Designation: E 2261 – 03

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

This standard is issued under the fixed designation E 2261; 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 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.

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:*

E 543 Practice for Agencies Performing Nondestructive Testing[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASNT Standard:*[3]

SNT-TC-1A Personnel Qualification in Nondestructive Testing

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

3. Terminology

3.1 General definitions of terms used in this practice can be found in Terminology E 1316, Section A, Common NDT terms, and Section C, Electromagnetic testing.

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, 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. The field is uniform on the surface but the strength decays exponentially with depth.

3.2.4 *alternating current field measurement*—a nondestructive examination technique that measures changes in an applied AC uniform magnetic field to detect and characterize discontinuities.

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 standardization block*—a reference standard with specified artificial slots, used to confirm the operational parameters and to indicate discontinuity detection sensitivity.

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 weld toe, the magnitude of which is proportional to the curvature of the current in the x-y plane.

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

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. These plot one component of magnetic field over an area, typically as a color contour plot or 3-D wire frame plot.

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[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 Methods.

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[2] *Annual Book of ASTM Standards*, Vol **03.03**.

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

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

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 uniform alternating current to flow across the weld, orthogonal to the toe. 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 0.4 in. [10 mm] of either side of the scan line at this location will interrupt or disturb the flow of the otherwise uniform electromagnetic field. 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 predicted 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.

4.2 Standardization data and instrument settings for each individual probe are determined at the factory and stored in a computer file, which is loaded at the start of the examination. System sensitivity is verified using an operation standardization block. System sensitivity 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, that is, greater than 0.04 in. [1 mm] is present then the discontinuity size prediction must compensate for the coating thickness. This can be accomplished using discontinuity-sizing tables in the system software. Using the wrong coating thickness would have a negative effect on depth sizing accuracy if the discrepancy was 0.04 in. [1 mm] or more. As the current flow is arranged normal to the weld toe there is no perturbation in that direction so that no indication occurs at the interface due to changes in permeability. 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.

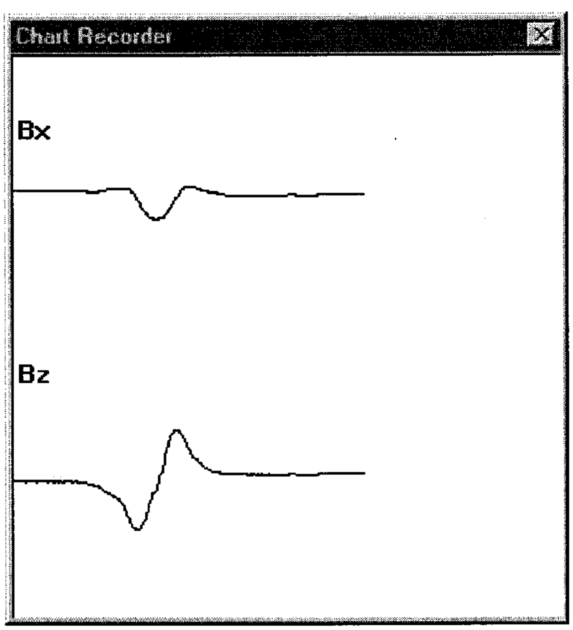

FIG. 1 Typical Bx and Bz Traces as a Probe Passes Over a Crack

5. Significance and Use

5.1 The purpose of the alternating current field measurement method is to evaluate welds in the area of the toe for surface breaking discontinuities such as 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).

5.2 *Comparison with Conventional Eddy Current Examination*—conventional eddy current coils are typically configured to sense the field from the weld in the immediate vicinity of the emitting element, whereas alternating current field measurement probes are typically designed to sense the magnetic field from the weld distant from the exciter.

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 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 E 543, with reference to sections on electromagnetic examination. The applicable edition of Practice E 543 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, which will affect productivity.)

7.1.3 Size, material grade and type, and configuration of welds to be examined.

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 standardization block 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 material 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 discontinuity. 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. 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.

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

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. This will cause the X-Y plot to rise.

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 un-equal sided 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.

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 will 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.

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.

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 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.

8.10.2 *Instrument-induced Phase Offset*—the measurements of magnetic field are at a chosen and fixed phase so that unlike during 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 thick coating, that is, greater than 0.04 in. [1 mm] is present then the discontinuity size prediction must compensate for the coating thickness. This can be accomplished using discontinuity tables in the system software. Using the wrong coating thickness would reduce the depth sizing accuracy if the discrepancy was 0.04 in. [1 mm] or more.

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 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. The set up data for each probe is stored on the PC and is transmitted to the instrument whenever a probe is selected or changed. (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 and also as an X-Y plot. 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 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.

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

10. Alternating Current Field Measurement Weld Standards

10.1 Weld standards are not required when the technique is to be used to examine carbon steel welds.

10.2 *Materials other than carbon steel*:

10.2.1 If the technique is to be used on other material then it may be necessary to standardize the probes on this material as many of the probes are only standardized by the equipment manufacturer for use with carbon steel. 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 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 other than carbon steel, then a standardization block should be manufactured from the material with at least three elliptical slots of differing depth. This should be used to produce a standardization curve of actual depths versus the predicted depths from the carbon steel software model.

10.3 Reference weld standards for materials other than steel shall not be used for discontinuity characterization unless the artificial discontinuities can be demonstrated to be similar to the discontinuities detected.

10.4 *Typical Artificial Discontinuities in Discontinuity Characterization Standards.*

10.4.1 *Elliptical slots*—slots of different depths typically 0.08 in. and 0.2 in. [2 mm and 5 mm] deep as used in the operation standardization block may be used as a quality check and also for the production of new probe files. If the material is other than carbon steel then these slots may be used in the production of standardization curves. These slots should be less than 0.02 in. [0.5 mm] wide.

10.5 *Reference Standards*:

10.5.1 Discontinuity depths are specified by giving the deepest point of the discontinuity. Discontinuity depths shall be measured and accurate to ±0.010 in. [±0.25 mm] of the depth specified. All other discontinuity dimensions (such as length) shall be accurate to within ±0.040 in. [±1.00 mm] of the dimension specified.

10.6 *Artificial Slots for the Operation Standardization Block*:

10.6.1 The operation standardization block has specific artificial discontinuities. It is used to check that the instrument and probe combination is functioning correctly. Unless otherwise specified by the client, the artificial discontinuities for the operation standardization block are as follows:

10.6.1.1 *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. 2, discontinuities A and B.)

10.7 *Manufacture and Care of the Operation Standardization Blocks and Non-carbon Steel Weld Standards*:

10.7.1 *Drawings*—for each operation standardization block and standard, there shall be a drawing that includes the as-built measured slot dimensions, material type and grade, and the serial number of the actual operation standardization block or weld standard.

10.7.2 *Serial Number*—each operation standardization block or weld standard shall be identified with a unique serial number and stored so that it can be obtained and used for reference when required.

10.7.3 *Slot Spacing*—artificial slots should be positioned longitudinally to avoid overlapping of indications and interference from end effects.

10.7.4 Proper machining practices shall be used to avoid excessive cold-working, over-heating, and undue stress and permeability variations.

10.7.5 Blocks should be stored and shipped so as to prevent mechanical damage.

11. Equipment Performance Check

11.1 *Instrument Settings*:

11.1.1 *Operating Frequency*—using the appropriate operation standardization block the procedure in 11.2.2 below is intended to help the user select an operating frequency. Demonstrably equivalent methods may be used. The standard operating frequency is 5 kHz, but depending on which equipment is being used then higher or lower operating frequencies are available. A higher operating frequency will give better sensitivity on good surfaces. If the system available is not capable of operating at the frequency described by this

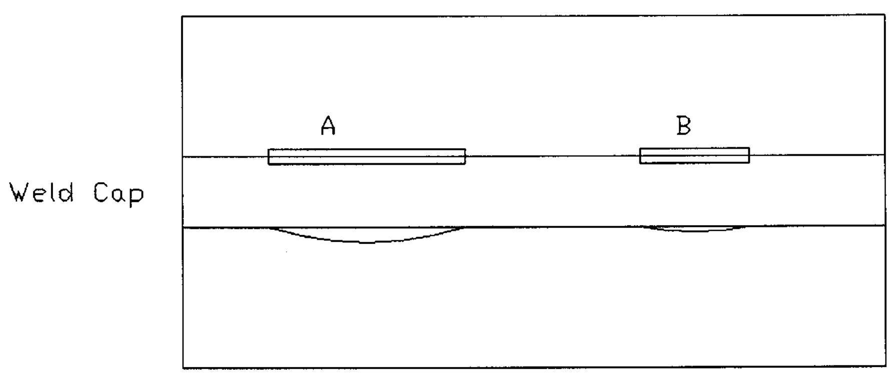

FIG. 2 Flat Plate Sample Serial Number XXX Showing Size and Location of Semi-Elliptical Slots (Plan View and Side View. Not to Scale)

practice, the inspector shall declare to the client that conditions of reduced sensitivity may exist.

11.2 *Test System Check and Procedure*:

11.2.1 The test system shall consist of an alternating current field measurement instrument, the PC, the probe and the operation standardization block.

11.2.2 The equipment performance check will be performed using the appropriate operation standardization block containing slots of 2.0 in. × 0.20 in. [50 mm × 5 mm] and 0.8 in. × 0.08 in. [20 mm × 2 mm]. The probe is placed at the toe of the weld with the nose of the probe parallel to the longitudinal direction of the weld. The probe is then scanned across the operation standardization block and over the 2.0 in. × 0.2 in. [50 mm × 5 mm] slot producing a standardized data plot. Discontinuity indications are created when (1) the background level Bx value is reduced and then returns to the nominal background level, Fig. 1, and this is associated with (2) a peak or positive (+ve) indication followed by a trough or negative (-ve) indication (or a trough followed by a peak, depending on direction of scan) in the Bz values. The resultant effect of the changes in Bx and Bz is a downward loop in the X-Y plot, Fig. 3. The presence of a discontinuity is confirmed when all three of these indications are present, that is, the Bx, the Bz and a downward loop in the X-Y plot. The loop should fill approximately 50 % of the height and 175 % of the width of the X-Y plot. The scanning speed or data sampling rate can then be adjusted if necessary, depending on the length and complexity of weld to be examined.

11.2.2.1 Once the presence of the discontinuity has been confirmed by the Bx and Bz indications the discontinuity should be sized.

11.2.2.2 Discontinuity sizing is performed in the examination software and uses look-up tables of expected responses versus discontinuity sizes. These tables can be based upon mathematical models that simulate the current flow around the discontinuities and the resultant change in surface magnetic field by running the model for a large number of discrete discontinuities with various lengths and depths. The operator enters background and minimum values of Bx along with the Bz length and any coating thickness to allow the software to predict discontinuity length and depth. The results from the model must be checked against a library of real discontinuities to confirm the validity of the sizing tables.

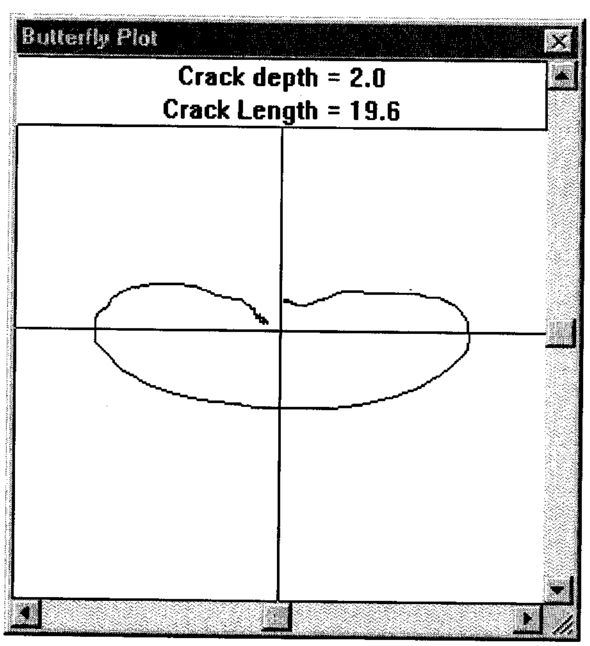

FIG. 3 Typical X-Y Plot Produced by Plotting the Bx and Bz Together

11.2.2.3 If these values differ from those expected from the operation standardization block then the instrument and probe settings should be checked. Each probe should have a unique probe file, the validity of which has been checked against the discontinuity sizing tables. The instrument settings can be checked using the software package.

11.2.3 Each combination of alternating current field measurement unit and probe to be used during the examination should be used with the operations standardization block. Results obtained with these combinations should be the same as the slots in the block. If they differ by more than 10 %, check that the correct probe files and gain have been used. If the correct probe files and gain have been used then there is a fault with the system, which will have to be determined. Do not use for examination unless standardization validity is confirmed within 10 %.

11.3 *Frequency of Systems Check*:

11.3.1 The system should be checked with all of the probes to be used during the examination prior to examining the first weld.

11.3.2 System performance should be checked at least every four hours with the probe in use or at the end of the examination being performed. If the discontinuity responses from the operation standardization block have changed by 10 %, the welds examined since the last operations standardization block check shall be re-examined after following the procedure in 11.2.3.

12. Examination Procedure

12.1 If necessary, clean the weld surface to remove obstructions and heavy ferromagnetic or conductive debris.

12.2 Following the guidelines in 9.3, select a suitable probe for the examination task, then, using the installed software, select a data file and a probe file.

12.2.1 The probe is placed at the toe of the weld with the nose of the probe parallel to the longitudinal direction of the weld.

12.2.2 The probe is then scanned along the weld. Discontinuity indications are created when the following three points are indicated:

12.2.2.1 The background level Bx value is reduced and then returns to the nominal background level, Fig. 1.

12.2.2.2 This is associated with a peak, or positive (+ve) indication followed by a trough, or negative (-ve) indication (or a trough followed by a peak, depending on direction of scan) in the Bz values. Fig. 1.

12.2.2.3 The resultant effect of the changes in Bx and Bz is a downward loop in the X-Y plot. Fig. 3.

12.2.3 The presence of a discontinuity is confirmed when all three of these indications are present, that is, the Bx, the Bz and a downward loop in the X-Y plot. The scanning speed or data sampling rate can be adjusted if necessary, depending on the length and complexity of weld to be examined.

12.3 *Compensation for Material Differences*:

12.3.1 To compensate for the small differences in readings caused by variations in permeability, conductivity or geometry for a given material, the data may be centered on the display area.

12.4 *Compensation for Ferromagnetic or Conductive Objects*:

12.4.1 Techniques that may improve alternating current field measurement results near interfering ferromagnetic or conductive objects include:

12.4.1.1 Comparison of baseline or previous examination data with the current examination data.

12.4.1.2 The use of special probe coil configurations.

12.4.1.3 Use of higher or lower frequency probes may suppress non-relevant indications.

12.4.1.4 The use of a complementary method or technique.

12.5 Size and record all discontinuity indications as described in Section 14.

12.6 Note areas of limited sensitivity, using indications from the operation standardization block as an indicator of discontinuity detectability.

12.7 Using a discontinuity characterization standard, evaluate relevant indications in accordance with acceptance criteria specified by the client, if applicable.

12.8 If desired, examine selected areas using an appropriate complementary method or technique to obtain more information, adjusting results where appropriate.

12.9 Compile and present a report to the client.

13. Examination Considerations

13.1 *Scanning Speed*:

13.1.1 The recommended scanning speed is 1 in. [25 mm]/second using the appropriate data sampling rate. This will produce a regular scan on the PC screen. If short welds are to be examined then a faster data sampling rate should be used. If long welds are to be examined and the whole weld needs to be seen on the PC screen then a slower data-sampling rate should be used. The weld length and speed of scanning will govern the data-sampling rate selected. With the introduction of faster software it is possible to select respective data sampling rates to produce faster scanning rates.

13.1.2 Acquire and record data from the operation standardization block at the selected examination speed.

13.1.3 Acquire and record data from the welds to be examined. Maintain as uniform a probe speed as possible throughout the examination to produce repeatable indications.

13.2 *Width of Scan*:

13.2.1 Unless otherwise stated, a non-array probe has a scan width of 0.80 in. [20 mm]. Both toes of the weld should be scanned and if the cap is wider than 0.80 in. [20 mm] an extra scan should be performed along the cap. If the weld cap is narrow, that is, 0.40 in. [10 mm] a central scan only could be performed.

13.3 *Continuous Cracking*:

13.3.1 Prior to the scanning of a weld, checks should be made that the discontinuity is not continuous by scanning the probe from 2 in. [50 mm] away from the weld towards the toe. If a discontinuity is present the Bx indication on the computer screen will dip as the probe approaches the weld toe. If this form of indication occurs then this procedure shall be repeated at intervals along the toe of the weld.

13.4 *Scanning Direction*:

13.4.1 The probe should always be scanned parallel to the weld toe and this will give recognizable indications from longitudinal discontinuities in the weld area. Scanning in this direction will also give recognizable indications from transverse discontinuities and discontinuities inclined to the toe of the weld.

13.5 *Circumferential Welds*:

13.5.1 The scanning pattern for a circumferential weld is shown in Fig. 4. Overlapping scans are required to ensure no discontinuities are missed if they occur at the end of a scan. The number of overlapping scans will vary depending on the component diameter. The overlap should be between 1 in. [25 mm] and 2 in. [50 mm] depending on the diameter of the tube or pipe. All detection shall be complete before any sizing operation is performed. Remember to check for continuous discontinuities before scanning.

13.6 *Linear Welds*:

13.6.1 The scanning pattern is similar for that of circumferential welds except that an edge effect may occur at the end of the weld or if the weld ends at a buttress. In the case of the end of the weld an edge-effect probe should be used but for the buttress a mini- or micro-probe should be used. These probes can also be used as an alternative to the edge effect probe. The standard weld probe should be used for sizing if at all possible.

13.7 *Attachments, corners and cutouts*:

13.7.1 The scanning patterns for the attachment welds and gussets are shown in Fig. 5, Fig. 6, and Fig. 7 where lines A1-A6, B1-B3 and C1 and 2 are the probe scan lines and positions 1-10 are the incremental positions along the weld

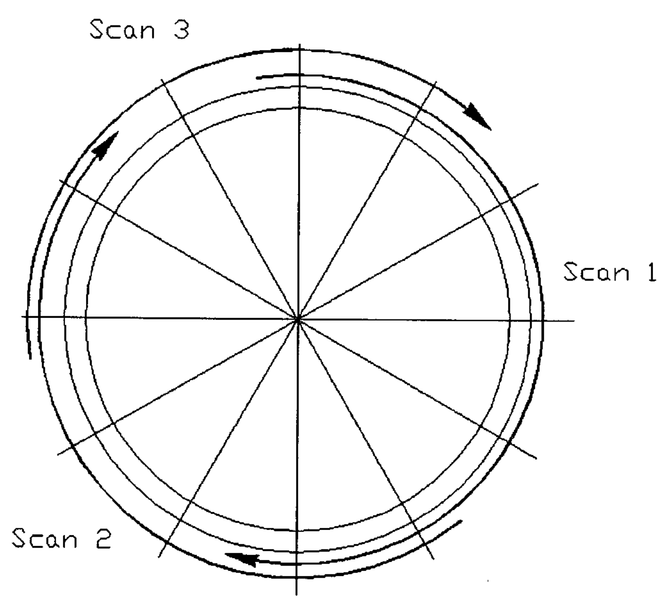

FIG. 4 Scanning Pattern for a Circumferential Weld

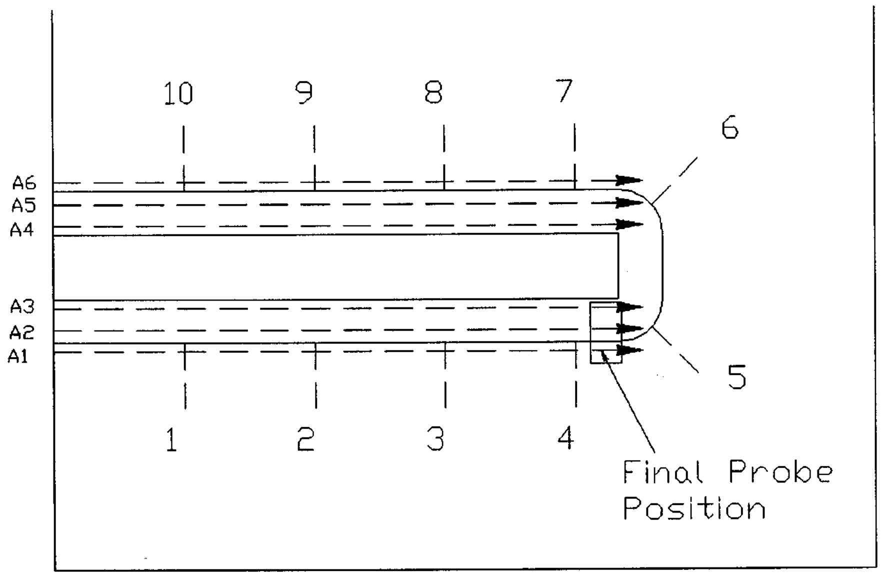

FIG. 5 Scanning Pattern for an Approach to an Attachment

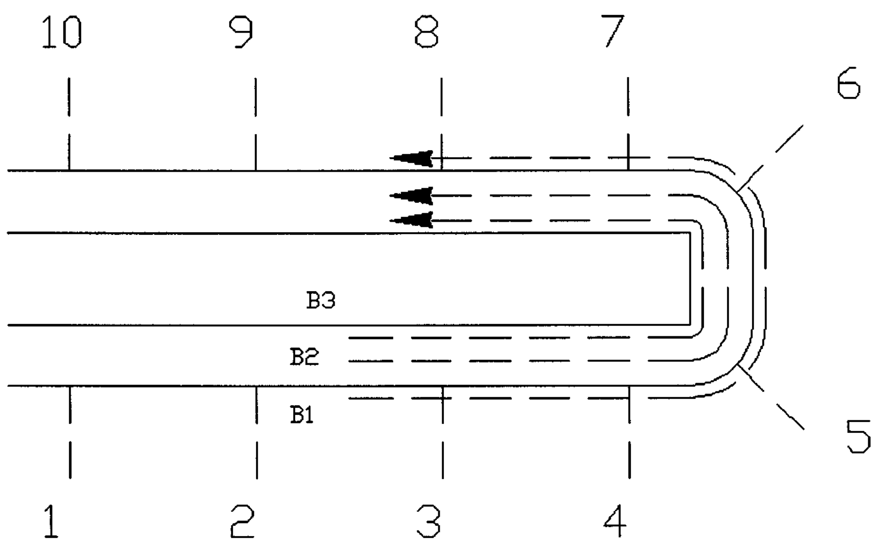

FIG. 6 Scanning Pattern for the End of an Attachment

length. The corners are difficult to scan and the micro- or mini-probes should be used where possible.

13.8 *Cut outs and cruciform geometries*:

13.8.1 The examination of this geometry is difficult due to the access problems; the scanning patterns and identification of the areas are shown in Fig. 8, Fig. 9, Fig. 10 and Fig. 11. The 90° mini- or micro- probe is essential for examining the cut-out areas.

13.9 *Ground-out Areas*:

13.9.1 The repair or groundout area is usually 0.5 in. [12.5 mm] wide, and the grind repair probe is designed for the examination of these areas. The probe should be scanned into one end of the groundout area and the scan continued through the other end. Areas with discontinuities should be noted and sized for length and depth with the grind repair probe.

14. Discontinuity Sizing Procedure

14.1 *Length*:

14.1.1 Once an area containing a discontinuity has been located, a repeat scan is taken commencing 2 in. [50 mm] before the discontinuity and ending 2 in. [50 mm] after the discontinuity. The Bz length of the discontinuity is determined by locating the extreme ends of the discontinuity using the peak (+ve) and trough (-ve) Bz locations on the X-Y plot. Once these positions are identified they will be marked on the weld toe. It should be noted that these positions should be just inside

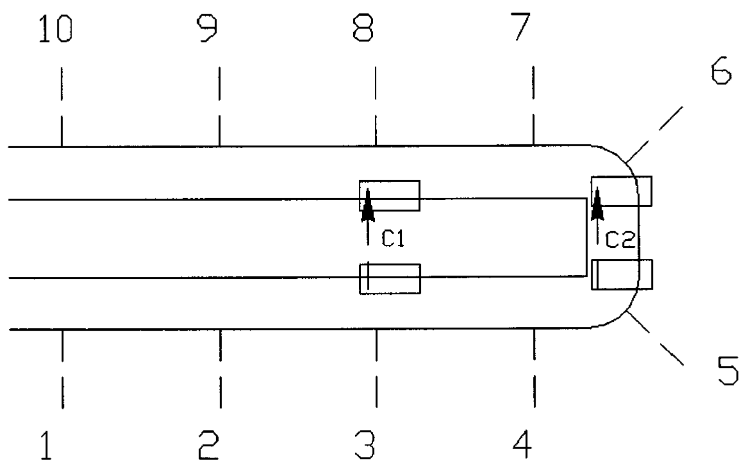

FIG. 7 Scanning Pattern Across an Attachment (Crack in the Toe End)

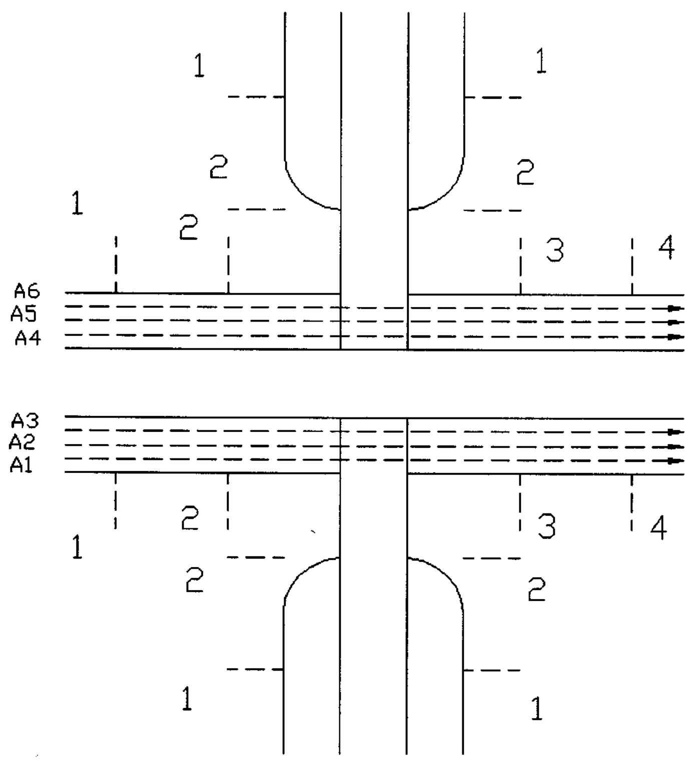

FIG. 8 Scans of the Main Weld

the actual ends of the discontinuity. Measure the distance between the two points - this is known as the Bz length and is not the actual length of the discontinuity. This value is used in the mathematical model to determine the true length and depth of the discontinuity.

14.2 *Depth*:

14.2.1 The depth of the discontinuity is calculated using the Bx minimum and Bx background values and the Bz length of the discontinuity measured from the Bz data. The Bx Minimum and Bx background values are determined from the original detection scan. Once these values have been put into the discontinuity depth table, which is part of the mathematical model, together with the Bz length value and coating thickness, if necessary, then, the discontinuity depth will be calculated using this mathematical model within the dedicated software.

15. Report

15.1 *Reporting Requirements*—a list of reporting requirements is given in Table 1. Reference should be made to the Client reporting requirements (7.1.14). The items listed below

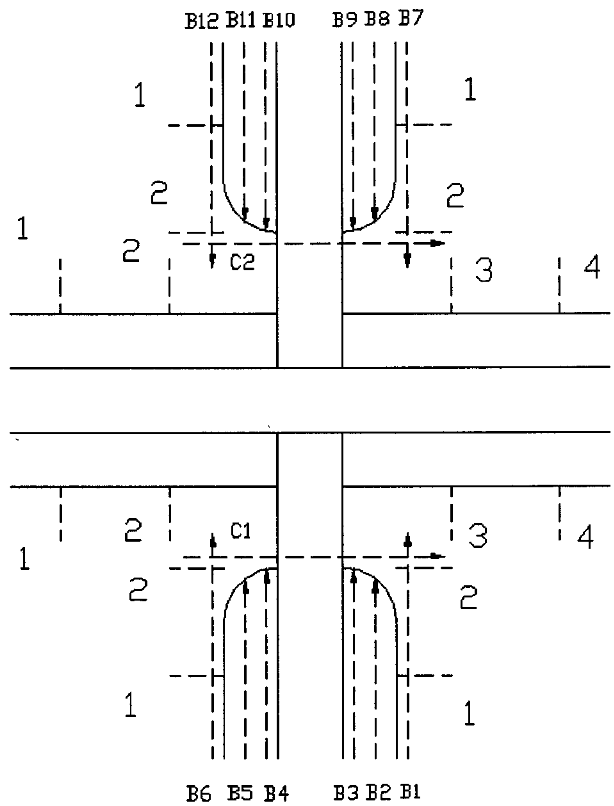

FIG. 9 Scans of the Horizontal Weld into a Cut Out

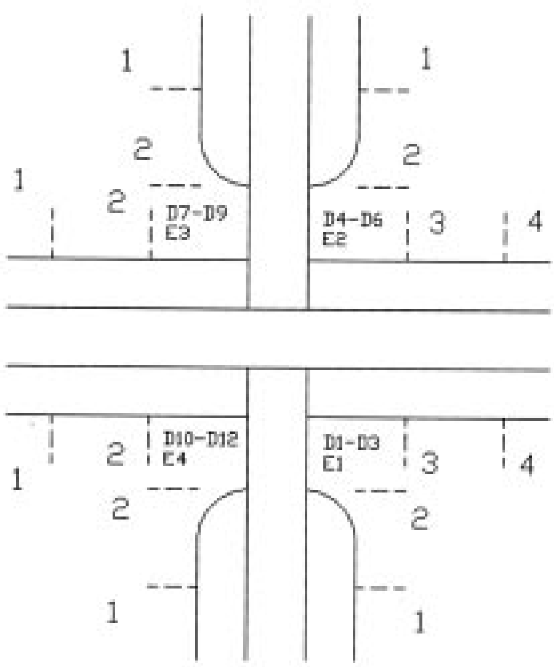

FIG. 10 Nomenclature for Vertical Welds

should be included in the examination report. All information below should be archived, whether or not it is required in the report.

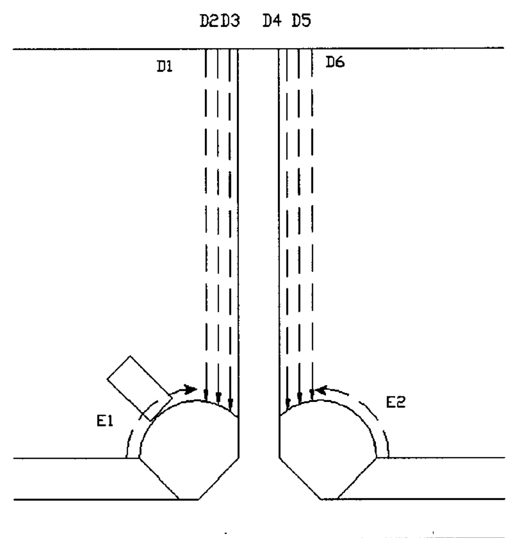

FIG. 11 Scans of Vertical Cut Out Weld and Cut Out Surface

15.1.1 Owner, location, type and serial number of component examined.

15.1.2 Size, material type and grade, and configuration of welds examined.

15.1.3 Weld numbering system.

15.1.4 Extent of examination, for example, areas of interest, complete or partial coverage, which welds, and to what length.

TABLE 1 Reporting Requirements

NOTE 1—The data report sheets generated by the alternating current field measurement examination will be specifically designed with the system and current examination requirements in mind. The essential information contained on a data sheet will include:

General Information
Date
Operators Name
Probe Operator
Component ID Number
File Number
Equipment Used

Scanning Data
Filename
Page Number
Position on Weld
Probe Number
Probe Direction
Tape Position
Examination Summary

Detailed Record of Indications / Anomalies
Filename
Page Number
Position on Weld
Start of Discontinuity (Tape reference)
End of Discontinuity (Tape reference)
Length of Discontinuity (inches/millimetres)
Remarks
Diagram/Drawing of component under examination

15.1.5 The names and qualifications of personnel performing the examination.

15.1.6 Models, types, and serial numbers of the components of the alternating current field measurement system used, including all probes.

15.1.7 For the initial data acquisition from the operation standardization block, a complete list of all relevant instrument settings and parameters used, such as operating frequencies, and probe speed. The list shall enable settings to be referenced to each individual weld examined.

15.1.8 Serial numbers of all of the operations standardization blocks used.

15.1.9 Brief outline of all techniques used during the examination.

15.1.10 A list of all areas not examinable or where limited sensitivity was obtained. Indicate which discontinuities on the operations standardization block would not have been detectable in those regions. Where possible, indicate factors that may have limited sensitivity.

NOTE 1—Factors which influence sensitivity to discontinuities include but are not limited to: operating frequency, instrument noise, instrument filtering, digital sample rate, probe speed, coil configuration, probe travel noise and interference described in Section 8.

15.1.11 Specific information about techniques and depth sizing for each discontinuity.

15.1.12 Acceptance criteria used to evaluate discontinuities.

15.1.13 A list of discontinuities as specified in the purchasing agreement.

15.1.14 Complementary examination results that influenced interpretation and evaluation.

15.2 Record data and system settings in a manner that allows archiving and later recall of all data and system settings for each weld. Throughout the examination, data shall be permanently recorded, unless otherwise specified by the client.

15.2.1 *Report form*. A typical report form using the dedicated software is shown in Table 2.

16. Keywords

16.1 alternating current field measurement; electromagnetic examination; ferromagnetic weld; non-conducting material; weld

TABLE 2 Alternating Current Field Measurement Report Form

<table>
<tr><td>Date:
Time:</td><td>Location:</td><td rowspan="5">Sketch of geometry:</td></tr>
<tr><td>Operator:</td><td>Probe Op:</td></tr>
<tr><td colspan="2">Component ID:</td></tr>
<tr><td colspan="2">Summary of discontinuities:</td></tr>
<tr><td colspan="2">Filename:</td></tr>
<tr><td colspan="2">Probe Number:</td><td>Probe File:</td></tr>
</table>

Distance from Datum	Direction of travel	Weld Position	Page	Examination report/ comments