Designation: E703 − 20

Standard Practice for Electromagnetic (Eddy Current) Sorting of Nonferrous Metals[1]

This standard is issued under the fixed designation E703; 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 a procedure for sorting nonferrous metals using the electromagnetic (eddy current) method. The procedure is intended for use with instruments using absolute or comparator-type coils for distinguishing variations in mass, shape, conductivity, and other variables such as alloy, heat treatment, or hardness that may be closely correlated with the electrical properties of the material. Selection of samples to evaluate sorting feasibility and to establish standards is also described.

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

1.3 *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]

E105 Practice for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Documents:*[3]

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 *AIA Standard:*[4]

NAS-410 Qualification and Certification of Nondestructive Testing Personnel

3. Terminology

3.1 Standard terminology relating to electromagnetic examination may be found in Terminology E1316, Section C: Electromagnetic Testing.

4. Summary of Practice

4.1 The techniques that are primarily used in electromagnetic sorting employ the absolute (single-) and comparative (two-) coil methods using either encircling or probe coils. The decision of whether to use single-coil or two-coil operation is usually based on empirical data. In the absolute-coil method (encircling or probe), the equipment is standardized by placing standards of known properties in the test coil. The value of the examined electrical parameter, which may be correlated with alloy, heat treatment temper, or hardness, is read on the display of an indicator. In the comparative coil method (encircling or probe coils), the test specimen in one coil is compared with a reference standard in a second coil to determine whether the test specimen is within or outside of the required limits.

4.1.1 *Absolute Coil Method:*

4.1.1.1 *Encircling Coil*—Various reference standards are inserted consecutively in the test coil, and the controls of the instrument are adjusted to obtain an appropriate response. Typically, three samples would be used representing the upper, lower, and mid-range for which standardization is required. The examination is then conducted by inserting the specimens to be sorted into the test coil, and observing the instrument response.

[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.

Current edition approved June 1, 2020. Published July 2020. Originally approved in 1979. Last previous edition approved in 2014 as E703 – 14. DOI: 10.1520/E0703-20.

[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 Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

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

4.1.1.2 *Probe Coil*—The probe coil is placed consecutively on the reference standards and the controls of the instrument are adjusted for appropriate response (see 4.1.1.1). The examination is then conducted by placing the probe on the specimens to be sorted and observing the instrument response.

4.1.2 *Comparative Coil Method:*

4.1.2.1 *Encircling Coil*—Reference standards representing the minimum or maximum limits, or both, of acceptance or sorting category are inserted in the reference and test coil. The instrument controls are adjusted for appropriate responses. The examination is then conducted by inserting specimens to be sorted in the test coil, leaving the known reference in the reference coil, and observing the instrument response.

4.1.2.2 *Probe Coil*—Both probe coils are placed on the reference standard representing the minimum or maximum limits, or both, of acceptance or sorting category. The instrument controls are adjusted for appropriate responses. The examination is then conducted by placing the test probe on the specimens to be sorted (the other probe is left on the reference standard) and observing the instrument response.

4.2 The range of instrument response must be so adjusted in the initial step that the anticipated deviations will be within the range of readout.

4.3 Both absolute and comparative methods using encircling coil(s) require comparing the specimens to be examined with the reference standards. Two or more samples representing the limits of acceptance may be required. In the absolute method, the electrical reference signal from the instrument is adjusted with the reference standard in the coil. In the comparative method, any electromagnetic condition, that is not common to the test specimen and the reference standard, will produce an imbalance in the system. The comparative method is usually more stable since it suppresses most of the interferences.

4.4 The examination process may consist of manual insertion of one specimen after another into the test coil or an automated feeding and classifying mechanism may be employed. In automated setups, it is sometimes necessary to establish empirically the time required for the test specimen to remain in the test coil while the reading is being taken, especially if low frequencies are employed.

5. Significance and Use

5.1 Absolute and comparative methods provide a measure for sorting large quantities of nonferrous parts or stock with regard to composition or condition, or both.

5.2 The comparative or two-coil method is used when high-sensitivity examination is required. The advantage of this method is that it almost completely suppresses interferences.

5.3 The ability to accomplish these types of separations satisfactorily is dependent upon the relation of the electric characteristics of the nonferrous parts to their physical condition.

5.4 These methods may be used for high-speed sorting in a fully automated setup where the speed of examination may approach many specimens per second depending on their size and shape.

5.5 Successful sorting of nonferrous material depends mainly on the variables present in the sample and the proper selection of frequency and fill factor.

5.6 The accuracy of a sort will be affected greatly by the coupling between the test coil field and the examined part during the measuring period.

6. Basis of Application

6.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally recognized nondestructive testing (NDT) personnel qualification practice or standard, such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, ISO 9712, or a similar document and certified by the employer or certifying agency, 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 Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contractual agreement.

6.3 *Acceptance Criteria*—Since acceptance criteria are not specified in this practice, they shall be specified in the contractual agreement.

7. Interferences

7.1 The influence of the following variables must be considered for proper interpretation of the results:

7.1.1 The correlation shall be established so that electrical properties of various groups do not overlap and are well defined in the standardization procedure used. For any given temper and alloy combination, there is an acceptable range of values. These ranges must be considered, not just a single value.

7.1.2 The examination frequency must be selected to provide a well-defined separation of variables.

7.1.3 The temperature of the reference standard and test specimen shall be controlled within limits that will permit a well-defined range of conductivity or permeability, or both, for which the correlation of the group or groups is valid. Cooling of the reference standard when high field strengths are used or allowing test specimens to cool or heat to an established ambient range, or both, may be required.

7.1.4 The geometry, mass, and thickness of the reference standard and test specimen shall be controlled within limits that will permit sorting.

7.1.5 Magnetic permeability variations can interfere when sorting paramagnetic materials.

7.1.6 Signal response can result from a change in relative motion between the test specimen and the test coil, such as the length of time the specimen is in a test coil (see 4.4).

7.1.7 Conductivity has an unambiguous relationship to hardness for certain alloys. However, when alloys are mixed, identical conductivity does not necessarily indicate the same hardness.

7.1.8 Care must also be exercised in using conductivity to sort overheated parts quenched at a high temperature as the conductivity reading for acceptable parts may repeat at a large increase in temperature.

7.1.9 Lift-off can result in a change in the test system output with probe coils. This effect is a change in the magnetic coupling between the test specimen and probe coil. Care must be exercised to prevent this effect from interfering with examination results; either mechanical or electronic compensation must be used.

7.1.10 For certain heat-treatable (aluminum) alloys, conductivity values can also repeat themselves during the aging cycle at a constant temperature. Thus, for such alloys, conductivity is not unique as a monitor of temper, etc. In this case, you must have an understanding of the temper expected of each alloy to determine if this test is possible.

8. Apparatus

8.1 *Electronic Apparatus*—The electronic apparatus shall be capable of energizing the test coils with alternating currents of suitable frequencies and power levels and shall be capable of sensing changes in the electromagnetic response of the coils. Equipment may include any suitable signal-processing devices (phase discriminator, filter circuits, etc.) and the output may be displayed by meter, oscilloscope, recorder, signaling devices, or any suitable combination required for the particular application.

8.2 Test coils may be of the encircling or probe-coil type and shall be capable of inducing an electromagnetic field in the test specimen and reference standard, and sensing changes in the electric or magnetic characteristics of the test specimen.

8.2.1 When selecting the test coil, the objective should be to obtain a coil fill factor as large as possible. This means that the inside of the test coil should be filled by the test specimen as much as possible. This is of primary importance for examinations requiring high sensitivity.

8.2.2 For complicated test specimen shapes, a corresponding insert shall be provided to ensure that each test specimen can be placed in the same position within the test coil. These inserts, as well as any other accessories, should consist of non-ferromagnetic, electrically nonconductive material.

8.3 *Mechanical Handling Apparatus*— A mechanical device for feeding and sorting the test specimens may be used to automate a particular application.

9. Sampling

9.1 Sampling (see Practices E105 and E122) is a method to obtain assurance that materials are of satisfactory quality. Instead of 100 % inspection, a portion of the material is examined to show evidence of the quality of the whole. There are two important needs for this approach: first, the final inspection or examination is made to assure that products delivered are in conformance with specification requirements; second, to control parts and assemblies while they are being processed. Statistical acceptance sampling tables and statistical process-control sampling tables have been developed to meet these needs.

9.2 Acceptance sampling may be conducted on an accept/reject (or attributes) basis; that is, determining whether or not the units of the sample meet the specification. Examination of the samples may also be conducted on a measurements (or variables) basis; that is, determining actual readings on the units in the sample. The majority of acceptance sampling is carried out on a sampling by attributes basis and the usual acceptance sampling table is designed for accept/reject.

9.3 Process control sampling may be conducted on material during the course of production to prevent large quantities of defective parts being found in the acceptance examinations. Many parts and materials are subjected to several successive machining or processing operations before they become finished units. Parts can be most effectively controlled during production by examining small samples of these parts at frequent regularly scheduled intervals. The object of this process check is to provide a continuous picture of the quality of parts being produced. This helps prevent production of defective parts by stopping and correcting the problem as soon as it begins to appear in the manufacturing process and thereby keeping the process in control. Sampling may be by attributes or by variables and process control sampling tables are used. The measurements (variables) control chart is by far the most effective process control technique.

9.4 Statistical sampling tables have four definite features: *(1)* specification of sampling data—that is, the size of the samples to be selected, the conditions under which the samples are to be selected, and the conditions under which the lot will be accepted or rejected; *(2)* protection afforded—that is, the element of risk that the sampling schedules in a given table will reject good lots or accept bad ones; *(3)* disposal procedure—that is, a set of rules that state what is to be done with lots after sampling has been completed; and *(4)* cost required—that is, average inspection cost required to accept or reject a lot.

10. Reference Standards

10.1 Two reference standards of the precise size and configuration of the product to be examined are usually used to set up for sorting by the absolute coil method (see 11.2). Three reference standards of the precise size and configuration are usually used for sorting by the comparative coil (see 11.3) method.

10.2 Three reference standards are usually required for a three-way mix (see 11.4).

10.3 The reference standard should be selected to represent the extremes of acceptable and unacceptable groups or a range of hardness or conductivity to assure no overlap in the sort.

10.4 Other arrangements can be used and are acceptable but are not described in this procedure.

10.5 Reference standards must be stored in such a way as to minimize exposure to conditions that can affect their temper and conductivity.

11. Standardization

11.1 The electromagnetic sorting method is primarily one of comparison between specimens. Empirical data and physical examinations on samples representing properties to be separated determine the validity of the sort. The standardization