



# Standard Practice for Electromagnetic Examination of Ferromagnetic Steel Wire Rope<sup>1</sup>

This standard is issued under the fixed designation E 1571; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the application and standardization of instruments that use the electromagnetic, the magnetic flux, and the magnetic flux leakage examination method to detect flaws and changes in metallic cross-sectional areas in ferromagnetic wire rope products.

1.1.1 This practice includes rope diameters up to 2.5 in. (63.5 mm). Larger diameters may be included, subject to agreement by the users of this practice.

1.2 *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<sup>2</sup>

E 1316 Terminology for Nondestructive Examinations<sup>2</sup>

## 3. Terminology

3.1 *Definitions*—See Terminology E 1316 for general terminology applicable to this practice.

### 3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dual-function instrument*—a wire rope NDT instrument designed to detect and display changes of metallic cross-sectional area on one channel and local flaws on another channel of a dual-channel strip chart recorder or another appropriate device.

3.2.2 *local flaw (LF)*—a discontinuity in a rope, such as a broken or damaged wire, a corrosion pit on a wire, a groove worn into a wire, or any other physical condition that degrades the integrity of the rope in a localized manner.

3.2.3 *loss of metallic cross-sectional area (LMA)*—a relative measure of the amount of material (mass) missing from a

location along the wire rope and is measured by comparing a point with a reference point on the rope that represents maximum metallic cross-sectional area, as measured with an instrument.

3.2.4 *single-function instrument*—a wire rope NDT instrument designed to detect and display either changes in metallic cross-sectional area or local flaws, but not both, on a strip chart recorder or another appropriate device.

## 4. Summary of Practice

4.1 The principle of operation of a wire rope nondestructive examination instrument is as follows:

4.1.1 *AC Electromagnetic Instrument*—An electromagnetic wire rope examination instrument works on the transformer principle with primary and secondary coils wound around the rope (Fig. 1). The rope acts as the transformer core. The primary (exciter) coil is energized with a low frequency alternating current (ac), typically in the 10 to 30 Hz range. The secondary (search) coil measures the magnetic characteristics of the rope. Any significant change in the magnetic characteristics in the core (wire rope) will be reflected as voltage changes (amplitude and phase) in the secondary coil. Electromagnetic instruments operate at relatively low magnetic field strengths; therefore, it is necessary to completely demagnetize the rope before the start of an examination. This type of instrument is designed to detect changes in metallic cross-sectional area.

4.1.2 *Direct Current and Permanent Magnet (Magnetic Flux) Instruments*—Direct current (dc) and permanent magnet instruments (Figs. 2 and 3) supply a constant flux that magnetizes a length of rope as it passes through the sensor head (magnetizing circuit). The total axial magnetic flux in the rope can be measured either by Hall effect sensors, an encircling (sense) coil, or by any other appropriate device that can measure absolute magnetic fields or variations in a steady magnetic field. The signal from the sensors is electronically processed, and the output voltage is proportional to the volume of steel or the change in metallic cross-sectional area, within the region of influence of the magnetizing circuit. This type of instrument measures changes in metallic cross-sectional area.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 03.03.

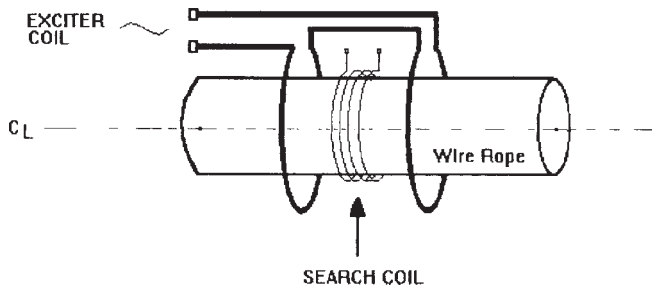


FIG. 1 Schematic Representation of an Electromagnetic Instrument Sensor-Head

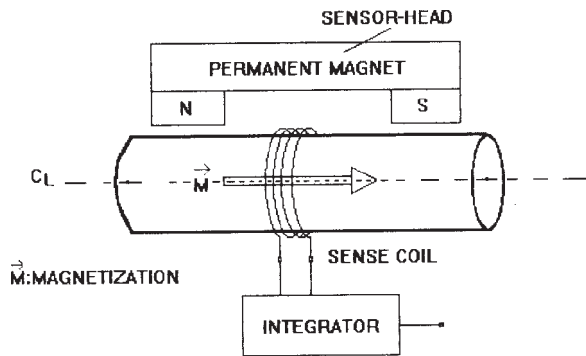


FIG. 2 Schematic Representation of a Permanent Magnet Equipped Sensor-Head Using a Sense Coil to Measure the Loss of Metallic Cross-Sectional Area

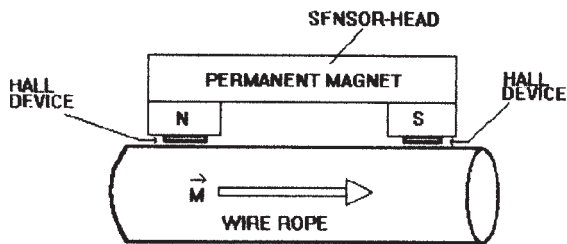


FIG. 3 Schematic Representation of a Permanent Magnet Equipped Sensor-Head Using Hall Devices to Measure the Loss of Metallic Cross-Sectional Area

4.1.3 *Magnetic Flux Leakage Instrument*—A direct current or permanent magnet instrument (Fig. 4) is used to supply a constant flux that magnetizes a length of rope as it passes through the sensor head (magnetizing circuit). The magnetic flux leakage created by a discontinuity in the rope, such as a broken wire, can be detected with a differential sensor, such as

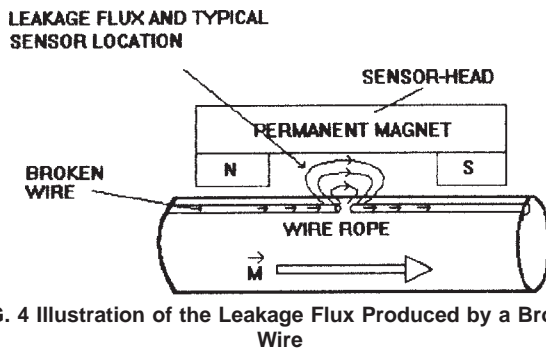


FIG. 4 Illustration of the Leakage Flux Produced by a Broken Wire

a Hall effect sensor, sensor coils, or by any appropriate device. The signal from the sensor is electronically processed and recorded. This type of instrument measures LFs. While the information is not quantitative as to the exact nature and magnitude of the causal flaws, valuable conclusions can be drawn as to the presence of broken wires, internal corrosion, and fretting of wires in the rope.”

4.2 The examination is conducted using one or more techniques discussed in 4.1. Loss of metallic cross-sectional area can be determined by using an instrument operating according to the principle discussed in 4.1.1 and 4.1.2. Broken wires and internal (or external) corrosion can be detected by using a magnetic flux leakage instrument as described in 4.1.3. The examination procedure must conform to Section 9. One instrument may incorporate both magnetic flux and magnetic flux leakage principles.

## 5. Significance and Use

5.1 This practice outlines a procedure to standardize an instrument and to use the instrument to examine ferromagnetic wire rope products in which the electromagnetic, magnetic flux, magnetic flux leakage, or any combination of these methods is used. If properly applied, the electromagnetic and the magnetic flux methods are capable of detecting the presence, location, and magnitude of metal loss from wear and corrosion, and the magnetic flux leakage method is capable of detecting the presence and location of flaws such as broken wires and corrosion pits.

5.2 The instrument’s response to the rope’s fabrication, installation, and in-service-induced flaws can be significantly different from the instrument’s response to artificial flaws such as wire gaps or added wires. For this reason, it is preferable to detect and mark (using set-up standards that represent) real in-service-induced flaws whose characteristics will adversely affect the serviceability of the wire rope.

## 6. Basis of Application

6.1 The following items require agreement by the users of this practice and should be included in the rope examination contract:

6.1.1 Acceptance criteria.

6.1.2 Determination of LMA, or the display of LFs, or both.

6.1.3 Extent of rope examination (that is, full length that may require several setups or partial length with one setup).

6.1.4 Standardization method to be used: wire rope reference standard, rod reference standards, or a combination thereof.

6.1.5 Maximum time interval between equipment standardizations.

6.2 *Wire Rope Reference Standard* (Fig. 5):

6.2.1 Type, dimension, location, and number of artificial anomalies to be placed on a wire rope reference standard.

6.2.2 Methods of verifying dimensions of artificial anomalies placed on a wire rope reference standard and allowable tolerances.

6.2.3 Diameter and construction of wire rope(s) used for a wire rope reference standard.

6.3 *Rod Reference Standards* (Fig. 6):

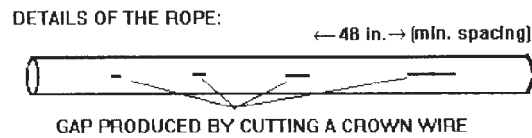
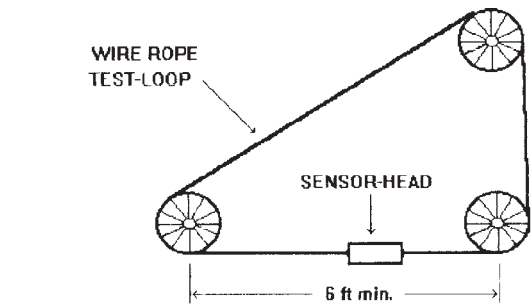


FIG. 5 Example of a Wire Rope Reference Standard

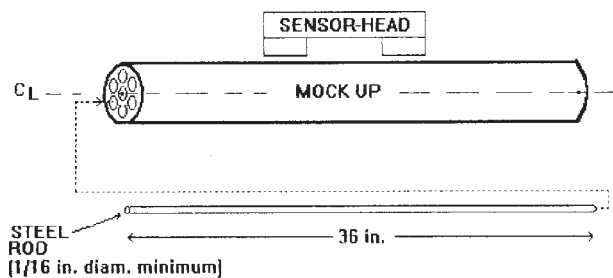


FIG. 6 Example of a Rod Reference Standard

6.3.1 Rod reference standard use, whether in the laboratory or in the field, or both.

6.3.2 Quantity, lengths, and diameters of rod reference standards.

## 7. Limitations

### 7.1 General Limitations:

7.1.1 This practice is limited to the examination of ferromagnetic steel ropes.

7.1.2 It is difficult, if not impossible, to detect flaws at or near rope terminations and ferromagnetic steel connections.

7.1.3 Deterioration of a purely metallurgical nature (brittleness, fatigue, etc.) may not be easily distinguishable.

7.1.4 A given size sensor head accommodates a limited range of rope diameters, the combination (between rope outside diameter and sensor head inside diameter) of which provides an acceptable minimum air gap to assure a reliable examination.

### 7.2 Limitations Inherent in the Use of Electromagnetic and Magnetic Flux Methods:

7.2.1 Instruments designed to measure changes in metallic cross-sectional area are capable of showing changes relative to that point on the rope where the instrument was standardized.

7.2.2 The sensitivity of these methods may decrease with the depth of the flaw from the surface of the rope and with decreasing gaps between the ends of the broken wires.

### 7.3 Limitations Inherent in the Use of the Magnetic Flux Leakage Method:

7.3.1 It may be impossible to discern relatively small-diameter broken wires, broken wires with small gaps, or

individual broken wires within closely-spaced multiple breaks. It may be impossible to discern broken wires from wires with corrosion pits.

7.3.2 Because deterioration of a purely metallurgical nature may not be easily distinguishable, more frequent examinations may be necessary after broken wires are detected to determine when the rope should be retired, based on percent rate of increase of broken wires.

## 8. Apparatus

8.1 The equipment used shall be specifically designed to examine ferromagnetic wire rope products.

8.1.1 The energizing unit within the sensor head shall consist of permanent or electromagnets, or ac or dc solenoid coils configured to allow application to the rope at the location of service.

8.1.2 The energizing unit, excluding the ac solenoid coil, shall be capable of magnetically saturating the range (size and construction) of ropes for which it was designed.

8.1.3 The sensor head, containing the energizing and detecting units, and other components, should be designed to accommodate different rope diameters. The rope should be approximately centered in the sensor head.

8.1.4 The instrument should have connectors, or other means, for transmitting output signals to strip chart recorders, data recorders, or a multifunction computer interface. The instrument may also contain meters, bar indicators, or other display devices, necessary for instrument setup, standardization, and examination.

8.1.5 The instrument should have an examination distance and rope speed output indicating the current examination distance traveled and rope speed or, whenever applicable, have a proportional drive chart control that synchronizes the chart speed with the rope speed.

### 8.2 Auxiliary Equipment

The examination results shall be recorded on a permanent basis by either

8.2.1 a strip chart recorder

8.2.2 and/or by an other type of data recorder

8.2.3 and/or by a multifunctional computer interface.

## 9. Examination Procedure

9.1 The electronic system shall have a pre-examination standardization procedure.

9.2 The wire rope shall be examined for LFs or LMA, or both, as specified in the agreement by the users of this practice. The users may select the instrument that best suits the intended purpose of the examination. The examination should be conducted as follows:

9.2.1 The rope must be demagnetized before examination by an electromagnetic instrument. If a magnetic flux or a magnetic flux leakage instrument is used, it may be necessary to repeat the examination to homogenize the magnetization of the rope.

9.2.2 The sensor head must be approximately centered around the wire rope.

9.2.3 The instrument must be adjusted in accordance with a procedure. The sensitivity setting should be verified prior to starting the examination by inserting a ferromagnetic steel rod

or wire of known cross-sectional area. This standardization signal should be permanently recorded for future reference.

9.2.4 The wire rope must be examined by moving the head, or the rope, at a relatively uniform speed. Relevant signal(s) must be recorded on suitable media, such as on a strip chart recorder, on a tape recorder, or on computer file(s), for the purpose of both present and future replay/analysis.

9.2.5 The following information shall be recorded as examination data for analysis:

9.2.5.1 Date of examination,

9.2.5.2 Examination number,

9.2.5.3 Customer identification,

9.2.5.4 Rope identification (use, location, reel and rope number, etc.),

9.2.5.5 Rope diameter and construction,

9.2.5.6 Instrument serial number,

9.2.5.7 Instrument standardization settings,

9.2.5.8 Strip chart recorder settings,

9.2.5.9 Strip chart speed,

9.2.5.10 Location of sensor head with respect to a well-defined reference point along the rope, both at the beginning of the examination and when commencing a second set-up run,

9.2.5.11 Direction of rope or sensor head travel,

9.2.5.12 Total length of rope examined, and

9.2.5.13 examination speed.

9.2.6 To assure repeatability of the examination results, two or more operational passes are required.

9.2.7 When more than one setup is required to examine the full working length of the rope, the sensor head should be positioned to maintain the same magnetic polarity with respect to the rope for all setups. For strip chart alignment purposes, a temporary marker should be placed on the rope at a point common to the two adjacent runs. (A ferromagnetic marker shows an indication on a recording device.) The same instrument detection signals should be achieved for the same standard when future examinations are conducted on the same rope.

9.2.8 When determining percent LMA, it must be understood that comparisons are made with respect to a reference point on the rope representing maximum metallic cross-sectional area. The reference point may have deteriorated such that it does not represent the original (new) rope. The reference point must be inspected visually to evaluate its condition. When determining percent LMA, it must be understood that comparisons are made with respect to a reference point on the rope that represents the rope's maximum metallic cross-sectional area. The reference point's condition may have deteriorated during the rope's operational use such that it no longer represents the original (new) rope values. The reference point must be examined visually, and possibly by other means, to evaluate its current condition.

9.2.9 If the NDT indicates existence of significant rope deterioration at any rope location, an additional NDT of this location(s) should be conducted to check for indication repeatability. Rope locations at which the NDT indicates significant deterioration must be examined visually in addition to the NDT.

9.3 Local flaw baseline data for LF and LMA/LF instruments may be established during the initial examination of a (new) rope. Whenever applicable, gain settings for future examination of the same rope should be adjusted to produce the same amplitude for a known flaw, such as a rod or wire attached to the rope.

## 10. Reference Standard

### 10.1 General:

10.1.1 The instrument should be standardized with respect to the acceptance criteria established by the users of this practice.

10.1.2 Standardization should be done the first time the instrument is used, during periodic checks, or in the event of a suspected malfunction.

10.1.3 The instrument should be standardized using one or more of the following: wire rope reference standard with artificial flaws (see Fig. 5), or rod reference standards (see Fig. 6).

For clarification, the following sections – 10.2 and 10.3 – are useful for laboratory purposes to more fully understand instrument limitations.

### 10.2 Wire Rope Reference Standard:

10.2.1 The wire ropes selected for reference standards should be first examined to ascertain and account for the existence of interfering, preexisting flaws (if they exist) prior to the introduction of artificial flaws. The reference standard shall be that rope appropriate for the instrument and sensor head being used and for the wire rope to be examined unless rod reference standards are used. The reference standard shall be of sufficient length to permit the required spacing of artificial flaws and to provide sufficient space to avoid rope end effects. The selected configuration for the reference standard rope shall be as established by the users of this practice.

10.2.2 Artificial flaws placed in the wire rope reference standard shall include gaps produced by removing, or by adding, lengths of outer wire. The gaps shall have typical lengths of  $\frac{1}{16}$ ,  $\frac{1}{8}$ ,  $\frac{1}{4}$ ,  $\frac{1}{2}$ , 1, 2, 4, 8, 16, and 32 in. (1.6, 3.2, 6.4, 12.7, 25.4, 50.8, 101.6, 203.2, 406.4, and 812.8 mm, respectively). The gaps shall typically be spaced 30 in. (762 mm) apart. There shall be a minimum of 48 in. (1219 mm) between gaps and the ends of the wire rope. Some of the gap lengths may not be required. All wire ends shall be square and perpendicular to the wire.

10.2.3 Stricter requirements than those stated above for local flaws and changes in metallic cross-sectional area may be established by the users if proven feasible for a given NDT instrument, subject to agreement by the users.

### 10.3 Rod Reference Standard:

10.3.1 Steel rods are assembled in a manner such that the total cross-sectional area will be equal to the cross-sectional area of the wire rope to be examined. The rod bundle is to be placed in the sensor head in a manner simulating the conditions that arise when a rope is placed along the axis of the examination head. Individual rods are to be removed to simulate loss of metallic area caused by wear, corrosion, or missing wires in a rope. This procedure gives highly accurate control of changes in instrument response and can be used to adjust and standardize the instrument.

10.3.2 The rods for laboratory standardization procedures should be a minimum of 3 ft (Approx. 1 m) in length to minimize end-effects from the rod ends, or as recommended by the instrument manufacturer.

10.3.3 Shorter rods or wires may be used for a pre-examination check in the field.

10.4 *Adjustment and Standardization of Apparatus Sensitivity:*

10.4.1 The procedure for setting up and checking the sensitivity of the apparatus is as follows:

10.4.1.1 The reference standard shall be fabricated as specified in the agreement by the users.

10.4.1.2 The sensor head shall be adjusted for the size of material to be examined.

10.4.1.3 The sensor head shall be installed around the reference standard.

10.4.1.4 The reference standard shall be scanned, and, whenever applicable, gain and zero potentiometers, chart recording scale, or other apparatus controls shall be adjusted for required performance.

10.4.1.5 If standardization is a static procedure, as with an electromagnetic instrument (see 4.1.1), the standard reference rope shall be passed through the detector assembly at field examination speed to demonstrate adequate dynamic performance of the examination instrument. The instrument settings that provide required standardization shall be recorded.

## 11. Test Agency Qualification

11.1 *Nondestructive Testing Agency Qualification*—Use of an NDT agency (in accordance with Practice E 543) to perform the examination may be agreed upon by the using parties. If a systematic assessment of the capability of the agency is specified, a documented procedure such as Practice E 543 shall be used as the basis for the assessment.

## 12. Keywords

12.1 electromagnetic examination; flux leakage; local flaws (LF); magnetic flux; magnetic flux leakage; percent loss of metallic cross-sectional area (LMA); rod reference standards; sensor head; wire rope; wire rope reference standard

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