Designation: ~~E2928/E2928M – 17~~ E2928/E2928M – 23

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

This standard is issued under the fixed designation E2928/E2928M; 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 reappproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ Scope*

1.1 This practice describes procedures to be followed during alternating current field measurement examination of drillstring threads on tubulars used for oil and gas exploration and production for detection and, if required, sizing of service-induced surface breaking discontinuities transverse to the pipe.

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

1.3 This practice does not establish acceptance criteria. Typical industry practice is to reject these connections on detection of a confirmed crack.

1.4 While the alternating current field measurement technique is capable of detecting discontinuities in these connections, supplemental surface NDT methods such as magnetic particle testing for ferrous metals and penetrant testing for non-ferrous metals may detect ~~more~~additional discontinuities.

1.5 *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~~ both systems may result in nonconformance with the standard.

1.6 *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~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing
E1316 Terminology for Nondestructive Examinations
E2261 Practice for Examination of Welds Using the Alternating Current Field Measurement Technique

[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.

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

~~2.2 *ASNT Standards*[3]~~
~~SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing~~
~~ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel~~

~~2.3 *ISO Standard:*[4]~~
~~ISO 9712 Non-Destructive Testing: Qualification and Certification of NDT Personnel~~

3. Terminology

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

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

3.2.3 *uniform* ~~*field—*~~*field, n—*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 ~~testpiece~~ test piece and is observable beyond the direct coupling of the exciting coil.

3.3 *Definitions of Terms Specific to This Standard:*

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

3.3.2 ~~*box—*~~*box, n—*the female thread in a drillstring connection.

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

3.3.4 ~~*Bz—*~~*Bz, n—*the z component of the magnetic field normal to the examined pipe surface, the magnitude of which is proportional to the lateral deflection of the induced currents in the plane of that surface.

3.3.5 *configuration* ~~*data—*~~*data, n—*standardization data and instrumentation settings for a particular probe stored in a computer ~~file.~~ file or device memory.

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

3.3.7 ~~*longitudinal—*~~*longitudinal, adj—*following from the above definition, a longitudinal discontinuity is parallel to the pipe axis and therefore perpendicular to the scan direction.

3.3.8 *operational standardization* ~~*block—*~~*block, n—*a reference standard with specified artificial notches, used to confirm the operation of the system.

3.3.9 ~~*pin—*~~*pin, n—*the male thread in a drillstring connection.

3.3.10 *satellite* ~~*signals—*~~*signals, n—Bx* and *Bz* signals observed when the probe passes a discontinuity in an adjacent thread root.

3.3.11 *surface* ~~*plot—*~~*plot, n—*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.

3.3.12 *time base* ~~*plots—*~~*plots, n—*these plot the relationship between *Bx* or *Bz* values with time.

3.3.13 ~~*transverse—*~~*transverse, adj—*as is normal in drilling, the terms transverse and longitudinal are defined in reference to the pipe axis. Therefore, a transverse discontinuity is parallel to the thread and hence to the scan direction. This is different to the situation for weld inspection, covered in Guide E2261.

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

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 ~~Practices~~Practice

4.1 In a basic alternating current field measurement system, a small probe is moved around the thread root. The probe contains an exciter coil, which induces an AC magnetic field in the material surface aligned to the direction of the thread root. This, in turn, causes alternating current to flow across the threads. 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~~ferromagnetic materials and 0.08 to 0.3 in. [2 to 7 mm] deep in ~~non-ferrous~~non-ferromagnetic 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. 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 the values of these quantities or the physical locations of key points, or both, 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 thread may be detected (in ferritic metals only) by the flux leakage effect.

4.2 Configuration data is loaded at the start of the examination. System sensitivity and operation is verified using an operation standardization block. System operation is checked and recorded prior to and at regular intervals during the examination. This can be accomplished using discontinuity-sizing tables in the system software. Data is recorded in a manner that allows archiving and subsequent recall for each thread. 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.

5. Significance and Use

5.1 The purpose of the alternating current field measurement method is to evaluate threads for surface breaking discontinuities such as fatigue cracks running along the thread root. The examination results may then be used to determine the fate of the ~~tool.~~

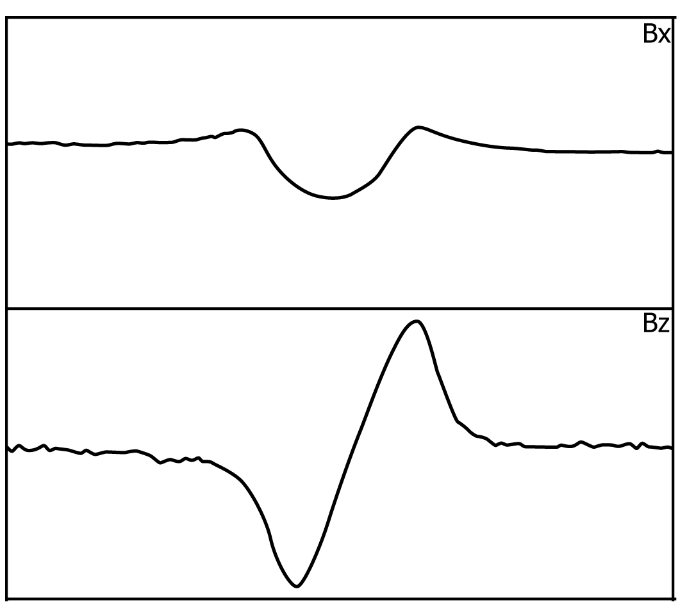

FIG. 1 Example *Bx* and *Bz* Traces as a Probe Passes Over a Crack (The orientation of the traces may differ depending upon the instrumentation.)

test piece. This may involve re-examination by an alternative technique, immediate scrapping of the ~~tool,~~ test piece, or reworking to remove discontinuities (beyond the scope of this practice). This practice is not intended for the examination of threads for non-surface breaking discontinuities.

6. Basis of Application

6.1 *Personnel Qualification*—~~if~~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, SNT-TC-1A, ISO 9712, 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 Specification E543, with reference to sections on electromagnetic examination. The applicable edition of Specification 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 threaded 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 recommended probe scan speed is to be stated by the manufacturer. However, detection of smaller discontinuities requires a slower probe scan speed or cleaning of surface, or both.

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

7.1.4 A thread numbering or identification system.

7.1.5 Extent of examination, for example: complete or partial coverage, which threads and to what extent.

7.1.6 Type of alternating current field measurement instrument and probe; and description of operations standardization block used, including such details as dimensions and material.

7.1.7 Required thread cleanliness.

7.1.8 Environmental conditions, equipment and preparations that are the responsibility of the client; common sources of noise that may interfere with the examination, such as motor drive for rotary table.

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

7.1.10 Acceptance criteria to be used in evaluating discontinuities.

7.1.11 Disposition of examination records and reference standards.

7.1.12 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 unlikely to be permeability differences in a ferromagnetic material between different parts of a thread, if a probe is scanned across a permeability change such as an area of residual magnetism, this may produce indications which could be similar to those from a discontinuity. Differentiation between a discontinuity signal and a permeability change signal can be achieved by comparing scans from neighboring threads. The signal from a discontinuity will die away quickly. If there is no significant change in indication amplitude two or more threads away along the pipe axis then the indication is likely due to the permeability changes in the component.

8.3 *Magnetic State:*

8.3.1 *Demagnetization*—It must be ensured that the surface being examined is in a low magnetization state, or that any magnetization is uniform over the surface. Therefore the procedure followed with any previous magnetic technique deployed must include demagnetization of the surface, or ensuring that connections are magnetically saturated. 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.

8.4 *Thread Geometry:*

8.4.1 When a probe scans away from the shoulder of a pin connection, the *Bx* indication value will decrease with little change in the *Bz* value. In the representative plot of Fig. 2, this appears as a drop in the X-Y plot. The *Bx* indication value will also decrease as a probe approaches the open end of a thread (pin or box).

8.5 *Crack Geometry Effects:*

8.5.1 Since the effect of a discontinuity on the signals can be detected some distance away, "satellite" signals are observed as the probe passes one thread (or two threads) away from a sufficiently-large discontinuity. The satellite signals will be smaller than the main discontinuity signal, and symmetrically spaced one thread revolution either side. Care should be taken not to classify these signals ~~as additional~~ in adjacent threads as discontinuities.

8.5.2 A large discontinuity may jump across a thread crown from one root to the neighboring one. This causes a sudden rise in *Bx* signal where the discontinuity leaves the root, and a sudden decrease in *Bx* signal at the same place in the neighboring thread where the discontinuity enters the root.

8.5.3 *Line Contact*—when contacts occur across a discontinuity then minor loops occur within the main X-Y plot loop produced

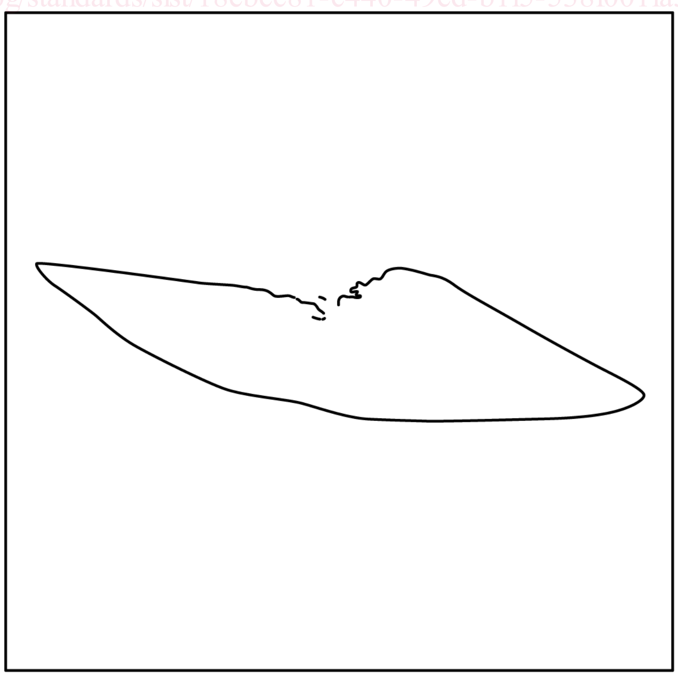

FIG. 2 Example X-Y Plot Produced by Plotting the *Bx* (vertical) and *Bz* (horizontal) Together (The orientation of the plot may differ depending upon the instrumentation.)

by the discontinuity. This can be differentiated from adjacent multiple discontinuities when there will be a number of separate loops, each returning to the background level.

8.5.4 *Longitudinal Discontinuities*—~~in~~In the unlikely event that a discontinuity exists parallel to the pipe axis of the ferromagnetic test piece then the *Bx* may rise instead of fall and the *Bz* signal will remain the same as for a short transverse discontinuity. The X-Y plot will then go upwards instead of down in the representative plot of Fig. 2. The extent of this flux leakage signal above the surface is related to the opening of the discontinuity, so it may not be seen for tightly closed discontinuities.

8.6 *Instrumentation:*

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

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

8.6.1.2 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, such as a shoulder on a pin. 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 are not acceptable and appear 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 examination 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.

8.6.2 *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.

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 thread 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 processor, either internally, or in the form of 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 Section 14). The software runs on the processor and, on start up, all communications between the processor 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 either on the processor or on the probe and is transmitted to the instrument whenever a probe is selected or changed. This configuration data may include different settings dependent on the thread type and size being examined. 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 standardization block (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 display 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 Section 14) 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 Mechanicsm:*

9.2.1 Ideally, the pipe is placed on a rotary rig such that the pipe can be rotated about its own axis, allowing the probe to move down the axis. In this way, the complete thread can be examined without having to move the probe around the pipe, thus avoiding twisting of the probe cable. Alternatively, if the pipe cannot be rotated, an array probe can be used to examine the complete thread in one turn of the probe.

9.3 *Probes:*

9.3.1 The probes selected should be appropriate for the form of examination to be carried out dependent on thread size, geometry, size of detectable discontinuity and component material.

9.3.1.1 *Universal Thread Probe*—used with interchangeable shoes that are each designed to fit a particular thread size and type. It is important to select the correct shoe for the thread to be examined to avoid excessive lift-off or probe rock, and probe wear.

9.3.1.2 *Array Probe*—made up of a number of elements; each element is sensitive to a discrete section of the thread (typically a single root, but may be part of a root for large threads). The array probe is generally used for scanning a complete thread in one full rotation. The probe may have interchangeable scrapers to fit a particular thread size. In this case, it is important to select the correct scrapers for the thread to be examined to avoid excessive lift-off or probe rock, and probe wear.

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 3-D 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. The geometry of the notches used in the operation standardization block and the discontinuity sizing model must be consistent with the excitation field.

10. Alternating Current Field Measurement Standardization Blocks

10.1 *Artificial Notches for the Operation Standardization Block:*

10.1.1 The operation standardization block 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 standardization block are elliptical notches. The notch geometry will be specified by the equipment manufacturer to be consistent with the crack size estimation model. Typical notch dimensions are as follows:

10.1.1.1 *Notch in Thread ~~Sample~~Sample—*~~—~~An elliptical notch placed in a thread root, near ~~to~~ the pin shoulder, with dimensions of at least 0.6 by 0.06 in. [15 by 1.5 mm] to give a suitably large signal for comparison with that ~~expected.~~expected (Fig. 3~~)~~).

10.1.1.2 Notch in plate with a groove to mimic a thread root, if no thread sample is available—An elliptical notch placed in the

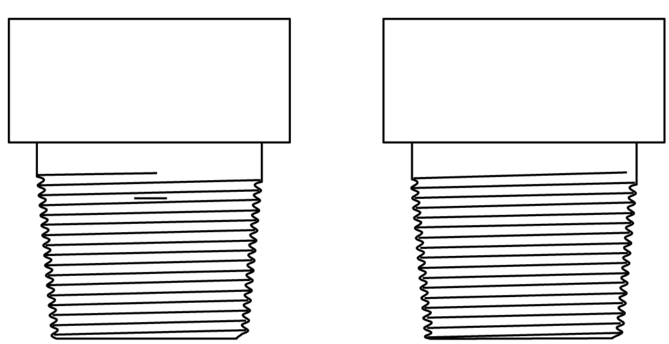

FIG. 3 Pin Thread Sample Serial Number XXX Showing Size and Location of Reference Notch (Plan View and Side View. Not to Scale)