



Designation: E3052 – 21

Standard Practice for Examination of Carbon Steel Welds Using An Eddy Current Array¹

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1. Scope*

1.1 This practice covers the use of an eddy current array (ECA) or an eddy current sensor for nondestructive examination of carbon steel welds. It includes the detection and sizing of surface-breaking cracks in such joints, accommodating for nonmagnetic and nonconductive coating up to 5 mm thick between the sensor and the joint. The practice covers a variety of cracking defects, such as fatigue cracks and other types of planar discontinuities, at various locations in the weld (heat-affected zone, toe area, and weld cap, for example). It covers the length and depth sizing of such surface-breaking discontinuities. This practice can be used for flush-ground and not flush-ground welds. For specific ferrous alloys or specific welded parts, the user may need a more specific procedure.

1.2 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

1.4 *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

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.

E1316 Terminology for Nondestructive Examinations

E2884 Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays

E2905 Practice for Examination of Mill and Kiln Girth Gear Teeth—Electromagnetic Methods

2.2 ASNT Documents³

SNT-TC-1A Recommended Practice for 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 Nondestructive Testing—Qualification and Certification of Nondestructive Testing Personnel

2.4 AIA Standard:⁵

NAS-410 Certification and Qualification of Nondestructive Testing Personnel

3. Terminology

3.1 *Definitions*: For definitions of terms relating to this practice, refer to Terminology E1316, Guide E2884, and Practice E2905. The following definitions are specific to the examination of carbon steel welds using an eddy current array:

3.1.1 *air reference measurement, n*—the measured response of the sensor and instrumentation to a nonmagnetic and electrically insulating reference material such as air.

3.1.1.1 *Discussion*—This measurement is typically used as part of the standardization process and to verify operation of the instrument. Measurements on conductive materials after standardization with an air reference measurement should provide absolute electrical properties, such as electrical conductivity, and lift-off values.

3.1.2 *encoder, n*—a spatial sensing device (based on mechanical, optical, or electromagnetic principles, for example) that allows for accurate monitoring of a sensor's

³ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

⁵ Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, <http://www.aia-aerospace.org>.

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

position during data collection and is typically used to construct spatially referenced data presentations.

3.1.3 *examined part reference measurement, n*—the measured response of the sensor and instrumentation to a region of the part to be examined for which no discontinuities are present.

3.1.3.1 *Discussion*—This measurement is typically used to compensate for differences in material properties between the examined material and a reference material used to develop a correlation between the eddy current sensor response and a characteristic of a discontinuity, such as a crack depth.

3.1.4 *known material reference measurement, n*—the measured response of the sensor and instrumentation to a given material with known, homogeneous electrical conductivity and magnetic permeability (such as aluminum 6061-T6, for example) for which no discontinuities are present.

3.1.4.1 *Discussion*—This measurement is typically used as part of the standardization process and to verify operation of the instrument.

4. Significance and Use

4.1 *Eddy Current Arrays for Crack Detection and Sizing in Carbon Steel Welds*—Eddy current sensor arrays permit rapid examination of carbon steel welds for surface-breaking cracks located on the surface closest to the sensor array. As described in Guide E2884, these sensor arrays can have multiple drive-sense pairs for each element of the array or a large single drive winding construct with multiple individual sense elements. However, not all ECA probe designs allow for accurate depth sizing of such discontinuities over a significant range (several millimeters, for example). To achieve proper crack depth sizing, the system shall exhibit certain characteristics, such as: (1) a lift-off signal that allows monitoring the lift-off over the range of values of interest for the examination, (2) suitable separation between the lift-off signal and the defect signal (this depends upon the instrument used and can be viewed as a phase separation in an impedance plane display), (3) the capability to make use of the lift-off values for crack depth determination, (4) the capability to take into account material properties variations for crack depth determination along and across the weld, and (5) a uniform sensitivity for the sensing elements of the array in order to provide an effective single-pass examination, which is expected when using an array sensor.

4.2 *Array Sensors and Single Sensing Element Sensors*—Depending on the weld geometry, it may be possible to use either a sensor array or a sensor with a single sensing element. The sensor array generally provides a better spatial representation of the weld properties and an improved probability of detection for discontinuities. The size of the array, as well as the size and number of individual sensing elements within the array depend on the weld geometry and other factors such as target discontinuities. When a single-sensing element sensor is used, it shall produce signals that exhibit the characteristics listed in 4.1 and the maximum distance from the scan line to a target discontinuity, potentially detectable at a specified probability of detection, is typically 5 mm. Imaging of the weld

region can be obtained with a single element sensor if raster scanning is performed.

4.3 *Conformable Sensors*—Examining welds that are not ground flush typically requires a conformable array sensor, minimally along one axis. A conformable sensor is key to allowing the individual sensing elements to follow the profile of the weld cap, and to provide a uniform response over the region of interest during the examination when the array is oriented transverse to the weld and scanned along the length of the weld.

4.4 *Crack Depth Range*—The crack depth sizing range over which the array sensor can provide accurate measurement depends on the sensor geometry, such as individual sensing element size and configuration. For example, larger sensing elements may provide the ability to size deeper cracks, but offer limited detection capability for shallow cracks. Appropriate array sensor selection and operating frequency is critical to ensure adequate performance for a given application. Typical operating frequencies range between 10 kHz and 500 kHz.

4.5 *Coating Thickness Range*—The coating thickness range over which the array sensor can reliably detect and size cracks depends on the individual sensing element size and overall probe geometry, among other parameters. For any coated weld examination, a verification that the coating thickness is within the probe specification range is critical to ensure adequate results.

4.6 *Crack Length Range*—The crack length range over which the array sensor performs best depends on the individual sensing element size and on any data processing performed on the data. The size of the individual sensing element mainly affects the minimum crack length detectable, while data processing (a high pass filter, for example) may have a critical impact on the maximum measurable crack length.

4.7 *Sensitivity Uniformity*—In order to provide a high probability of detection and allow accurate length and depth sizing, it is critical that the sensitivity across the sense elements of the array be uniform. The array sensor shall exhibit variations in sensitivity no greater than 15 %. The sensitivity across the array depends on the size and configuration of single sensing elements and shall be considered to determine the overall array accuracy. Overlapping individual sensing elements may be required to achieve the adequate level of sensitivity uniformity (for example, this can be achieved with multiple staggered rows of single sensing elements or with a linear array oriented at a non-perpendicular angle to the scan direction).

4.8 *Sizing and Accuracy*—Depending on the material properties and weld surface condition, there is an optimal measurement performance range for the system. The instrument and sensor array probe, the air reference measurement and known material reference measurement, along with the operation procedure typically allow depth sizing within ± 30 % of its true depth. Depth sizing accuracy is reduced when the system is operated outside its optimal range.

5. Interferences

5.1 *Material Properties:*