



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

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1. Scope

1.1 This practice covers the use of eddy current array sensors 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 (typical) 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 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 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](#)

[E2261 Practice for Examination of Welds Using the Alternating Current Field Measurement Technique](#)

[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 Other Standards:

[ISO 9712 Nondestructive Testing—Qualification and Certification of Nondestructive Testing Personnel⁴](#)

[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 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*—the instrument shall process this measurement as a reference response for signal adjustment. Measurements on conductive materials after air reference measurement should provide absolute electrical properties and lift-off values.

3.1.2 *encoder*—a spatial sensing device (based on mechanical, optical, or electromagnetic principles, for example) allowing for accurate monitoring of a sensor's position during data collection, used to construct spatially referenced data presentations.

3.1.3 *examined part reference measurement*—the measured response of the sensor and instrumentation to the magnetic part to be examined.

3.1.3.1 *Discussion*—the instrument shall be capable of measuring and recording the response of the sensor on the part to be examined, and compensate for specific material properties.

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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 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>.

3.1.4 *known material reference measurement*—the measured response of the sensor and instrumentation to a given material with known, homogeneous properties (such as aluminum 6061-T6, for example).

3.1.4.1 *Discussion*—the instrument shall process this as a reference response for signal adjustment and standardization to provide values that are similar for all of the sense elements.

4. Significance and Use

4.1 *Eddy Current Array for Crack Detection and Sizing in Carbon Steel Welds*—Eddy current array allows for a fast examination of carbon steel welds for surface-breaking cracks located on the surface closest to the sensor. 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 that lift-off over an adequate range of values, 2) suitable phase separation between the lift-off signal and the defect signal, 3) the capability to make use of the lift-off monitoring 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 across the sensing elements of the array in order to provide an effective single-pass examination, as it 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 would provide a better spatial representation of the weld and an improved probability of detection. 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 subsection 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.

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 allow 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 maximize the 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 (e.g. multiple staggered rows of single sensing elements is typical).

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 $\pm 30\%$ of its true depth. Depth sizing accuracy is reduced when the system is operated outside its optimal range.

5. Interferences

5.1 *Material Properties:*

5.1.1 *Base Metal*—Magnetic permeability and electrical conductivity of the metal can affect the eddy current measurements, and as such, may have an impact on the crack sizing accuracy. The system must be able to compensate for variations in the magnetic permeability and electrical conductivity typically found in carbon steels, by using, for example a standardization technique that measures and compensates for base metal properties.

5.1.2 *Variations Across the Weld*—In welded structures, the magnetic permeability and electrical conductivity may vary between the weld metal, the heat affected zone, and the base metal. Considering the array sensor is moved along the weld axis, each individual sensing element is usually exposed to relatively constant material properties. However, from one individual sensor to another within the array, significant properties variation may exist and the inspection system shall be able to compensate for those local variations in order to avoid noise and undesired signals in the C-scans.

5.2 *Weld Geometric Features*—Geometric features in the weld such as bumps and craters can create non-relevant localized signals that will contribute to increasing the noise level perceived by each sensor. Typically, such geometric features produce signals that exhibit a