies:**

Category: B-A Pressure Retaining Welds in Reactor Vessels

Item Number: B1.21 Circumferential Shell-to-Head Welds

B1.22 Meridional Head Welds

Category B-B Pressure Retaining Welds in Vessels Other than Reactor Vessels

Item Number: B2.11 Pressurizer Circumferential Shell-to-Head Welds

B2.12 Pressurizer Longitudinal Shell Welds

B2.31 Steam Generator (Primary Side) Head Circumferential Welds

B2.40 Steam Generator (Primary Side) Tubesheet-to-Head Weld

B3.110 Pressurizer Nozzle-to-Vessel Weld

B3.130 Steam Generator (Primary Side) Nozzle-to-Vessel Weld(s)

C-A Pressure Retaining Welds in Pressure Vessels

Item Number: C1.10 Shell Circumferential Welds

C1.20 Head Circumferential Welds

C1.30 Tubesheet-to-Shell Welds

C-B Pressure Retaining Nozzle Welds in Vessels

Item Number: C2.20 Nozzles in Vessels > ½ in. Nominal Thickness

II. **Code Requirement:** ASME Section XI, Appendix I, I-2100, 1989 Edition and ASME Section V, Article 4, 1989 Edition.

III. **Code Requirement for Which the Alternative is Requested:**
ASME Section XI, Appendix I, I-2100 references ASME Section V, Article 4 for the ultrasonic examination of welds in ferritic pressure vessels greater than 2 inches in thickness. Duke Energy Corporation proposes alternatives to the following requirements of ASME Section V, Article 4:

1. T-432.3.1, Angle Beam Calibration, (e) beam spread, vertical plane. These data are intended for use in comparing successive sets of system calibration data. A further intent is to have these data available as more sophisticated methods of flaw sizing are developed.

2. T-434.1 Beam Spread Measurement. Measurements of beam spread in the vertical plane of angle beam search units shall be performed at the beginning of each period of extended use (or every three months, whichever is less).

3. T-441.3.2.8 Recording Angle Beam Examination Data for Planar Reflectors, (c), (2) Through-Wall Dimension.

   (a) For reflectors 20 to 100% DAC, the minimum sweep reading and its position and location along the length of the reflector for 20% DAC when approaching the reflector from the maximum signal direction.

   (b) For reflectors 20 to 100% DAC, the maximum sweep reading and its position and location along the length of the reflector for 20% DAC when moving away from the reflector's maximum signal direction.

   (c) For reflectors exceeding 100% DAC, minimum sweep reading and its position and location along the length of the reflector for 50% of the maximum amplitude when approaching the reflector from the maximum signal direction.

   (d) For reflectors exceeding 100% DAC, maximum sweep reading and its position and location along the length of the reflector for 50% of the maximum amplitude when moving away from the reflector's maximum signal direction.

4. T-441.3.2.8 Recording Angle Beam Examination Data for Planar Reflectors, (c), (3) Length Dimension. The length of the reflector shall be obtained by recording the position and location along the length of weld as determined by 20% of DAC for each end of the reflector.

IV. **Basis for the Alternative:** ASME Section V, Article 4 describes the required flaw sizing techniques. These techniques use amplitude levels (-6dB, 50% DAC or 20% DAC) to measure flaw height and length. The orientation of the flaw, the size of the flaw relative to the sound beam width and the surface texture of the flaw affect measurement accuracy. In addition, the accuracy of the amplitude based sizing method is also dependent on the surface condition of the component, adequacy of coupling and hand pressure of the examiner.

EPRI Report NP-6273, "Accuracy of Ultrasonic Flaw Sizing Techniques for Reactor Pressure Vessels" March 1989, addresses the precision of the dB drop method. This report concludes that sizing with dB drop would over estimate the through-wall extent of the flaw if the flaw is smaller than the beam width. The examiner is actually measuring the width of the sound beam instead of the flaw height.

Correcting the flaw height by subtracting the beam spread from the through-wall measurement is a method recognized in Regulatory Guide 1.150. However, The EPRI report concludes, and field experience shows that correcting for beam spread can result in a negative through-wall measurement. Flaw sizing with Time-of-Flight Diffraction decreases the uncertainties in flaw sizing and makes the use of beam spread unnecessary.

V. **Alternative Method for Flaw Sizing:** Duke Energy Corporation proposes using a Time-of-Flight Diffraction sizing technique to measure the length and through-wall dimension of non-geometric reflectors in ferritic pressure vessel welds greater than 2 inches in thickness. Equipment, procedures and personnel will be qualified in accordance with ASME Section XI, Code Case N-662, "Ultrasonic Examination of RPV and Piping and Bolts and Studs, Section XI, Division 1" Supplements 4 and 6. Qualification will be administered through the Performance Demonstration Initiative (PDI).

VI. **Justification for the Granting of Relief:** Use of a Time-of-Flight Diffraction technique qualified in accordance with Code Case N-662 for sizing planar flaws in ferritic pressure vessels would increase the accuracy of the ultrasonic examination and improve the level of quality.

VII. **Implementation:** Duke Energy Corporation will use equipment, personnel and procedures for ultrasonic sizing of planar flaws as described in Section V of this relief request for the remainder of the inspection interval.

Evaluated By James J. McGuire Date 6/22/99

Reviewed By R. Kevin Rhyne Date 6/22/99

Attachment 2

ASME Code Case N-662

Code Case N-662

Ultrasonic Examination of RPV and Piping and Bolts and Studs Section XI, Division 1

Applicability: 1989 Edition with the 1989 Addenda and Later Editions and Addenda through the 1998 Edition

Inquiry: What alternative requirements may be used for ultrasonic examination of RPV, piping, bolts and studs in lieu of Appendices I and VIII?

Reply: It is the opinion of the Committee that, in lieu of the ultrasonic examination requirements for RPV and piping and bolts and studs of Appendices I and VIII, the following requirements may be used.

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Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

CHAPTER A EXAMINATION COVERAGE

A.1 PIPING

(a) The required piping examination volume shall be examined in two axial directions. When examination in the circumferential direction is required, the circumferential examination shall be performed in two directions.

(b) Alternatively, when examinations of ferritic welds from both sides is not possible, full coverage credit may be claimed from a single side using a procedure qualified for single-side examination in accordance with Chapter B, Supplement 3. When examination of austenitic welds from both sides is not possible, full coverage credit may be claimed from a single side using a procedure qualified for single-side examination in accordance with Chapter B, Supplement 2, with all flaws on the opposite side of the weld.

A.2 REACTOR PRESSURE VESSEL SHELL WELDS

(a) The clad-to-base-metal interface region, including at least 15% T (measured from clad-to-base-metal interface), shall be examined from four directions, using a procedure qualified in accordance with Chapter B, Supplement 4. Examination directions shall include scans parallel and perpendicular to the weld.

(b) If the clad-to-base-metal-interface procedure demonstrates detectability of flaws with a tilt angle relative to the weld centerline of at least 45 deg., the remainder of the examination volume is considered fully examined if coverage is obtained in one parallel and one perpendicular direction. This shall be accomplished using a procedure and personnel qualified for single-side examination in accordance with Chapter B, Supplement 6. Subsequent examinations may be performed using examination techniques qualified for a tilt angle of at least ± 10 deg.

A.3 REACTOR PRESSURE VESSEL NOZZLE-TO-SHELL WELDS

***(a)* Examinations Conducted from the Inside**

(1) The clad-to-base-metal interface and the adjacent examination volume to a depth of at least 15% T (measured from the clad-to-base-metal interface) shall be examined from four orthogonal directions, using a procedure qualified in accordance with Chapter B, Supplement 4.

(2) When the examination volume defined in (1) cannot be effectively examined in all four directions, the examination shall be augmented by examination from the nozzle bore, using a procedure qualified in accordance with Chapter B, Supplement 7.

(3) The remainder of the examination volume not covered by (1) or by a combination of (1) and (2) shall be examined in at least one radial direction from:

(a) the nozzle bore using a procedure qualified in a accordance with Chapter B, Supplement 7, or

(b) the vessel shell using a procedure qualified for single-sided examination in accordance with Chapter B, Supplement 6.

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***(b)* Examinations Conducted from the Outside**

(1) The clad-to-base-metal interface and the adjacent examination volume to a depth of at least 15% T (measured from the clad-to-base-metal interface) shall be examined from one radial and two opposing circumferential directions using a procedure qualified in accordance with Chapter B, Supplement 4, for examination performed in the radial direction, and Supplement 5B, for examination performed in the circumferential directions.

(2) The remainder of the examination volume not covered by (1) shall be examined in at least one radial direction using a procedure qualified for a single-side examination in accordance with Chapter B, Supplement 6.

A.4 BOLTS AND STUDS

Ultrasonic examination of bolts and studs shall be performed using procedure and personnel qualified in accordance with Chapter B, Supplement 8. The volume specified in IWB-2500 and IWC-2500 shall be examined.

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1

CHAPTER B
PERFORMANCE DEMONSTRATION FOR ULTRASONIC EXAMINATION SYSTEMS

B-1000 SCOPE

B-1100 GENERAL

(a) This Chapter provides requirements for performance demonstration for ultrasonic examination procedures and personnel used to detect and size flaws.

(b) Each organization (e.g., Owner or vendor) shall have a written program that ensures compliance with this Case. Each organization that performs ultrasonic examinations shall qualify its procedures and personnel in accordance with this Case. The organization may contract implementation of the program.

(c) Performance demonstration requirements apply to personnel who detect, record, or interpret indications or size flaws in welds or components.

(d) The performance demonstration requirement specified in this Case do not apply to personnel whose involvement is limited to mounting a scanning device, marking pipe, or other situations where knowledge of ultrasonics is not important.

(e) Operators of fully-automated data collection systems need not be qualified to the requirements of this Case, provided that

(1) the data analyst is qualified to the requirements of this Case, and is responsible for system calibration and verifying systems sensitivity;

(2) the analyst is responsible for establishment of examination sensitivity; and

(3) the system meets the definition of automated system, below.

(f) Systems used for acquisition (collection) of ultrasonic data are classified as automated, semi-automated, or manual, as define below.

(1) Automated system - A system that is fully software-controlled by input parameters or specification from an operator and that digitally acquires and records the complete real-time output for each transducer during the collection process. All system calibrations, examination, and scanning parameters used during collection are verifiable during off-line analysis. All required real-time information (e.g., A-scan waveforms, C-scan or B-scans images) can be processed off line for analysis. No adjustments to the ultrasonic parameters can be made without knowledge and concurrence of the analyst.

(2) Semi-automated system or manual system. A system that is not fully software-controlled, i.e., that requires an operator to make ultrasonic parameter adjustments during the collection process, that will affect the off-line analysis. The following are some characteristics of semi-automated or manual systems:

(a) complete real-time output for each transducer is not recorded;

(b) all system calibrations, and examination, and scanning parameters cannot be verified during off-line analysis;

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

(c) the examination cannot be reconstructed from the recorded data;
(d) adjustments to the ultrasonic parameters can be made without knowledge and concurrence of the analyst.

B-2000 GENERAL EXAMINATION SYSTEM REQUIREMENTS

B-2100 PROCEDURE REQUIREMENTS

(a) The examination procedure shall contain a statement of scope that specifically defines the limits of procedure applicability (e.g., materials, thickness, diameter, and product form).
(b) The procedure shall provide specific instructions with sufficient detail to assure that the Owner can determine that the qualified procedure is followed during field applications.
(c) The examination procedure shall specify a single value or a range of values for the variables listed in B-2100(e).
(d) Any calibration method may be used provided it is described and complies with B-2100(e)(5).
(e) The examination procedure shall specify the following essential variables:

(1) instrument or system, including manufacturer and model or series of pulser, receiver, and amplifier, including:

(a) instrument settings for center frequency, pulse width, and filtering or smoothing;
(b) operation, e.g., voltage, spike, square wave, tone burst;

(2) search units, including:

(a) center frequency and either bandwidth or waveform duration as defined in B-4000;
(b) mode of propagation and nominal inspection angles;
(c) number, size, shape, and configuration of active elements and wedges or shoes;

(3) search unit cable, including:

(a) type;
(b) maximum length;
(c) maximum number of connectors;

(4) detection and sizing techniques, including:

(a) scan pattern and beam directions;
(b) maximum scan speed;
(c) minimum and maximum pulse repetition rate (bolting only);
(d) minimum spatial sample spacing in scan and index directions, i.e., sample surface distance between points where an A-scan is recorded(automated systems);
(e) extent of scanning and action to be taken for access restrictions;

(5) methods of calibration for detection and sizing (e.g., actions required to insure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system, whether displayed, recorded, or automatically processed, are repeated from examination to examination);

(6) inspection and calibration data to be recorded;

(7) method of data recording;

(8) recording equipment (e.g., strip chart, analog tape, digitizing) when used;

(9) methodology and criteria for discrimination of indications (e.g., geometric versus flaw indications and for length and depth sizing of flaws);

(10) surface preparation requirements;

(*11*) any other identifiable factor that could substantially influence the effectiveness of the examination.

B-2200 PERSONNEL REQUIREMENTS

Personnel shall meet the requirements of Appendix VII and shall be qualified in accordance with B-3000.

B -3000 QUALIFICATION TEST REQUIREMENTS

B -3100 QUALIFICATION TEST REQUIREMENTS

B -3110 DETECTION

(*a*) Qualification test specimens shall meet the requirements of the appropriate Supplement listed in Table B-3110-1

(*b*) The examination procedure and personnel are qualified for detecting flaws upon successful completion of the performance demonstration specified in the appropriate Supplement listed in Table B-3110-1.

(*c*) For piping welds whose requirements are in course of preparation the requirements of Appendix III, as supplemented by Table I-2000-1, shall be met.

B-3120 SIZING

(*a*) Qualification test specimens shall meet the requirements of the appropriate Supplement listed in Table B-3110-1.

(*b*) The examination procedure, and personnel are qualified for sizing flaws upon successful completion of the performance demonstration specified in the appropriate Supplement listed in Table B-3110-1.

(*c*) For piping welds whose requirements are in course of preparation, the requirements of Appendix III, as supplemented by Table I-2000-1, shall be met.

(*d*) RMS error shall be calculated as follows:

$$\text{RMS} = \left[\frac{\sum_{i=1}^{n} (m_i - t_i)^2}{n} \right]^{1/2}$$

where

m_i = measured flaw size

t_i= true flaw size

n = number of flaws measured

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1

TABLE B-3110-1
COMPONENT QUALIFICATION SUPPLEMENTS

Component Type	Applicable Supplement
Piping Welds	
Wrought Austenitic	2
Ferritic	3
Cast Austenitic	[Note (1)]
Dissimilar Metal	Appendix VIII, Supplement 10
Overlay	Appendix VIII, Supplement 11
Coordinated Implementation	Appendix VIII, Supplement 12
Vessels	
Clad-to-Base-Metal Interface Region	4
Nozzle Inside Radius Section	5A or 5B
Reactor Vessel Welds Other Than Clad-to-Base-Metal Interface	6
Nozzle-to-Vessel Weld	7
Coordinated Implementation	13
Bolts and Studs	8

NOTE:
(1) In the course of preparation

B-3130 ESSENTIAL VARIABLE RANGES

(*a*) Any two procedures with the same essential variable [B-2100(d)] are considered equivalent. Pulsers, search units, and receivers that vary within the tolerance specified in B-4100 are considered equivalent. When the pulser, search units, and receivers vary beyond the tolerances of B-4100, or when the examination procedure allows more than one value or range for an essential variable, the qualification test shall be repeated at the minimum and maximum value, as applicable from B-4100 (e.g., at the lowest and highest allowed settings or frequencies) for each essential variable with all other variables remaining at nominal values. Changing the essential variable may be accomplished during successive personnel performance demonstrations. Each examiner need not demonstrate qualification over the entire range of every essential variable.

(*b*)When the procedure does not specify a range for essential variables and establishes criteria for selecting values, the criteria shall be demonstrated during the procedure qualification.

B-3140 REQUALIFICATION

When a change in an examination procedure causes an essential variable to exceed a qualified range, the examination procedure shall be requalified for the revised range.

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1

B-4000 ESSENTIAL VARIABLE TOLERANCES

B-4100 PROCEDURE MODIFICATIONS

B-4110 PULSERS, RECEIVERS, AND SEARCH UNITS

Components of the same make, model number and physical description are substitutable without further consideration. The qualified procedure may be modified to substitute or replace pulsers, receivers, or search units without requalification when the following conditions are met.

(*a*) Instruments with reject, damping, or pulse tuning controls, have discrete settings specified in the procedure.

(*b*) Pulsers and receivers shall be evaluated using ASTM E 1324, Guide for Measuring Some Electronic Characteristics of Ultrasonic Instruments, with the following exceptions:

(*1*) The lower (F_L) and upper (F_U) limits for receivers shall be determined between frequencies that are 6 dB below the peak frequency.

(*2*) The receiver center frequency (F_C) shall be determined by:

$$Fc = \frac{F_L + F_U}{2}$$

(3) The receiver bandwidth (BW) shall be determined by:

$$BW = \frac{F_U - F_L}{Fc} \times 100$$

(*c*) Search units shall be evaluated using ASTM E 1065, Evaluation of the Characteristics of Ultrasonic Search Units.

(*d*) Examination systems shall be evaluated using Supplement 1.

(*e*) Replacements of the instrument or the pulser section of the instrument system shall be with the following tolerances of the original equipment as measured into a 50 ohm, non-inductive, non-capacitive, resistive load:

(*1*) pulse amplitude, ± 10%;

(*2*) pulse rise time, ± 10%;

(*3*) pulse duration, ± 10%.

(*f*) Replacements of the instrument or the receiver section of the instrument system shall be within the following tolerances of the original equipment:

(*1*) lower and upper frequency limits at the -6 dB point, ± 0.2 MHz;

(*2*) center frequency for instrument receivers with bandwidths less than 30%, ± 5%;

(*3*) center frequency for instrument receivers with bandwidths equal to or greater than 30%, ± 10%.

(*g*) Replacement search units of the same manufacturer's model, size, and nominal frequency may be used without requalification.

(*h*) Replacement search units not of the same manufacturer's model, that are of the same nominal size and frequency, shall be within the following tolerances of the original search units:

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

(*1*) propagation mode is the same;

(*2*) measured angle, ± 3 deg.;

(*3*) center frequency for search units with bandwidths less than 30%, ± 5%;

(*4*) center frequency for search units with bandwidths equal to or greater than 30%, ± 10%;

(*5*) waveform duration, ± 1/2 cycle or 20%, whichever is greater (measured at -20 dB), or bandwidth, ± 10%;

(i) As an alternative to (e) through (h) above, equipment replacement, including interconnecting cabling, is acceptable if the examination system is within the following tolerances of the original system, as measured according to the requirements of Supplement 1:

(*1*) system center frequency ± 5%, for examination systems with bandwidths less than 30%;

(*2*) system center frequency ±10%, for examination systems with bandwidths equal to or greater than 30%;

(*3*) system bandwidth, -10% and no upper limit.

B-4120 SEARCH UNIT CHARACTERIZATION

Characterization measurements of the search unit shall be made using either a sinusoidal tone burst technique or shock excitation. When using shock excitation, the characterization pulser and UT instrument pulser shall be the same within the limits of B 4110(e).

B-4200 COMPUTERIZED SYSTEM ALGORITHMS

When the performance demonstration uses prerecorded data, algorithms for automated decisions may be altered when the altered algorithms are demonstrated to be equivalent to those qualified. When the performance demonstration results meet the acceptance requirements of B-3000, the algorithm shall be considered qualified.

B-4300 CALIBRATION METHODS

Alternative calibration methods may be demonstrated equivalent to those described in the qualified procedure without requalification. This demonstration of equivalence shall be conducted for each beam angle and mode of propagation to which it applies, as follows.

(*a*) Calibrate the examination system in accordance with the alternative methods.

(*b*) Compare the sensitivity of the alternative calibration method to that of the qualified calibration method.

(*c*) The alternative calibration method is acceptable when the system sensitivity is no more than 2 dB below that obtained by the qualified method.

B-5000 RECORD OF QUALIFICATION

B-5100 GENERAL

The organization's performance demonstration program shall specify the documentation that shall be maintained as qualification records. Documentation shall include identification of personnel, NDE procedures, equipment and specimens used during qualification, and results of the performance demonstration.

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1

CHAPTER B SUPPLEMENTS

SUPPLEMENT 1 — EVALUATING ELECTRONIC CHARACTERISTICS OF ULTRASONIC SYSTEMS

1.0 SYSTEM FREQUENCY CHARACTERISTICS

1.1 The frequency response, also known as the frequency spectrum, shall be determined by measuring the amplitude of the pulse echo response from a target as a function of frequency. This response shall be used as a basis for establishing the center frequency and bandwidth of the ultrasonic system.

CAUTION: The required output signal test point from the ultrasonic instrument may require access to ultrasonic circuitry inside the instrument chassis. The use of high impedance test probes may also be required if the signal of interest is not buffered.

1.2 Connect the ultrasonic instrument including the search unit and, if applicable, the wedge, as shown in Fig. S1-1A. The output signal from the ultrasonic instrument that is used in data analysis for flaw detection or flaw sizing (i.e., the output signal after amplification, filtering, and video detection) shall be input to a device that is capable of measuring the frequency spectrum (e.g., a spectrum analyzer or a digitizing circuit with a software package that determines the frequency response of waveforms). If a digitizing circuit is used, the rate of digitizing shall be at least five times the nominal (labeled) frequency of the search unit.

(*a*) If the receiver or transmitter provides variable signal filtering or frequency control, the signal controls shall be set as specified in the examination procedure. Check all connections in the test setup to ensure that it is safe to turn on the ultrasonic system.

(*1*) Flat or non-focused search units shall be adjusted so that the distance (Z_O) from the face of the search unit to the target is 2 in. (see Fig. S1-1B). A smooth, flat block with minimum dimensions 2 in. x 2 in. x 1 in. thick is the target. Using a manipulator, adjust the search unit angle with respect to the block until the return echo is maximized indicating that the sound field is perpendicular to the block. Adjust the receiver section gain controls until the ultrasonic signal amplitude from the block is 80% of full scale without saturating the ultrasonic signal. Plot the frequency spectrum of the ultrasonic signal as shown in Fig. S1-2A.

(*2*) Determination of the frequency response for focused search units shall follow the same procedure for flat search units, except that the distance Z_O shall be adjusted to maximize echo from the target.

1.3 System Frequency Response Results

(*a*) Lower Frequency Limit (F_L)-The lower frequency limit (MHz) at a specific frequency control setting is the lowest frequency on the frequency response curve that is 6 dB below the maximum amplitude as shown in Fig. S1-2A.

(*b*) Upper Frequency Limit (F_U)—The upper frequency limit (MHz) at a specific frequency control setting is the highest frequency on the frequency response curve that is 6 dB below the maximum amplitude as shown in Fig. S1-2A.

(*c*) Center Frequency (F_C)—The center frequency (MHz) at a specific frequency control setting shall be calculated in accordance with B-4110, (b)(2).

(*d*) Bandwidth (*BW*)- The bandwidth (%) at a specific frequency control setting shall be calculated in accordance with B-4110, (b)(3).

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

(*e*) The system frequency response results, (a) through (d) above, shall be obtained for the remaining receiver and transmitter control module setting combinations used in the performance demonstration. These values shall be recorded.

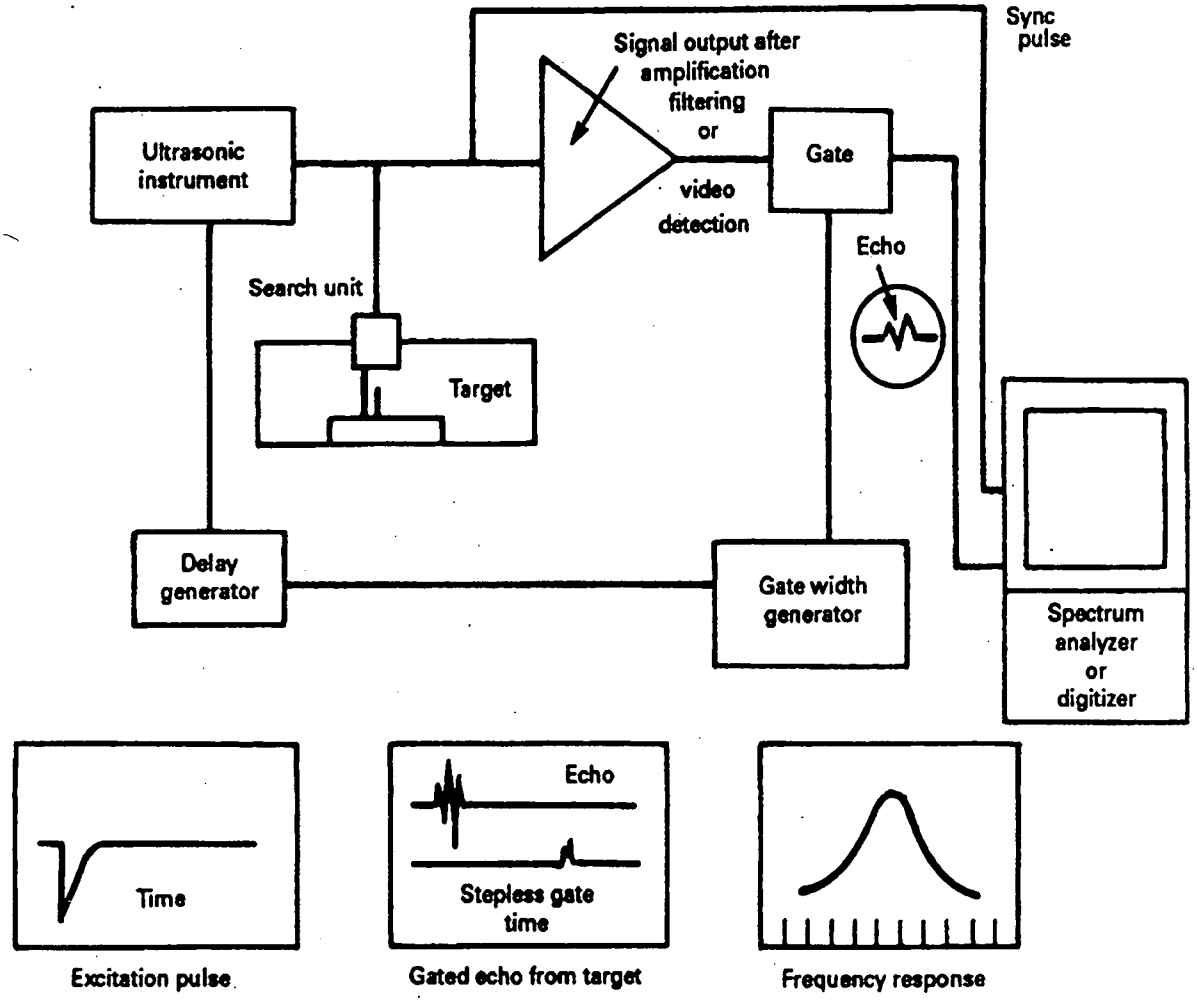

FIG: S1-1A System Configuration

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

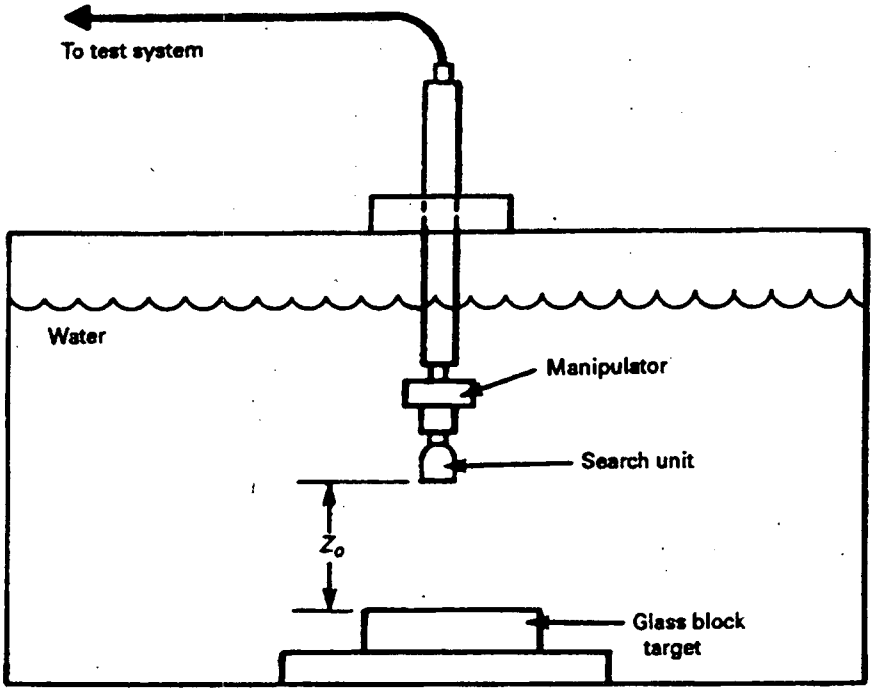

Figure. S1-1B Test Configuration

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

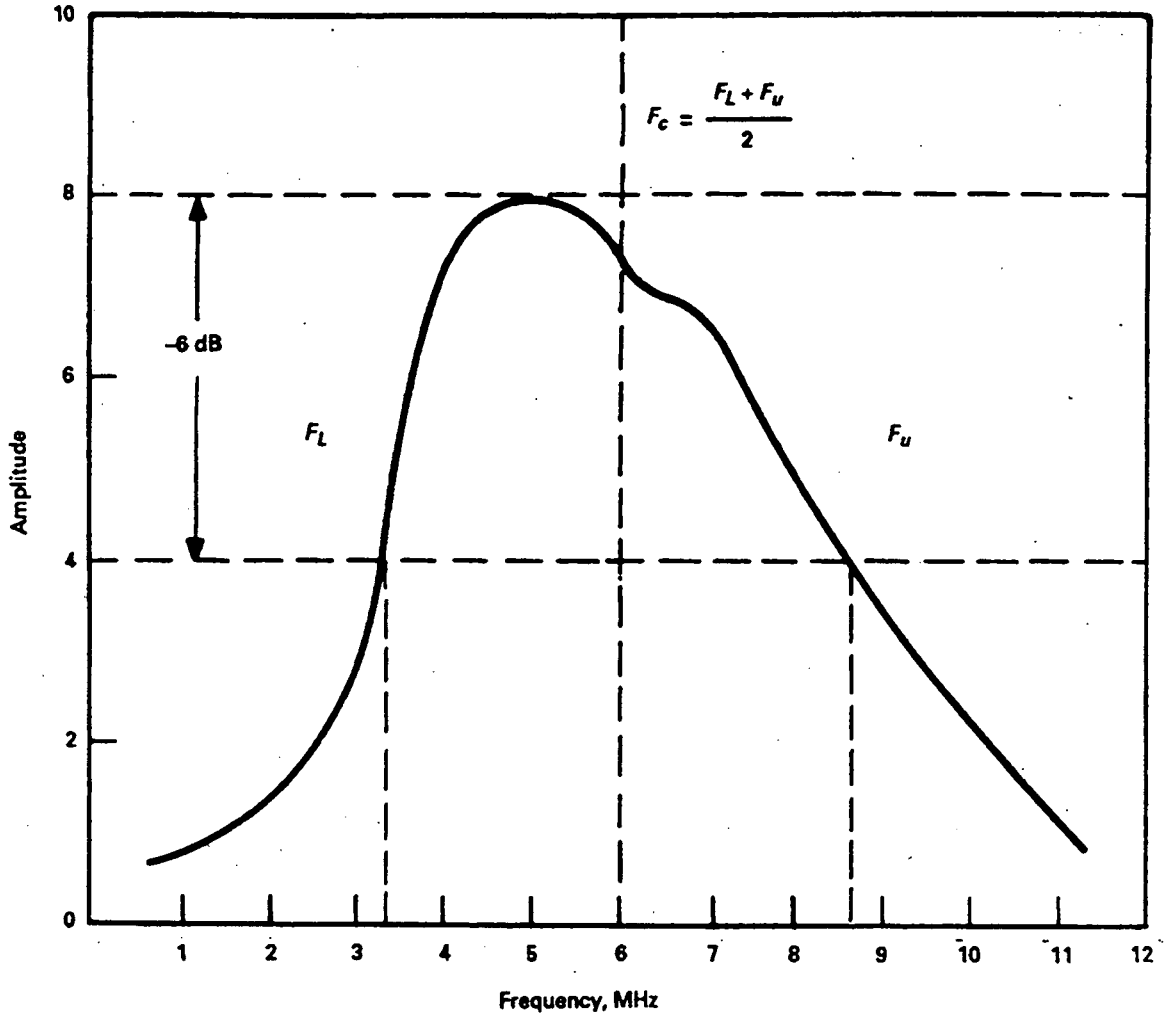

Figure S1-2a Frequency Response Curve

SUPPLEMENT 2 — QUALIFICATION REQUIREMENTS FOR WROUGHT AUSTENITIC PIPING WELDS

1.0 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, access limitations). The same specimens may be used to demonstrate both detection and sizing qualification.

1.1 General.

(*a*) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(*b*) The specimen set shall consist of at least four specimens having different nominal pipe diameters and thickness. The set shall include pipe specimens not thicker than 0.1 in. more than the minimum thickness, nor thinner than 0.5 in. less than the maximum thickness for which the examination procedure is applicable. It shall include the minimum, ±NPS 1/2, and maximum pipe diameters and thickness for which the examination procedure is applicable. If the procedure is applicable to pipe diameters of 24 in. or larger, the specimen set must include at least one specimen 24 in. or larger in diameter but need not include the maximum diameter.

(*c*) The specimen set shall include examples of the following fabrication condition:

(*1*) unground weld reinforcement (crowns);

(*2*) wide crowns, such that the total crown width is 1 1/2 to 2 times the nominal pipe wall thickness;

(*3*) geometric conditions that normally require discrimination from flaws (e.g., counterbore, weld root conditions such as excessive ID reinforcement);

(*4*) typical limited-scanning surface conditions (e.g., diametrical shrink, single-side access due to safe ends or fittings).

(*d*) All flaws in the specimen set shall be cracks.

(*1*) Mechanical fatigue cracks and either IGSCC or thermal fatigue cracks shall be used. No more than 25% of the flaws shall be mechanical fatigue cracks.

(*2*) At least 50% of the cracks shall be coincident with fabricated conditions described in (*c*) above.

1.2 Detection Specimens

(*a*) Specimens shall be divided into grading units. Each grading unit shall include at least 3 in. of weld length. If a grading unit is designed to be unflawed, at least 1 in. of unflawed material shall exist on either side of the grading unit. The segment of weld length used in one grading unit shall not be used in another grading unit. Grading units need not be uniformly spaced around the pipe specimen.

(*b*) Detection sets for personnel qualification shall be selected from Table S2-1. The number of unflawed grading units shall be at least twice the number of flawed grading units.

(*c*) For the initial procedure qualification, detection sets shall include the equivalent of three personnel qualification sets. Extension of qualifications to qualify new values of essential variables requires at least one personnel qualification set.

(*d*) When the procedure is intended to detect IGSCC, at least four field-removed, IGSCC-flawed grading units shall be included in the detection test set.

(*e*) Flawed grading units shall meet the following criteria for flaw depth, orientation, and type.

(*1*) A minimum of 1/3 of the flaws, rounded to the next higher whole number, shall have depths between 5% and 30% of the nominal pipe wall thickness. At least 1/3 of the flaws, rounded to the next higher whole number, shall have depths greater than 30% of the nominal pipe wall thickness.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

(*2*) At least one and a maximum of 10% of the flaws, rounded to the next higher whole number, shall be oriented axially. The remainder of the flaws shall be oriented circumferentially.

1.3 Sizing Specimens

(*a*) The minimum number of flaws shall be ten.

(*b*) Flaws in length sizing sample sets shall meet the requirements of para. 1.2(e)(l), when given in conjunction with a detection test. When the length sizing test is administrated independently, the flaw depth requirements do not apply.

(*c*) Flaws in the depth sizing sample set shall be distributed as follows:

Flaw Depth (% Wall Thickness)	Minimum Percentage of Flaws
5-30%	20%
31-60%	20%
61-100%	20%

The remaining flaws shall be in any of the above categories.

(*d*) When the procedure is intended to size IGSCC, at least three IGSCC flaws shall be included in the test set. These IGSCC flaws may be field-removed or fabricated by laboratory methods.

2.0 CONDUCT OF PERFORMANCE DEMONSTRATIONS

Flaw location and specimen identification shall be obscured to maintain a "blind test." Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.

2.1 Detection Test.

(*a*) Flawed and unflawed grading units shall be randomly mixed.

(*b*) Detection tests shall include length sizing.

2.2 Length and Depth Sizing Tests

(*a*) Each reported flaw in the detection test shall be length sized.

(*b*) When only length sizing is being tested, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(*c*) For the depth sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

3.0 ACCEPTANCE CRITERIA

3.1 Detection Acceptance Criteria.

(*a*) Personnel demonstrations shall meet the requirements of Table S2-1 for both detection and false calls.

(*b*) Procedure qualifications shall demonstrate detectability of each flaw, within the scope of the procedure. Successful personnel demonstrations may be combined to satisfy the requirements for procedure qualifications.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

(c) If the procedure is intended to detect IGSCC, failure to detect more than one of the IGSCC flaws is unacceptable for personnel qualifications.

3.2 Sizing Acceptance Criteria

(*a*) The RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths, shall not exceed 0.75 in.

(*b*) The RMS error of the flaw depths estimated by ultrasonics, as compared with the true depths, shall not exceed 0.125 in.

TABLE S2-1
PERFORMANCE DEMONSTRATION DETECTION TEST
ACCEPTANCE CRITERIA

Detection Test Acceptance Criteria		False Call Test Acceptance Criteria	
No. of Flawed Grading Units	**Minimum Detection Criteria**	**No. of Unflawed Grading Units**	**Maximum Number of False Calls**
5	5	10	0
6	6	12	1
7	6	14	1
8	7	16	2
9	7	18	2
10	8	20	3
11	9	22	3
12	9	24	3
13	10	26	4
14	10	28	5
15	11	30	5
16	12	32	6
17	12	34	6
18	13	36	7
19	13	38	7

SUPPLEMENT 3 —QUALIFICATION REQUIREMENTS FOR FERRITIC PIPING WELDS

Qualification of examination procedures, and personnel for ferritic pipe examination shall be accomplished by satisfying the requirements of Supplement 2, except that the sample material shall be ferritic and the sample set defects shall be mechanically or thermally induced fatigue cracks. In addition, the set shall include pipe specimens not thicker than 0.1 in. more than the minimum thickness, nor thinner than 1.0 in. less than the maximum thickness for which the examination procedure is applicable.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

SUPPLEMENT 4—QUALIFICATION REQUIREMENTS FOR THE CLAD TO BASE-METAL INTERFACE OF REACTOR VESSEL

1.0 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure. The same specimens may be used to demonstrate both detection and sizing qualifications.

1.1 Detection Specimens.

(a) Specimens shall have sufficient volume to minimize spurious reflections. Specimens need not contain a butt weld. Specimen length and width shall be at least 12 in. There shall be at least 10 sq. ft of clad surface in the specimen set.

(b) Specimen thickness:

(1) When the examination procedure requires the examination to be performed from the vessel ID (clad surface), the specimen minimum thickness shall be 3 in. or the maximum thickness of the vessel (whichever is less).

(2) When the examination procedure requires the examination to be performed from the vessel OD surface, the specimen shall be at least 90% of the maximum thickness to be examined.

(c) The performance demonstration shall be on the same type cladding as that to be-examined, with the following exceptions:

(1) Demonstration on shielded metal arc welding (SMAW) single-wire cladding is transferable to multiple wire or strip-clad processes.

(2) Demonstration of multiple-wire or strip-clad is considered equivalent but is not transferable to SMAW type clad.

(d) The surface condition of the test specimens shall be representative of the general condition of the vessel scanning surface.

(e) The detection test matrix shall include flaws with the following description.

(1) Flaw type. At least 70% of the flaws shall be cracks. Notches are limited to when the examination is performed from the clad surface, i.e., no corner-trap applications. Machined notches shall meet the following requirements:

(a) Notches shall have a maximum width of 0.010 in. at the tip. The width at the clad-to-base-metal interface shall not exceed 0.020 in.

(b) Notches shall conform to the following:

(1) Notch depth shall not exceed 0.25 in.

(2) Notches shall be semi-elliptical.

(2) For procedure qualification, at least 40% of the flaws shall be oriented parallel to the clad direction, ±10 deg., and at least 40% shall be oriented perpendicular to the clad direction, ±10 deg. For personnel qualification, at least 20% in either direction is sufficient.

(3) The flaw sizes shall be uniformly distributed in through-wall depths among the following ranges:

(a) 0.075-0.200 in.
(b) 0.201-0.350 in.
(c) 0.351-0.550 in.
(d) 0.551-0.750 in.

(4) No flaw shall have an aspect ratio (depth/length) less than 0.1.

*(5)*Flaws smaller than 50% of the allowable flaw size, as defined in IWB-3500, need not be included as detection flaws. For procedures applied from the inside surface, the minimum

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

thickness specified in the scope of the procedure shall be used to calculate a/t. For procedures applied from the outside surface, the thickness of the test specimen shall be used to calculate a/t.

*(f)*The number of flaws in a personnel detection demonstration shall be selected from Table S4-1.

(g) For initial qualification detection sets for procedure qualification shall include the equivalent of three personnel qualification sets. Extension of qualifications to qualify new value of essential variables requires at least one personnel qualification set.

*(h)*The requirements of IWA-3000 shall be used to determine whether closely-spaced flaws are to be treated as separate flaws.

(i) Flaw location and specimen identification shall be obscured to maintain a "blind test."

TABLE S4-1

PERFORMANCE DEMONSTRATION DETECTION TEST ACCEPTANCE CRITERIA

Number of Flaws	Minimum Detection Criteria
7	7
8	8
9	9
10	10
11	11
12	11
13	12
14	13
15	14
16	14
17	15
18	16
19	17
20	18

1.2 Sizing Specimens

(*a*) Personnel qualification demonstrations shall contain at least 10 flaws, at least 70% of which shall be cracks.

(*b*) Procedure qualifications shall include the equivalent of three personnel qualification sets.

(*c*) Sizing specimens shall conform to the requirements of 1.1(b), 1.1(c), 1.1(d), and 1.1(e)

2.0 CONDUCT OF PERFORMANCE DEMONSTRATIONS

2.1 Detection Test

(*a*) Flaw locations shall be obscured to maintain a "blind test." Divulging particular specimen results or candidate viewing of unmasked specimens is prohibited.

(*b*) If a flaw is reported within the greater of 1.0 in. or 10% of the metal path length to the flaw, from its true location (x, y, and z) it shall be considered detected. All other reported flaws shall be considered false calls.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

2.2 Length and Depth Sizing Test

(*a*) Each reported flaw in the detection test shall be length sized.

(*b*) When only length sizing is being tested, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(*c*) For the depth sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

3.0 ACCEPTANCE CRITERIA

3.1 Detection Acceptance Criteria

(*a*) Procedure qualifications shall demonstrate detectability of each flaw within the scope of the procedure.

(*b*) Personnel are qualified if the results of the performance demonstration satisfy the acceptance criteria of Table S4-1 and no flaw greater than 0.25 in. depth is missed.

(*c*) For procedure and personnel demonstrations, the number of false calls shall not exceed A/10, rounded to the next whole number, where A is the total scan area of specimens in the test measured in square feet.

3.2 Sizing Acceptance Criteria

(*a*) The RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths, shall not exceed 0.75 in.

(*b*) The RMS error of the flaw depths estimated by ultrasonics, as compared with the true depths, shall not exceed 0.15 in.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

SUPPLEMENT 5A — QUALIFICATION REQUIREMENTS FOR NOZZLE INSIDE RADIUS SECTION EXAMINATIONS FROM THE INSIDE SURFACE

Examination procedures and personnel are qualified for nozzle inside radius section examination. From the inside radius section examination, from the inside surface, when the following requirements are met. Personnel qualified for detection or depth sizing in accordance with the requirements of Supplement 4, are qualified in accordance with this Supplement, with no additional demonstration, provided the procedure used by the personnel to qualify in accordance with Supplement 4, other than changes required to adapt to the nozzle geometry, is also qualified in accordance with this Supplement.

1.0 SPECIMEN REQUIREMENTS

(*a*) For PWR vessels, both the inlet and outlet configurations shall be included in the demonstration.

(*b*) Flaws shall meet the requirements of Supplement 4, except that they shall be oriented as shown in IWB-2500-7. The entire size distribution need not be contained in every specimen, provided one or more examples of the smallest category are included.

(*c*) The minimum nozzle diameter contained in the scope of the procedure shall be included.

(*d*) Qualification on clad nozzle mockups may be used for qualification for examination of unclad nozzles. Qualifications on unclad nozzle mockups shall not be used for qualification for examination of clad nozzles.

1.1 Detection Specimens Detection specimens shall conform to the following requirements.

*(a)*There shall be a minimum of three flaws in each specimen.

*(b)*The specimen set shall contain a minimum of 10 flaws.

1.2 Sizing Specimens

*(a)*The sizing test matrix shall contain a minimum of 10 flaws; at least 50% of which shall be cracks.

*(b)*Any notches included in the test set shall meet the requirements and limitations of Supplement 4, 1.1 (e).

2.0 CONDUCT OF PERFORMANCE DEMONSTRATION

2.1 Detection Test

Procedure and equipment qualifications shall be performed as a "blind test."

2.2 Depth Sizing

(*a*) Depth sizing will be performed without knowledge of the true flaw depths.

(*b*)The sizing results from each of the specimens shall be combined for grading.

3.0 ACCEPTANCE CRITERIA

(*a*) Examination procedures and equipment are qualified if each flaw is detected and identified. The number of false calls shall not exceed D/10 rounded up to the next whole number, where D is the nominal nozzle ID in. If only a portion of a nozzle is examined, proportional credit for false calls shall be allowed. The total number of false calls shall not exceed 3.

(*b*) Personnel not previously qualified to Supplement 4 are qualified for detection if the requirements for procedure qualification in (a) above are satisfied.

(*c*) Examination procedures, equipment, and personnel (not previously qualified to Supplement 4) are qualified for depth sizing if the results of the sizing demonstration meet the sizing acceptance criteria of Supplement 4.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

SUPPLEMENT 5B -- QUALIFICATION REQUIREMENTS FOR NOZZLE INSIDE RADIUS SECTION EXAMINATIONS FROM THE OUTSIDE SURFACE

1.0 PROCEDURE REQUIREMENTS

The examination procedure shall include or provide for the following:

(a) A computational model that calculates misorientation angles and the maximum metal path distance to the required inspection volume. Misorientation angle is shown in Fig. S5B-1. These calculations apply to the central ray of the ultrasonic beam.

(b) A scope statement that specifies the maximum acceptable misorientation angle and metal path for the examinations.

(c) Division of the surface of the required examination volume into grids of 1.0 in. or less in the nozzle axis direction and 10 deg. or less of azimuth.

(d) Documenting the misorinetation angle and metal path distance in each grid cell location for each search or scan.

(e) Documenting the search unit or scan that produces the minimum misorientation angle when multiple search units are used.

2.0 SPECIMEN REQUIREMENTS

Demonstration specimens shall meet the requirements of Supplement 4, except as modified by (a) through (e). Flaw depths shall be distributed over the range of depths required by Supplement 4.

(a) One or more full size or sections of full size nozzle mockups shall be used.

(b) Nozzle mockup material and configurations shall be representative of nozzles installed in operating reactor vessels, but may be any thickness, diameter, or radius suitable for demonstration in accordance with 3.0, below.

(c) Flaws shall be uniformly distributed in examination zones A and B of Fig. S5B-2. At least half of the flaws shall be located within ±45 deg. of nozzle azimuth angles 90 deg. or 270 deg.

(d) All flaws shall be located in the required inspection volume and shall be oriented in the radial axial plane of the nozzle inside radius as shown in Fig. IWB-2500-7.

(*e*) For in nozzles with bore diameters not more than 4 in. at least 50% of the flaws in the demonstration test set shall be cracks; the balance may be notches. The maximum misorientation shall be demonstrated with cracks.

3.0 CONDUCT OF PERFORMANCE DEMONSTRATIONS

3.1 Procedure Qualification Demonstrations

(a) The qualification shall demonstrate the following:

(1) Examination surfaces to be used, i.e., vessel plate, outer blend radius, and nozzle boss;

(2) Maximum metal path length;

(3) Maximum misorientation angles.

(b) The demonstration shall include at least 10 flaws for detection and sizing, in one or more mockups.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

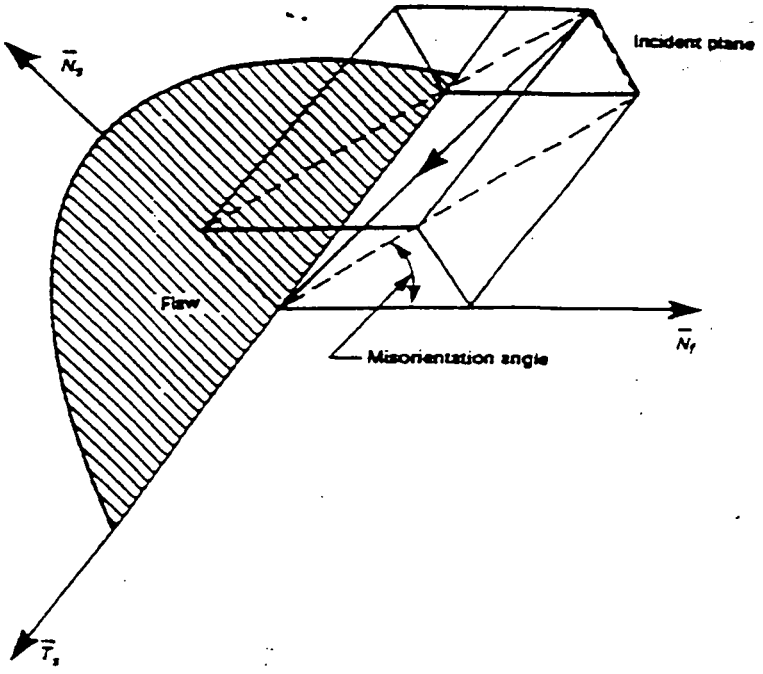

FIG. 558-1 MISORIENTATION ANGLE

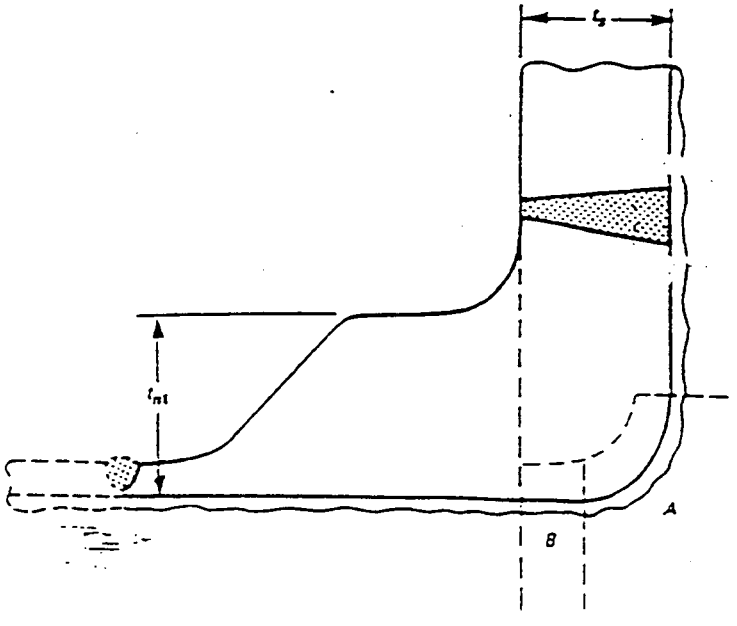

FIG. 558-2 FLAW DISTRIBUTION ZONES

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

(c) The initial demonstration shall be performed as a "blind test."

(d) After a successful initial demonstration, the scope of the procedure, 1.0 (b), may be extended by

(*1*) additional demonstrations on additional mockups or

(*2*) nonblind demonstrations on at least one flaw using scan parameters calculated to provide the desired maximum path length or misorientation angles. Detection shall be demonstrated to specific criteria listed in the examination procedure for any extension of procedure scope.

3.2 Procedure Qualification Documentation. The examination procedure, modeling program and methods, and the qualification results shall be documented to the extent necessary to determine that inservice examinations produce equivalent or smaller misorinetation angles than the procedures demonstrated.

3.3 Personnel Qualification

(a) Personnel previously qualified in accordance with the requirements of Supplement 4, for the same type of procedure (manual or automated), from the outside surface, using the same type of instruments and data recording and analysis equipment, shall be qualified as follows:

(1) Successful demonstration shall include at least three additional flaws for each scan surface which is qualified.

(2) Examinations shall be conducted from each of the scan surfaces covered by the procedure.

(3) The candidate shall demonstrate a selection of essential variables covered by the procedure, but need not demonstrate the full range.

(b) Personnel not previously qualified in accordance with the requirements of Supplement 4 shall be qualified as follows:

(1) The candidate shall demonstrate the procedure on one or more mockups.

(2) The demonstration shall contain at least the minimum number of detection and depth sizing flaws specified in Supplement 4.

(3) The demonstration shall include examinations from each of the scan surfaces described in the procedure.

(4) The demonstration need not cover the full range of all the essential variables.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

4.0 ACCEPTANCE CRITERIA

4.1 Detection Acceptance Criteria

(*a*) Examination procedures are qualified if each flaw is detected and identified. The number of false calls shall not exceed D/10, rounded up to the next whole number, where D is the nominal nozzle ID, in. The number of false calls shall not exceed three. If only a portion of a nozzle is examined, proportional credit for false calls is be allowed. The number of false calls shall not exceed three.

(*b*) Personnel previously qualified in accordance with the requirements of 3.3(a) are qualified, if each of the flaws presented are detected. The number of false calls shall not exceed the number specified in 4.1(a).

(*c*) Personnel not previously qualified in accordance with the requirements of Supplement 4 are qualified, if the results of the demonstration meet the requirements of Table S4-1. The number of false calls shall not exceed the number specified in 4.1(a).

4.2 Depth Sizing Acceptance Criteria

(*a*) Examination procedures are qualified if the results of the sizing demonstration meet the requirements of, Supplement 4, 3.2.

(*b*) Personnel previously qualified in accordance with the requirements of 3.3(a) are qualified, if the results from the sizing test, when added to the candidate's results from Supplement 4, meet the acceptance criteria of Supplement 4, 3.2.

(*c*) Personnel not previously qualified in accordance with the requirements of Supplement 4 are qualified if the results of the demonstration meet the acceptance criteria of Supplement 4, 3.2.

5.0 COMPONENT EXAMINATIONS

The computational model shall be used to demonstrate that the proposed examination variables are within the bounds the qualification demonstration.

(*a*) Documentation showing coverage and misorientation angle shall be provided for each nozzle examination performed. The documentation shall be used to demonstrate that the component examination will achieve misorientation angles that do not exceed the misorientation angles for which the procedure was qualified.

(*b*) Modeling need not be applied for repeated examination of nozzles of the same design.

(*c*) If the misorientation angle or metal path of the component examination exceeds that of the qualification, additional angles and directions may be applied to examine these areas without need for requalification, provided the demonstrated misorientation angle or path length can be achieved.

(*d*) If 5.0(c) cannot be met, the area shall be declared an area of no coverage.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

SUPPLEMENT 6 — QUALIFICATION REQUIREMENTS FOR REACTOR VESSEL WELDS OTHER THAN CLAD-TO-BASE METAL INTERFACE

1.0 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure. The same specimens may be used to demonstrate both detection and sizing qualification.

1.1 Detection Specimens.

(a) Specimens shall have sufficient volume to minimize spurious reflections. The specimen need not contain a weld. Specimen length and width shall be at least 12 in. There shall be at least 10 sq ft of scan surface in the specimen set.

(b) The specimen set shall contain at least one sample that is at least 90% of the maximum thickness to be examined. The specimen set shall contain one or more flaws in each of the locations and size ranges shown in Table S6-1.

(c) When the examination procedure requires the examination to be performed from the vessel ID (clad surface), the cladding on the mockup shall be of the same type as the cladding on the component to be examined, with the following exceptions:

(1) demonstration on shielded metal arc weld (SMAW) single-wire cladding is transferable to multiple-wire or strip-clad processes;

(2) demonstration on multiple-wire or strip-clad is considered equivalent but is not transferable to SMAW type clad.

TABLE S6-1
DETECTION AND SIZING TEST FLAWS AND LOCATIONS

	Flaw Depth, In. (Notes 2, 3, and 4)				
Flaw Locations	0.075-0.200	0.201-0.3.50	0.351-0.550	0.551-0.750	0.751-2.0
Inner 10% * Note (1)	X	X	S	S	
Outer 10%	X	X	S	S	
11-30% T			X	X	S
31-60% T			X	X	S
61-89% T			X	X	S

LEGEND:
X Applies to detection and sizing flaws
S Applies only to sizing flaws
T Thickness of the test specimen which contains the flaw

NOTES:
(1) Does not apply to clad vessels (see Supplement 4).
(2) Flaws smaller than 50% of allowable flaw size specified in IWB-3500 need not be included as detection flaws without regard for their designation as S or X
(3) Flaws equal to or less than the allowable flaw size may be used as detection flaws without regard to their position in the Table.
(4) The thickness of the test specimen shall be used to determine the a/t ratios in IWB-3500.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97
1

(*d*) The surface condition of the test specimens shall be representative of the general condition of the vessel scanning surface.

(*e*) The detection test matrix shall include flaws with the following description.

(*1*) *Flaw Type.* At least 55% of the flaws shall be cracks. The balance of flaws may be cracks, or fabrication defects (e.g., lack of fusion and slag inclusions).

(*2*) Detection and sizing examinations shall include either surface connected flaws or flaws with unflawed ligaments of more than 0.2 in. Procedure demonstrations shall include examples of both.

(*3*) A weld direction shall be established, whether or not the specimen contains a weld. For procedure qualification, at least of 40% of the flaws shall be oriented parallel to the clad direction ±10 deg. and at least 40% shall be oriented perpendicular to the clad direction ±10 deg. For personnel qualification, at least 20% in either direction is sufficient.

(*4*) Flaws for the detection test matrix shall be selected from the detection test flaws included in Table S6-1. The flaws selected shall provide a demonstration of the minimum and maximum metal path ranges to be demonstrated as well as a uniform distribution of flaw sizes and locations.

(*5*) The number of flaws in a personnel detection demonstration shall be selected from Table S6-2. Procedure qualifications shall include at least 20 flaws uniformly distributed over the ranges defined in Table S6-1.

(*6*) The requirements of IWA-3000 shall be used to determine whether closely-spaced flaws are to be treated as separate flaws.

1.2 Sizing Specimens

(*a*) Qualification demonstrations shall contain at least 10 flaws for personnel and 20 for procedures at least 55% of which shall be cracks. The remainder may be manufacturing defects, such as slag, lack of fusion, or combinations thereof.

(*b*) Sizing specimens shall conform with the requirements of 1.1(b), 1.1(c), 1.1(d), and 1.1(e), except that the test matrix shall be selected from the sizing and detection test flaws included in Table S6-1.

2.0 CONDUCT OF PERFORMANCE DEMONSTRATIONS

2.1 Detection Test

(*a*) Flaw locations shall be obscured to maintain a "blind test." Divulging particular specimen results or candidate viewing of unmasked specimens is prohibited.

(*b*) If a flaw is reported within the greater of 1.0 in. or 10% of the metal path length to the flaw, from its true location (x, y, and z) it shall be considered detected. All other reported flaws shall be considered false calls.

2.2 Length and Depth Sizing Test

(*a*) Each reported flaw shall be length sized.

(*b*) For the length sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(*c*) When only depth sizing is being tested, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering", Volume 121/No.1, Page 97

TABLE S6-2
PERFORMANCE DEMONSTRATION PERSONNEL DETECTION TEST
ACCEPTANCE CRITERIA

NUMBER OF FLAWS	MINIMUM DETECTION CRITERIA
7	7
8	8
9	9
10	10
11	11
12	11
13	12
14	13
15	14
16	14
17	15
18	16
19	17
20	18

3.0 ACCEPTANCE CRITERIA

3.1 Detection Acceptance Criteria

(a) Procedure qualifications shall demonstrate detectability of each flaw within the scope of the procedure.

(b) Personnel are qualified if the results of the performance demonstration satisfy the acceptance criteria of Table S6-2 and no surface connected flaw greater than 0.25 in. depth or imbedded flaw (distance from nearest surface exceeds 10%T) greater than 0.5 in. was missed.

(c) For procedures and personnel demonstrations, the number of false calls, shall not exceed A/10, rounded to the next whole number, where A is the total scan area of specimens in the test measured in square feet.

3.2 Sizing Acceptance Criteria

(*a*) The RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths, shall not exceed 0.75 in.

(*b*) The RMS error of the flaw depths estimated by ultrasonics, as compared with the true depths, shall not exceed 0.25 in.

*(c)*The slope of the linear regression line shall be at least 0.7. The slope of the linear regression line is calculated as shown in Fig. S6-1.

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1

APPENDIX VIII — MANDATORY

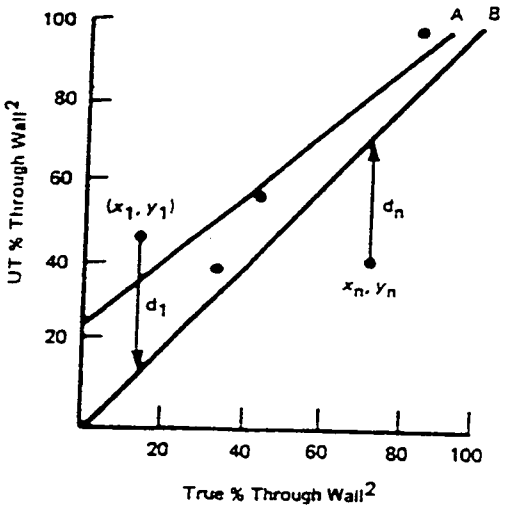
LINE A. Linear regression line, $y = a + bx$, giving the best fit of n data points $(x_1, y_1), \ldots (x_n, y_n)$ obtained by the least-square method where,

a = y intercept = $\frac{\Sigma y_i}{N} - b \frac{\Sigma x_i}{N}$

b = slope of the regression line

$$= \frac{N\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{N\Sigma x_i^2 - (\Sigma x_i)^2}$$

n = number of data points



LINE B: Ideal line, $y = x$ (perfect UT measurements).

CORRELATION COEFFICIENT: Correlation coefficient, defined as

$$r = \frac{n\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{\sqrt{[n\Sigma x_i^2 - (\Sigma x_i)^2]\ [n\Sigma y_i^2 - (\Sigma y_i)^2]}}$$

is a measure of "how well" the least-square regression line fits the data with respect to the ideal of $y = x$.

MEAN DEVIATION: Mean deviation is an indicator of accuracy of the measurements defined as

$$\text{Mean Deviation} = \frac{|d_1| + |d_2| + \ldots |d_n|}{n}$$

NOTES:
(1) *Standard Mathematical Tables*, 25th ed., William H. Beyer, Ph. D., Ed., CRC Press, Inc., Boca Raton, FL, 1979.
(2) Percent through-wall units apply to Supplements 2 and 3. Flaw depth units apply to Supplements 4 through 7.

FIG. S6-1 DEFINITION OF STATISTICAL PARAMETERS

Passed Main Committee 12/11/98,
Published January 99, "Mechanical Engineering". Volume 121/No.1, Page 97
1

SUPPLEMENT 7— QUALIFICATION REQUIREMENTS FOR NOZZLE-TO-VESSEL WELD EXAMINATIONS CONDUCTED FROM THE BORE

Successful demonstrations in accordance with Supplements 4 and 6 qualify procedures and personnel for nozzle-to-vessel weld examinations conducted from the bore, when the following requirements are met.

(a) The demonstration shall contain at least four flaws in one or more full-scale nozzle mock-ups. The specimens shall comply with supplement 6, 1.1, except that, flaw locations and orientations shall be selected from Table S7-1. At least one flaw from each category shall be included. At least 75% of the flaws shall be cracks or fabrication flaws. The balance may be notches. At least one flaw parallel to the weld shall provide a metal path distance with 10% of the equivalent path length to the weld centerline of the thickest component to be examined.

(b) For detection, the requirements of Supplement 6, 2.1 apply. Each flaw shall be detected with no false calls.

(c) For length sizing, the sizing results shall be added to the results of Supplements 4 and 6. The combined results shall meet the acceptance standards of Supplement 6, 3.2.

(d) For depth sizing, the flaw depths shall distributed over the ranges of Supplement 4, 1.1 for the inner 15% of the wall thickness, and Supplement 6, 1.1 for the remaining wall thickness. For the inner 15%, the depth sizing results shall be combined with the sizing results from Supplement 4. For the remaining wall thickness, the depth sizing results shall be combined with the sizing results from Supplement 6. The combined results shall meet the depth sizing acceptance criteria of Supplement 4, 3.2 and Supplement 6, 3.2, respectively.

TABLE S7-1
FLAW LOCATIONS AND ORIENTATIONS

	Parallel to Weld	Perpendicular to Weld
Inner 15%	X	X
OD Surface	X	
Subsurface	X	

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1

SUPPLEMENT 8
QUALIFICATION REQUIREMENTS FOR BOLTS AND STUDS

1.0 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure.

1.1 Specimens shall conform to the following requirements.

(*a*) The qualification process shall be performed with a full-scale section bolt or stud that is sufficient to contain the beam path and demonstrate the scanning technique.

(*b*) The qualification specimen shall be of similar chemical composition, tensile properties, and metallurgical structure as the bolt or stud to be examined. The scan surface of the qualification specimen shall have a configuration similar to the bolt or stud to be examined.

(*c*) Circumferentially oriented notches shall be located in the procedure qualification specimens at the minimum and maximum qualified metal paths. Notches located within one diameter of the end of the bolt or stud opposite the search unit are suitable for demonstrating the maximum metal path distance. Personnel qualification specimens may have notches at any location within the inspection volume. These notches are required on the outside threaded surface and the inner bore hole surface of bored studs with maximum depths and reflective areas as specified in Table S8-1.

(*d*) Additional notches may be located within the range specified in (c) above, provided they do not interfere with detection of other notches.

2.0 CONDUCT OF PERFORMANCE DEMONSTRATIONS

Specimen identification and notch locations shall be obscured to maintain a "blind test." A flaw shall be considered detected when the notch, as defined in 1.1, is found. The reported notch axial location shall be within the greater of ±1/2 in., or ±5% of the bolt or stud length, of the true location.

3.0 ACCEPTANCE CRITERIA

3.1 Examination procedures and personnel are qualified for detection when each qualification notch (as described in 1.1) has been detected and its response equals or exceeds the reporting criteria specified in the procedure. The notch response shall have a minimum peak signal to peak noise ratio of 2:1.

TABLE S8-1
MAXIMUM NOTCH DIMENSIONS

Bolt or Stud Diameter	Depth, in.[1]	Reflective Area, sq. in.
Larger than 4 in.	0.157	0.059
2 in. to 4 in.	0.107	0.027

Note
(1) For threaded surfaces, depth is measured from bottom of thread root to bottom of notch.

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1

SUPPLEMENTS 13 — REQUIREMENTS FOR COORDINATED IMPLEMENTATION OF SELECTED ASPECTS OF SUPPLEMENTS 4 AND 6

1.0 GENERAL

Candidates meeting the requirements of this Supplement in its entirety are considered qualified to Supplements 4 and 6. Detection and sizing may be performed separately.

2.0 COMBINED SUPPLEMENT 4 AND SUPPLEMENT 6 QUALIFICATION

Personnel qualification for Supplement 4 and 6 may be combined as follows:

*(a)*For detection, the total number of Supplement 4 and 6 flaws shall be at least 10 of which at least 50% shall be Supplement 4 flaws and at least 5 shall be from Supplement 6.

*(b)*For sizing, the total number of Supplement 4 and 6 flaws shall be at least 10, of which at least 50% shall be Supplement 4 flaws. At least 50% of the flaws in any sizing shall be cracks.

3.0 ACCEPTANCE CRITERIA

(a) Examination personnel are qualified for detection and length sizing when the results of any combined performance demonstration satisfy the acceptance of Supplement 4.

(b) Examination personnel are qualified for depth sizing when Supplement 4 and 6 flaws are sized within the respective acceptance criteria of those supplements.

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1