Designation: E2261/E2261M – 12

Standard Practice for
Examination of Welds Using the Alternating Current Field Measurement Technique[1]

This standard is issued under the fixed designation E2261/E2261M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice describes procedures to be followed during alternating current field measurement examination of welds for baseline and service-induced surface breaking discontinuities.

1.2 This practice is intended for use on welds in any metallic material.

1.3 This practice does not establish weld acceptance criteria.

1.4 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system might not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Standard:*[3]

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this practice refer to Terminology E1316, Section A, Common NDT terms, and Section C, Electromagnetic testing. The following definitions are specific to the alternating current field measurement technique:

3.2 *Definitions:*

3.2.1 *exciter*—a device that generates a time varying electromagnetic field, usually a coil energized with alternating current (AC); also known as a transmitter.

3.2.2 *detector*—one or more coils or elements used to sense or measure a magnetic field; also known as a receiver.

3.2.3 *uniform field*—as applied to nondestructive testing with magnetic fields, the area of uniform magnetic field over the surface of the material under examination produced by a parallel induced alternating current, which has been passed through the weld and is observable beyond the direct coupling of the exciting coil.

3.2.4 *graduated field*—as applied to nondestructive testing with magnetic fields, a magnetic field having a controlled gradient in its intensity.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *alternating current field measurement system*—the electronic instrumentation, software, probes, and all associated components and cables required for performing weld examination using the alternating current field measurement technique.

3.3.2 *operational reference standard*—a reference standard with specified artificial slots, used to confirm the operation of the system.

3.3.3 *Bx*—the x component of the magnetic field, parallel to the weld toe, the magnitude of which is proportional to the current density set up by the electric field.

3.3.4 *Bz*—the z component of the magnetic field normal to the inspected base metal/heat affected zone surface, the magnitude of which is proportional to the lateral deflection of the induced currents in the plane of that surface.

3.3.5 *X-Y Plot*—an X-Y graph with two orthogonal components of magnetic field plotted against each other.

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.07 on Electromagnetic Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard**

3.3.6 *time base plots*—these plot the relationship between Bx or Bz values with time.

3.3.7 *surface plot*—for use with array probes. This type of plot has one component of the magnetic field plotted over an area, typically as a color contour plot or 3-D wire frame plot.

3.3.8 *data sample rate*—the rate at which data is digitized for display and recording, in data points per second.

3.3.9 *configuration data*—standardization data and instrumentation settings for a particular probe stored in a computer file.

3.3.10 *twin fields*—magnetic fields generated in two orthogonal directions by use of two exciters

NOTE 1—Different equipment manufacturers may use slightly different terminology. Reference should be made to the equipment manufacturer's documentation for clarification.

4. Summary of Practice

4.1 In a basic alternating current field measurement system, a small probe is moved along the toe of a weld. The probe contains an exciter coil, which induces an AC magnetic field in the material surface aligned to the direction of the weld. This, in turn, causes alternating current to flow across the weld. The depth of penetration of this current varies with material type and frequency but is typically 0.004 in. [0.1 mm] deep in magnetic materials and 0.08 - 0.3 in. [2 - 7 mm] deep in non-ferrous materials. Any surface breaking discontinuities within a short distance of either side of the scan line at this location will interrupt or disturb the flow of the alternating current. The maximum distance from the scan line to a target discontinuity, potentially detectable at a specified probability of detection, is determined by the probe assembly size, but is typically 0.4 in [10 mm]. Measurement of the absolute quantities of the two major components of the surface magnetic fields (Bx and Bz) determines the severity of the disturbance (see Fig. 1) and thus the severity of the discontinuity. Discontinuity sizes, such as crack length and depth, can be estimated from key points selected from the Bx and Bz traces along with the standardization data and instrument settings from each individual probe. This discontinuity sizing can be performed automatically using system software. Discontinuities essentially perpendicular to the weld may be detected (in ferritic metals only) by the flux leakage effect. However confirmation of such transverse discontinuities (and detection of the same in non-ferritic metals) requires scans with the induced magnetic field perpendicular to the direction of the weld.

4.2 Configuration data is loaded at the start of the examination. System sensitivity and operation is verified using an operation reference standard. System operation is checked and recorded prior to and at regular intervals during the examination. Note that when a unidirectional input current is used, any decay in strength of the input field with probe lift-off or thin coating is relatively small so that variations of output signal (as may be associated with a discontinuity) are reduced. If a thick coating is present, then the discontinuity size estimation must compensate for the coating thickness. The coating thickness requiring compensation is probe dependent. This can be accomplished using discontinuity-sizing tables in the system software and an operator-entered coating thickness or automatically if the equipment measures the coating thickness or stand-off distance during the scanning process. Using the wrong coating thickness would have a negative effect on depth sizing accuracy if the coating thickness discrepancy is too large. Data is recorded in a manner that allows archiving and subsequent recall for each weld location. Evaluation of examination results may be conducted at the time of examination or at a later date. The examiner generates an examination report detailing complete results of the examination.

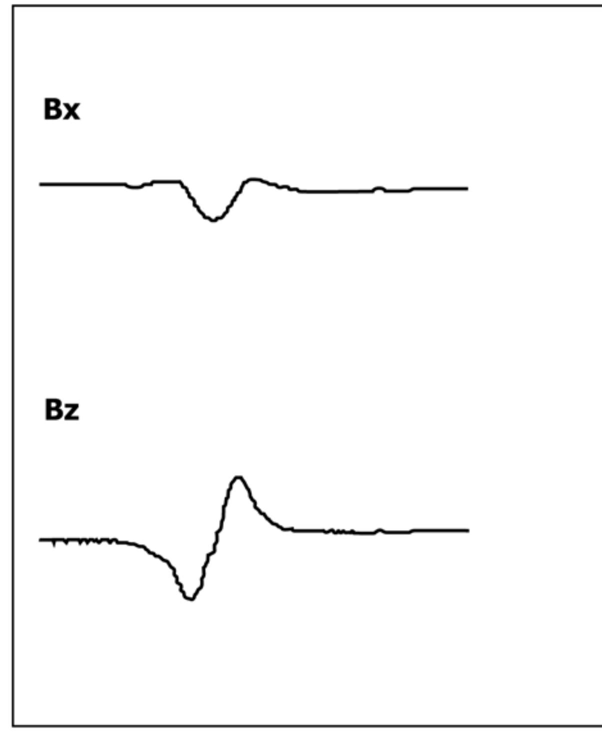

FIG. 1 Example Bx and Bz Traces as a Probe Passes Over a Crack
(The orientation of the traces may differ depending upon the instrumentation.)

5. Significance and Use

5.1 The purpose of the alternating current field measurement method is to evaluate welds for surface breaking discontinuities such as fabrication and fatigue cracks. The examination results may then be used by qualified organizations to assess weld service life or other engineering characteristics (beyond the scope of this practice). This practice is not intended for the examination of welds for non-surface breaking discontinuities.

6. Basis of Application

6.1 *Personnel Qualification:*

6.1.1 If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189 or SNT-TC-1A or a similar document and certified by the employer or certifying agent, as applicable.

The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.2 *Qualification of Nondestructive Evaluation Agencies*—if specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543, with reference to sections on electromagnetic examination. The applicable edition of Practice E543 shall be specified in the contractual agreement.

7. Job Scope and Requirements

7.1 The following items may require agreement by the examining party and their client and should be specified in the purchase document or elsewhere:

7.1.1 Location and type of welded component to be examined, design specifications, degradation history, previous nondestructive examination results, maintenance history, process conditions, and specific types of discontinuities that are required to be detected, if known.

7.1.2 The maximum window of opportunity for work. (Detection of small discontinuities may require a slower probe scan speed, or cleaning of surface, or both, which will affect productivity.)

7.1.3 Size, material grade and type, and configuration of welds to be examined. If required by type of equipment chosen, thickness of coating and variation of coating thickness.

7.1.4 A weld numbering or identification system.

7.1.5 Extent of examination, for example: complete or partial coverage, which welds and to what length, whether straight sections only and the minimum surface curvature.

7.1.6 Means of access to welds, and areas where access may be restricted.

7.1.7 Type of alternating current field measurement instrument and probe; and description of operations referece standard used, including such details as dimensions and material.

7.1.8 Required operator qualifications and certification.

7.1.9 Required weld cleanliness.

7.1.10 Environmental conditions, equipment and preparations that are the responsibility of the client; common sources of noise that may interfere with the examination.

7.1.11 Complementary methods or techniques may be used to obtain additional information.

7.1.12 Acceptance criteria to be used in evaluating discontinuities.

7.1.13 Disposition of examination records and reference standards.

7.1.14 Format and outline contents of the examination report.

8. Interferences

8.1 This section describes items and conditions, which may compromise the alternating current field measurement technique.

8.2 *Material Properties:*

8.2.1 Although there are permeability differences in a ferromagnetic material between weld metal, heat affected zone and parent plate, the probe is normally scanned along a weld toe and so passes along a line of relatively constant permeability. If a probe is scanned across a weld then the permeability changes may produce indications, which could be similar to those from a discontinuity. Differentiation between a transverse discontinuity signal and the weld signal can be achieved by taking further scans parallel to the indication, or using an array probe. The signal from a discontinuity will die away quickly. If there is no significant change in indication amplitude at 0.8 in. [20 mm] distance from the weld then the indication is likely due to the permeability changes in the weld.

8.3 *Magnetic State:*

8.3.1 *Demagnetization*—It must be ensured that the surface being examined is in the non-magnetized state. Therefore the procedure followed with any previous magnetic technique deployed must include demagnetization of the surface. This is because areas of remnant magnetization, particularly where the leg of a magnetic particle examination yoke was sited, can produce loops in the X-Y plot, which may sometimes be confused with a discontinuity indication.

8.3.2 *Grinding marks*—magnetic permeability can also be affected by surface treatments such as grinding. These can cause localized areas of altered permeability across the line of scan direction. The extent and pressure of any grinding marks should always be reported by the probe operator, since these can give rise to strong indications in both Bx and Bz, which may be confused with a discontinuity indication. If a discontinuity is suspected in a region of grinding, further scans should be taken parallel but away from the weld toe and perpendicular across the region of grinding. The indication from a linear discontinuity will die away quickly away from the location of the discontinuity so that the scan away from the weld toe will be flatter. If there is no significant change in indication amplitude at 0.80 in. [20 mm] distance from the weld then the indication is likely due to the effect of the grinding. The indication from a region of grinding will be the same for the perpendicular scan.

8.4 Residual stress, with accompanying permeability variations, may be present with effects similar to those due to grinding, but are much smaller.

8.5 *Seam Welds:*

8.5.1 Seam welds running across the line of scanning also produce strong indications in the Bx and Bz, which can sometimes be confused, with a discontinuity indication. The same procedure is used as for grinding marks with further scans being taken away from the affected area. If the indication remains constant then it will not have been produced by a linear discontinuity.

8.6 *Ferromagnetic and Conductive Objects:*

8.6.1 Problems may arise because of objects near the weld that are ferromagnetic or conductive which may reduce the sensitivity and accuracy of discontinuity characterization when they are in the immediate vicinity of the weld.

8.7 *Neighboring Welds:*

8.7.1 In areas where welds cross each other, there are indications, which may be mistaken for discontinuities. (See 8.5.)

8.8 *Weld Geometry:*

8.8.1 When a probe scans into a tight angle between two surfaces the Bx indication value will increase with little change in the Bz value. In the representative plot of Fig. 2, this appears as a rise in the X-Y plot. If the equipment is capable of measuring lift-off, the lift-off will also change.

8.9 *Crack Geometry Effects:*

8.9.1 *A discontinuity at an angle to the scan*—a discontinuity at an angle to the scan will reduce either the peak or the trough of the Bz as the sensor probe only passes through the edge of one end of the discontinuity. This produces an asymmetric X-Y plot. Additional scans may be made along the weld or parent plate to determine the position of the other end of the discontinuity.

8.9.2 *A discontinuity at an angle to the surface*—the effect of a discontinuity at a non-vertical angle to the probe is generally to reduce the value of the Bz signal. The value of the Bx signal will not be reduced. This has the effect of reducing the width of the X-Y plot in the representative plot of Fig. 2.

8.9.3 *Line contact or multiple discontinuities*—when contacts occur across a discontinuity then minor loops occur within the main X-Y plot loop produced by the discontinuity. If more than one discontinuity occurs in the scan then there will be a number of loops returning to the background.

8.9.4 *Transverse discontinuities*—if a transverse discontinuity occurs during the scan for longitudinal discontinuities then the Bx may rise instead of falling and the Bz signal will remain the same as for a short longitudinal discontinuity. The X-Y plot will then go upwards instead of down in the representative plot of Fig. 2. This flux leakage effect is, however, related to the opening of the discontinuity, so it may not be seen for tightly closed discontinuities. To confirm the presence of transverse discontinuities, further scans should be made with the probe orientated to give an induced field perpendicular to the weld, or through use of an array probe with twin fields.

8.9.5 Alternating current field measurement end effect - the field from the standard weld probe is able to propagate around the end of a weld and this can result in sloping changes in the Bx and Bz traces. A discontinuity indication may be obscured or distorted if the discontinuity or any active probe element is close to the weld end. The distance over which this effect occurs depends on probe type, but can be up to 2 in. [50 mm] for large probes. Smaller probes should be used in these situations as they have less susceptibility to edge effect.

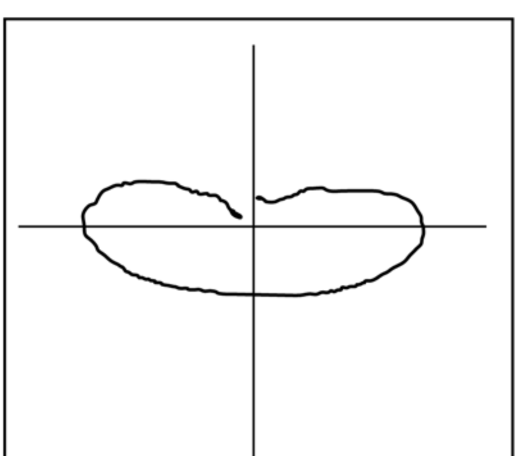

FIG. 2 Example X-Y Plot Produced by Plotting the Bx (vertical) and Bz (horizontal) Together
(The orientation of the plot may differ depending upon the instrumentation.)

8.10 *Instrumentation:*

8.10.1 The operator should be aware of indicators of noise[4], saturation or signal distortion particular to the instrument being used. Special consideration should be given to the following concerns:

8.10.1.1 The excitation frequency of operation should be chosen to maximize discontinuity sensitivity whilst maintaining acceptable noise levels.

8.10.1.2 Saturation of electronic components is a potential problem in alternating current field measurement because signal amplitude can increase rapidly as a probe is scanned into tight angle geometry. This could cause the Bx indication to rise above the top of the range of the A/D converter in the instrument. Data acquired under saturation conditions is not acceptable and appears as a flattening of the Bx response in the representative plots of Fig. 1 at the maximum possible signal value. If saturation conditions are observed, the equipment gain should be reduced until the Bx value no longer appears to saturate and the inspection repeated. After adjusting the equipment gain, an equipment operation check as described in 11.2 is recommended, except that the loop size will be smaller. Note that this gain adjustment does not affect the discontinuity sizing capability.

8.10.2 *Instrument-induced Phase Offset*—The measurements of magnetic field are at a chosen and fixed phase so that unlike during conventional eddy current examination the phase angle does not need to be considered. The phase is selected at manufacture of the probes and is stored in the probe file and is automatically configured by the instrument.

8.11 *Coating Thickness*

8.11.1 If a coating thickness exceeds the specified range for uncompensated operation then the discontinuity size estimation must compensate for the coating thickness. This can be accomplished by manually entering a coating thickness and using discontinuity tables in the system software. Otherwise, using the wrong coating thickness would reduce the depth sizing accuracy. Alternatively, the compensation may be performed automatically if the equipment measures the stand-off distance or coating thickness during the scanning process.

9. Alternating Current Field Measurement System

9.1 *Instrumentation*

9.1.1 The electronic instrumentation shall be capable of energizing the exciter at one or more frequencies appropriate to the weld material. The apparatus shall be capable of measuring the Bx and Bz magnetic field amplitudes at each frequency. The instrument will be supplied with a portable personal computer (PC) that has sufficient system capabilities to support the alternating current field measurement software, which will be suitable for the instrument and probes in use and the

[4] Nearby welding activities or cell phones may be a major source of interference.

examination requirements. The software provides control of the instrumentation including set-up, data acquisition, data display, data analysis and data storage. The software provides algorithms for sizing the discontinuities. (See 11.2.2) The software runs on the PC and, on start up, all communications between the PC and the instrument are automatically checked. When the software starts up it automatically sets up the instrument connected in the correct mode for alternating current field measurement examination. Configuration data for each probe is stored on the PC and is transmitted to the instrument whenever a probe is selected or changed. For non-magnetic materials, if configuration data is not available from the equipment manufacturer, a standardization may be performed on reference blocks prior to the material examination. Equipment operation is also checked by scanning over a reference standard. (See 11.2.2) Once the instrumentation is set up for a particular probe, the software can be used to start and stop data acquisition. During data acquisition at least two presentations of the data are presented on the PC screen in real time. (See 4.1). Data from the probe is displayed against time (with Fig. 1 as an example) and also as an X-Y plot (with Fig. 2 as an example). The data from the probe can also be displayed against position (see Fig. 1) if an encoder is used with the probe. Depending upon equipment type, manual or automatic position markers may be incorporated with the data. Once collected the data can be further analyzed offline using the software to allow, for example, discontinuity sizing (see 11.2.2) or annotation for transfer to examination reports. The software also provides facilities for all data collected to be electronically stored for subsequent review or reanalysis, printing or archiving.

9.2 *Driving Mechanism:*

9.2.1 When a mechanized system is in operation, a mechanical means of scanning the probe, or probes in the form of an array, along a weld or surface area at approximately constant speed may be used.

9.3 *Probes:*

9.3.1 The probes selected should be appropriate for the form of examination to be carried out dependent on length of weld, geometry, size of detectable discontinuity and surface temperature.

9.3.1.1 *Standard weld probe*—commonly used for weld examination whenever possible as it has its coils positioned ideally for discontinuity sizing.

9.3.1.2 *Tight access probe*—designed specifically for occasions where the area under examination is not accessible with the standard weld probe. It is not as accurate as the weld probe for sizing in open geometries such as butt welds.

9.3.1.3 *Grind repair probe*—designed for the examination of deep repair grinds. It has the same basic geometry as a standard probe but is more susceptible to produce indications from vertical probe movement.

9.3.1.4 *Mini-probe*—designed for restricted access areas such as cut outs and cruciforms and has a reduced edge effect. It may be limited to shallow discontinuities only and is more sensitive to lift off. This probe may be in the form of a straight entry or 90°.

9.3.1.5 *Micro-probe*—designed for high-sensitivity discontinuity detection in restricted access areas and has the same limitations as a mini-probe. This probe may be in the form of a straight entry or 90°.

9.3.1.6 *Array probe*—made up of a number of elements; each element is sensitive to a discrete section of the weld width. The elements may be oriented with their axes aligned longitudinally or transversely with respect to the weld toe. The array probe may have two orthogonal field exciters to allow examination for longitudinal and transverse discontinuities in a single scan. The array probe is generally used either for scanning a weld cap in one pass or for covering a section of plate.

9.3.1.7 *Edge effect probe*—designed to reduce the edge effect when carrying out examination only near the ends of welds. (A mini probe may also be used for the same examination.)

9.4 *Data Displays:*

9.4.1 The data display should include Bx and Bz indications as well as an X-Y plot.

9.4.2 When multi-element array probes are being used, the facility to produce color contour maps or 3D-wire frame plots representing peaks and troughs should be available.

9.5 *Excitation Mechanism:*

9.5.1 The degree of uniformity of the magnetic field applied to the material under examination is determined by the equipment manufacturer. Representative magnetic field distributions are a uniform magnetic field and a graduated magnetic field. The geometry of the slots used in the operation reference standard and the discontinuity sizing model must be consistent with the excitation field.

10. Alternating Current Field Measurement Reference Standards

10.1 *Artificial Slots for the Operation Reference Standard:*

10.1.1 The operation reference standard has specific artificial discontinuities. It is used to check that the instrument and probe combination is functioning correctly. It may also be used for standardization of the equipment for nonmagnetic materials. Unless otherwise specified by the client or equipment manufacturer, the artificial discontinuities for the operation reference standard are elliptical or rectangular slots. The slot geometry will be specified by the equipment manufacturer to be consistent with the crack size estimation model. Typical slot dimensions are as follows:

10.1.1.1 *Elliptical Slots*—Two elliptical slots placed in the weld toe with dimensions 2.0 in. × 0.2 in. [50mm × 5mm] and 0.8 in. × 0.08 in. [20 mm × 2 mm]. (Fig. 3, discontinuities A and B.)

10.1.1.2 *Rectangular Slots*—Three rectangular slots with depth 0.08 in. [2 mm] and lengths of 0.4 in. and 0.8 in. [10 mm and 20 mm] (Fig. 3, discontinuities C and D) and with depth 0.16 in. [4 mm] and length of 1.6 in. [40 mm] (Fig. 3, discontinuity E.)

10.1.2 These slots shall be less than 0.008 in. [0.2 mm] wide.

10.1.3 Artificial discontinuity depths are specified by giving the deepest point of the discontinuity. Discontinuity depths

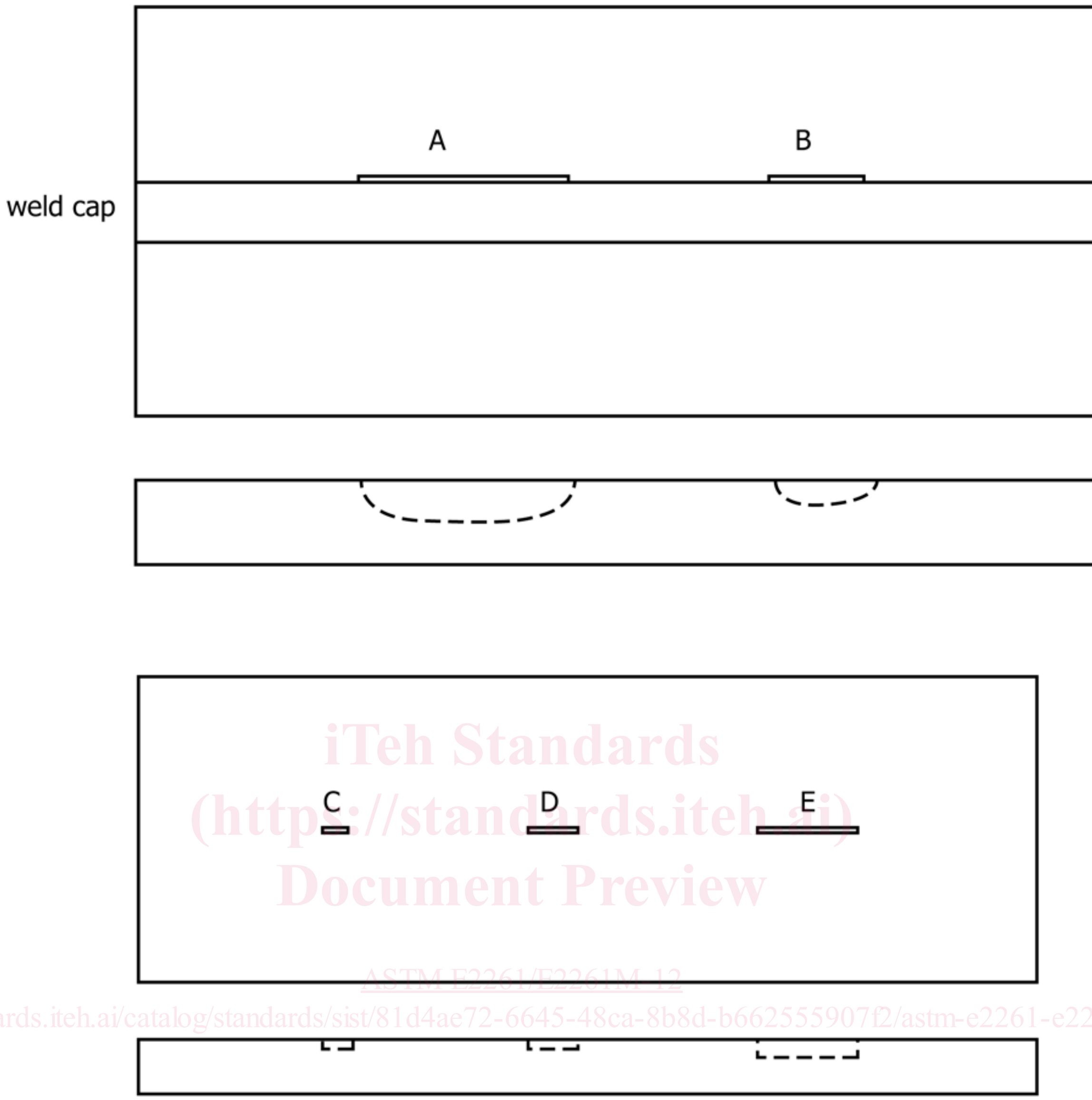

FIG. 3 Flat Plate Sample Serial Number XXX Showing Size and Location of Reference Slots (Plan View and Side View. Not to Scale)

shall be accurate to within ±10% of the depth specified, measured, and documented. The discontinuity length shall be accurate to within ±0.040 in. [±1.00 mm] of the dimension specified.

10.2 Reference standards having artificial or simulated discontinuities are not required for standardization when the technique is to be used to examine carbon steel welds or if configuration data is available for the examination material.

10.3 *Materials other than carbon steel:*

10.3.1 If the technique is to be used on materials other than carbon steel, then it may be necessary to standardize the probes on this material if configuration data is not available from the equipment manufacturer, refer to manufacturer's instructions.

NOTE 2—If this is not done then the sizes of the indications may be too small (so that small discontinuities may be missed) or too large (so that spurious indications may be called), or the Bx indication may saturate making the examination invalid. This standardization is done using a slot of reasonable size located at a weld toe of a representative sample. The gain settings are altered, either automatically or manually according to equipment type, until a loop of reasonable size is produced in the X-Y plot while background noise indications are kept low. When the technique is to be used to size the depths of discontinuities detected in material for which configuration data is unavailable, then a reference standard should be manufactured from the material with at least two slots of differing depth. This provides an adjustment coefficient that modifies the estimated depth from the sizing model.

10.4 Reference standards having artificial or simulated discontinuities for welds in materials other than carbon steel shall not be used for discontinuity characterization unless the signals from the artificial discontinuities can be demonstrated to be similar to the signals for discontinuities detected. To be considered similar, a direct comparison should be performed between responses to the simulated discontinuities and real cracks. This comparison should involve at least one limited sizing trial or a probability of detection (POD) study.

10.5 *Manufacture and Care of the Operation Reference Standards:*