Designation: E 543 – 02

Standard Practice for Agencies Performing Nondestructive Testing[1]

This standard is issued under the fixed designation E 543; 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.

This specification has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers minimum requirements for agencies performing nondestructive testing (NDT).

1.2 When using this practice to assess the capability of, or to accredit NDT agencies, Guide E 1359 shall be used as a basis for the survey. It can be supplemented as necessary with more detail in order to meet the auditor's specific needs.

1.3 This practice can be used as a basis to evaluate testing or inspection agencies, or both, and is intended for use for the qualifying or accrediting, or both, of testing or inspection agencies, public or private.

1.4 *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 94 Guide for Radiographic Testing[2]
E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method[2]
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[2]
E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[2]
E 164 Practice for Ultrasonic Contact Examination of Weldments[2]
E 165 Test Method for Liquid Penetrant Examination[2]
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[2]
E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[2]
E 215 Practice for Standardizing Equipment for Electromagnetic Examination of Seamless Aluminum-Alloy Tube[2]
E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[2]
E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing[2]
E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[2]
E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments[2]
E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods[2]
E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel, and Similar Alloys[2]
E 427 Practice for Testing for Leaks Using the Halogen Leak Detector (Alkali-Ion Diode)[2]
E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection[2]
E 431 Guide to Interpretation of Radiographs of Semiconductors and Related Devices[2]
E 432 Guide for Selection of a Leak Testing Method[2]
E 433 Reference Photographs for Liquid Penetrant Inspection[2]
E 479 Guide for Preparation of a Leak Testing Specification[2]
E 493 Test Methods for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode[2]
E 498 Test Methods for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode[2]
E 499 Test Methods for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode[2]
E 515 Test Method for Leaks Using Bubble Emission Techniques[2]
E 545 Test Method for Determining Image Quality in Direct Thermal Neutron Radiographic Examination[2]
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals[2]
E 569 Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation[2]

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[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.09 on Nondestructive Testing Agencies.

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products[2]
E 571 Practice for Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products[2]
E 587 Practice for Ultrasonic Angle-Beam Examination by the Contact Method[2]
E 588 Practice for Detection of Large Inclusions in Bearing Quality Steel by the Ultrasonic Method[2]
E 592 Guide to Obtainable ASTM Equivalent Penetrameter Sensitivity for Radiography of Steel Plates ¼ to 2 in. (6 to 51 mm) Thick with X Rays and 1 to 6 in. (25 to 152 mm) Thick with Cobalt-60[2]
E 650 Guide for Mounting Piezoelectric Acoustic Emission Sensors[2]
E 664 Practice for Measurement of the Apparent Attenuation of Longitudinal Ultrasonic Waves by Immersion Method[2]
E 690 Practice for In Situ Electromagnetic (Eddy-Current) Examination of Nonmagnetic Heat Exchanger Tubes[2]
E 703 Practice for Electromagnetic (Eddy-Current) Sorting of Nonferrous Metals[2]
E 709 Guide for Magnetic Particle Examination[2]
E 746 Test Method for Determining Relative Image Quality Response of Industrial Radiographic Film[2]
E 747 Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology[2]
E 748 Practices for Thermal Neutron Radiography of Materials[2]
E 749 Practice for Acoustic Emission Monitoring During Continuous Welding[2]
E 750 Practice for Characterizing Acoustic Emission Instrumentation[2]
E 751 Practice for Acoustic Emission Monitoring During Resistance Spot-Welding[2]
E 797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method[2]
E 801 Practice for Controlling Quality of Radiological Examination of Electronic Devices[2]
E 803 Test Method for Determining the *L/D* Ratio of Neutron Radiography Beams[2]
E 908 Practice for Calibrating Gaseous Reference Leaks[2]
E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing[2]
E 1001 Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves[2]
E 1004 Test Method for Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity[2]
E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology[2]
E 1030 Test Method for Radiographic Examination of Metallic Castings[2]
E 1032 Test Method for Radiographic Examination of Weldments[2]
E 1067 Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels[2]
E 1118 Practice for Acoustic Emission Examination of Reinforced Thermosetting Resin Pipe (RTRP)[2]
E 1139 Practice for Continuous Monitoring of Acoustic Emission from Metal Pressure Boundaries[2]
E 1211 Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors[2]
E 1212 Practice for Establishment and Maintenance of Quality Control Systems for Nondestructive Testing Agencies[2]
E 1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films[2]
E 1316 Terminology for Nondestructive Examinations[2]
E 1359 Guide for Surveying Nondestructive Testing Agencies[2]
E 1417 Practice for Liquid Penetrant Examination[2]
E 1419 Test Method for Examination of Seamless, Gas-Filled, Pressure Vessels Using Acoustic Emission[2]
E 1444 Practice for Magnetic Particle Examination[2]
E 1742 Practice for Radiographic Examination[2]
E 1781 Practice for Secondary Calibration of Acoustic Emission Sensors[2]
E 1888 Test Method for Acoustic Emission Testing of Pressurized Containers Made of Fiberglass Reinforced Plastic with Balsa Wood Cores[2]
E 1930 Test Method for Examination of Liquid Filled Atmospheric and Low Pressure Metal Storage Tanks Using Acoustic Emission[2]
E 1932 Guide for Acoustic Emission Examination of Small Parts[2]
E 2075 Practice for Verifying the Consistency of AE-Sensor Response Using an Acrylic Rod [2]

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[3]
ANSI/ASNT-CP-189 ASNT Standard for Qualification and Certification in Nondestructive Testing Personnel[3]
NAS-410 Certification and Qualification of Nondestructive Personnel (Quality Assurance Committee)[4]

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[5]

3. Terminology

3.1 *Definitions*—Additional definitions are contained in the specific specification or in Terminology E 1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *agency*—the public, independent, or in-house nondestructive testing organization selected by the authority to perform the examination(s) required by the purchase order or specification.

[3] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[4] Available from Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.2.2 *authority*—the owner, prime contractor, engineer, architect, or purchasing agent in responsible charge of the work, or duly recognized or designated representative.

3.2.2.1 *Discussion*—The agency and the authority may be the same in some cases.

4. Significance and Use

4.1 This practice is applicable where the systematic assessment of the competence of a nondestructive testing agency by a user or other party is desired.

4.2 It is intended that the requirements specified in this practice apply to independent, public, or in-house agencies to the extent required by the purchase order or specification. This practice does not apply to in-house equipment, methods, and examinations used for the exclusive purpose of internal process control. It is intended that this practice apply to all examination(s) used for the final acceptance examination(s) if such examination(s) are required by the purchase order or specification.

4.3 Criteria are provided for evaluating the capability of an agency to properly perform designated examinations and establishes essential characteristics pertaining to the organization, personnel, facilities, and quality systems of the agency. This practice may be supplemented by more specific criteria and requirements for particular projects.

5. Organization of the Agency

5.1 The following information concerning the organization of the agency shall be provided by documentation:

5.1.1 A description of the organization including:

5.1.1.1 The complete legal name and address of the main office,

5.1.1.2 The names and positions of the principal officers and directors,

5.1.1.3 The agency's ownership, managerial structure, and principal members,

5.1.1.4 The functional description of the agency's organization structure, operational departments, and support departments and services. This may be demonstrated in the form of charts that depict all the divisions, departments, sections and units, and their relationships,

5.1.1.5 All relevant organizational affiliates of the agency and the principal officers of affiliates and directors of the affiliates where applicable,

5.1.1.6 External organizations and organizational components and their functions that are utilized for significant technical support services, and

5.1.1.7 A brief history of the agency including its relationship with its organizational component affiliations and other supporting information.

5.1.2 A general description of the type of users of the agency's services.

5.1.3 A listing of the relevant technical services offered.

5.1.4 A list giving applicable dates of the qualifications, accreditations, and recognition of the agency by others.

6. Responsibilities and Duties

6.1 A nondestructive testing agency's capabilities should include, but not be limited to, one or more of the following methods: magnetic particle, penetrant, radiographic/fluoroscopic, ultrasonic, eddy current, and leak testing.

NOTE 1—A comparison of selected NDE Methods is provided as Appendix X1.

6.2 It is the responsibility of the agency to ensure that:

6.2.1 It performs only examinations for which it is adequately equipped and staffed.

6.2.2 Its employees perform only examinations for which they are adequately qualified.

6.2.3 Its equipment is calibrated and personnel are certified in accordance with applicable specifications.

6.2.4 All equipment is properly maintained.

6.2.5 It informs the authority of any discrepancy or limitation imposed on the testing accuracy by such factors as surface finish, form, shape, or procedure.

6.3 The following duties are those usually performed by the agency:

6.3.1 To perform all examinations in accordance with specified standards or quality-control criteria, or both. (The necessary documents shall be furnished by the authority, or the agency, or both, as specified in the applicable purchase agreements.) The agency should call to the attention of the authority at once any irregularity or deficiency noted in the documents.

6.3.2 To submit promptly to the authority formal reports of all examinations that indicate compliance or noncompliance of the material with 6.3.1. The agency should be prepared to substantiate examination results when required.

6.4 The agency may, in accordance with an agreement with the authority, report only compliance or noncompliance with the applicable specifications or control documents. The authority reserves the right for disposition of noncomplying material.

6.5 The authority may, at its discretion, inspect the procedures, equipment, and personnel program of the agency.

7. Human Resources of the Agency

7.1 The agency shall document the following:

7.1.1 Written outline or chart defining operational personnel positions and their lines of responsibility and authority.

7.1.2 Summary job description for each professional, scientific, supervisory, and technical position category, documenting the required education, training, or experience, or a combination thereof.

7.1.3 Records or resumes that document the qualifications, work experience, and training history of each person in a position described in 7.1.2.

7.2 The agency shall make available a description of its means of ensuring the continued competence of its personnel to perform NDT, including the maintenance of written records to document the results.

8. Personnel Qualification

8.1 Nondestructive testing (NDT) personnel shall be qualified in accordance with a nationally recognized NDT personnel qualifications practice or standards such as ANSI/ASNT-CP-189, SNT-TC-1A, MIL STD 410, NAS-410, or a similar document. The practice or standard used and the applicable revision shall be specified in the contractual agreement between parties.

PROCEDURE MANUAL

9. Minimum Requirements

9.1 Each agency shall have prepared a written Procedures Manual for the type of work for which the agency is contracted. The manual shall be prepared in accordance with the requirements of Practice E 1212. Additional requirements or clarifications are contained in 9.2 through 9.6. The manual shall be of sufficient detail to provide complete guidance for their use by the agency's personnel.

9.1.1 The agency management shall designate a person or persons within the agency who has responsibility for maintaining the agency's quality system. This person(s) shall have direct access to top management. This person shall conduct and document an internal audit at least once every year to verify that the quality system is functioning properly.

9.2 *Process Control (Operational Procedures)*—This section shall contain the information necessary to control the various activities necessary for the examination of materials. Items covered shall include receiving and preparing material, identification and marking, test procedures and specifications to use, reports, and return of material.

9.3 *Personnel Qualification*—The requirements, procedures for training, certification, and recertification for each level of qualification.

9.4 *Equipment Maintenance and Calibration*—This section shall contain all of the following:

9.4.1 *Inventory Listing*—All available equipment shall be listed with the following information noted:

9.4.1.1 Name of the manufacturer.

9.4.1.2 Equipment model and serial number.

9.4.1.3 Characteristics subject to calibration.

9.4.1.4 Range of operation and range of calibration.

9.4.1.5 Reference to recognized standardization procedures acceptable to the authority, if applicable.

9.4.1.6 Frequency of calibration.

9.4.1.7 Allowable tolerances or maximum sensitivity.

9.4.1.8 Source of verification.

9.4.2 *Calibration*—Each instrument or machine, when calibration is required, shall have either a calibration sticker affixed, or record of certification on file, containing the following:

9.4.2.1 Instrument calibrated.

9.4.2.2 Serial number.

9.4.2.3 Calibration date.

9.4.2.4 Calibration next due.

9.4.2.5 Name of individual who performed last calibration. If calibration is not required, a sticker, stating no calibration is necessary shall be affixed, or a record shall be on file to this effect.

9.4.3 The equipment shall be calibrated against currently certified standards calibrated by accepted government or industrial agencies (or shall indicate that it is calibrated as used, or that no calibration is necessary) at least at the following specific intervals in accordance with a written procedure which shall also specify who is to calibrate each equipment type:

9.4.3.1 *Magnetic Particle*:

(1) Timer and Ammeter—Check every 90 days, unless subjected to electrical repair or inadvertently damaged, at which time calibration is required prior to use.

(2) Black Lights—Maintain a minimum level of intensity, as specified by the agency.

(3) Suspension Concentration Test—Check prior to use or daily, whichever is less restrictive.

9.4.3.2 *Penetrant*:

(1) Penetrants and Emulsifiers—Check monthly for contamination.

(2) Dryers—Check monthly for thermostat accuracy.

(3) Black Lights—Maintain a minimum level of intensity, as specified by the agency.

9.4.3.3 *Radiographic*—Calibrate densitometers prior to each use, utilizing calibrated film strips.

9.4.3.4 *Ultrasonic*—The authority shall approve the required calibration intervals.

9.4.3.5 *Leak Testing*:

(1) The equipment shall be calibrated at the beginning of each shift.

(2) The standards shall be calibrated at 6-month intervals.

9.4.3.6 *Eddy Current*—Calibration of the system at the start and end of each run and at the beginning of each shift (or turn) using the reference standard (secondary) is normally required. This or other required calibration intervals shall be approved by the authority.

9.4.3.7 Written records of the results of the checks and calibrations are to be maintained at a central location. The above checks are minimum and do not relieve the responsibility of constantly checking and immediately repairing any item which may affect test results. A history of the repairs, modifications, or substitutions shall be maintained.

9.5 *Equipment Operation and Technique File*:

9.5.1 Each type of equipment in use shall have a complete manual which contains all information necessary to operate and maintain the equipment in accordance with applicable codes and specifications. The manual shall include the maintenance procedures and schedules for each type of equipment and the calibration schedule of each type of equipment.

9.5.2 A technique file should be maintained for each type of equipment. It should be available for the guidance of the technician. The manual shall include:

9.5.2.1 Summary of test procedure.

9.5.2.2 Step-by-step preparation of material for examination.

9.5.2.3 Defect calibration standard, if applicable.

9.5.2.4 Control of essential variables, such as the time required for each test step (if applicable).

9.5.2.5 What indications should appear at each step.

9.5.2.6 Indications and their evaluations.

9.5.2.7 Recording of test results.

9.6 *Records and Documentation*:

9.6.1 *Records*—All applicable records pertaining to 9.2 through 9.5 shall be maintained in a central file and in other accessible files as necessary, and should be available for examination by the authority.

9.6.2 The internal process forms or job record forms shall be filed with the written report to the authority and become a part of the permanent record. They should include the following minimum information:

9.6.2.1 Order and reference numbers.

9.6.2.2 Specification.

9.6.2.3 Type of test and procedure identification.

9.6.2.4 Serial or part numbers, alloy numbers, heat and lot numbers, as applicable.

9.6.2.5 Special instructions from the customer.

9.6.2.6 Customer's (authority's) name.

9.6.2.7 Results of the examination.

9.6.2.8 A notation of all known deviations from any standard test method(s) referenced and all requirements of the test method(s) that were not performed by the agency.

9.6.3 All applicable internal reports should be signed by the technician performing the work and by Level II or Level III personnel. A procedure for auditing of reports by Level III personnel must be included.

9.6.4 Personnel qualification records should be developed in accordance with 8.1 and be available in an active file as long as employment continues. When personnel leave the agency, the records may be transferred to an inactive file but should not be discarded for a period of five years or as otherwise specified.

9.6.5 *Specification File*—The company should maintain an orderly file containing all codes, specifications, and amendments under which it is performing work. The company does not have to possess codes and specifications for which it has no use.

10. Keywords

10.1 equipment calibration; laboratory evaluation; NDT laboratories; personnel certification; quality control; quality manual

ANNEX

(Mandatory Information)

A1. EQUIPMENT FOR NONDESTRUCTIVE TESTING

A1.1 General

A1.1.1 The agency responsible for nondestructive examination of material should be equipped with, or have access to, at least the equipment listed for the applicable processes.

A1.1.2 Nondestructive testing systems can include multiple examination stations with extensive supporting mechanisms and controls. Others may be simply utilizing only manual application of a basic instrument.

NOTE A1.1—Sections A1.2 through A1.8 of the practice are intended to be educational although they do contain some mandatory requirements. Section 2 provides a list of documents which include specific requirements in the applicable test methods.

A1.2 Magnetic Particle Equipment

A1.2.1 *Equipment for Magnetization of Parts* shall be capable of inducing a flux density of sufficient intensity and direction to perform the required examination. Either a-c or d-c (fullwave or half-wave rectified) equipment or permanent magnets shall be used as specified by the contract, purchase order, or specification to produce the required magnetization.

A1.2.1.1 The part or a section of the part may be magnetized by induction or by passing current through the part or section by permanent conductors, contact plates, clamps, or prods. After proper cleaning of the part, the magnetic particles may be applied either wet or dry.

A1.2.1.2 The magnetic field is induced in the part by the use of any of the following:

(1) Yoke—Used to magnetize sections of parts. It is a *U*-shaped iron core with a coil around the cross bar or a *U*-shaped or flexible permanent magnet. The magnetic field across the open ends is used to induce a magnetic field in the part or section. The yoke's fixed or movable legs are used with the open ends in contact with the part. The yoke is normally operated by line voltages (110 or 220 V).

(2) Coil—Used to magnetize parts or sections. It is a current-carrying conductor formed into a coil of several turns. The magnetic field inside the coil is used to induce a magnetic field into the part or section.

(3) Prods—Used to magnetize sections of parts. They are rods, normally ½ to 1 in. (12.7 to 25.4 mm) in diameter and 8 to 10 in. (203 to 254 mm) in length, made of copper with a handle on one end. The ends of a pair of prods are placed on the part and current passed from one prod to the other through the part. The magnetic field is produced in the area between the prods.

(4) Clamps—Used to magnetize sections of parts. They are spring-loaded clamps with braided copper pads on the inside of the jaws. The clamps are clamped onto the part and a current is passed from one clamp to the other through a part.

(5) Pads—Used in stationary equipment to magnetize parts. They are braided copper or lead pads placed at each end of the part. Current is passed from one pad to the other through the part. Pads are normally used with stationary equipment and rigged so that the pads are in contact with the part under pressure.

A1.2.1.3 The coils, prods, clamps, and pads are energized with high-amperage low-voltage currents. Therefore, equipment must be available to transform line current and, when required, to rectify it. The equipment should contain an ammeter to indicate the magnetizing amperage, suitable switches, and, when required, timers to control the length of time that the current is applied. If different amperages are required, the equipment shall produce the maximum required amperage with a suitable control for reducing the amperage to the required lower levels. Cables should be of adequate but not excessive length and large enough to carry the required amperage.

A1.2.1.4 Magnetic particles may be applied either wet or dry. Dry particles should be applied uniformly with a dusting or light blowing action. Wet particles should be applied by aerosol cans or by hosing. Provisions should be available to ensure that the required amount of particles are in suspension when the spray is applied and to periodically check the concentration of the solution.

A1.2.1.5 Adequate lighting shall be available when the parts are viewed for indications. When fluorescent dyed particles are used, ultraviolet light (3200 to 3800 Å (320 to 380 nm)) must be available. Adequate white light must be available when viewing visible dyed particles and should be available for use, as needed, when viewing fluorescent dyed particles.

A1.2.2 *Equipment for Demagnetization* should be capable of demagnetizing all part configurations, to the minimum residual field specified in the specification or purchase document, regardless of size and configuration. Demagnetization is normally accomplished by stepping down a-c or d-c voltage while the direction of the d-c is changed between each step, or by withdrawing the part from an a-c field. Demagnetization can be accomplished by induced fields or by passing a current through the part. Induced fields using coils are generally the most effective method. Facilities should include a coil, cables (when required) and equipment to produce adequate voltages and amperages, reversing and stepdown switches, and a meter to indicate residual external magnetic fields.

NOTE A1.2—See Guide E 709, Reference Photographs E 125, Terminology E 1316, and Practice E 1444 for other requirements for magnetic particle inspection.

A1.3 X- and Gamma-ray Radiographic Equipment

A1.3.1 *Radiation Source*—The radiation source shall be capable of producing sufficient energy and intensity to examine materials in accordance with required specifications. Either X rays or gamma rays may be used unless otherwise specified by the contract, specification, or purchase order.

A1.3.1.1 X-ray equipment should contain voltage and amperage controls (when applicable) and meters, a timer to time the length of the exposure, or other approved controls, and provisions for positioning the tube head and the part being X rayed (when applicable). The voltage and amperage range of the equipment must be adequate to penetrate the thickness of the material to be evaluated and produce acceptable film densities.

A1.3.1.2 Gamma rays are produced by radioactive materials, such as cobalt-60 and iridium-192. Different isotopes emit gamma rays in a specific energy range. The isotope (size, energy level, and strength) should be selected in view of the application (material, thickness, required image quality indicator, sensitivity) and a reasonable exposure time.

A1.3.2 *Safety and Monitoring Equipment* consistent with good practice and current regulations should be available and normally includes safety switches, survey meters, film badges, dosimeters, signs, ropes, lead-lined room, and so forth, as applicable. Also, lead sheet, shot, or leaded rubber should be available to control or reduce scattered radiation.

A1.3.3 *Radiographic Quality Level and Identification Equipment*. Image Quality Indicators (IQI's) are used to evaluate the sensitivity of both setup and processing techniques. They must be made from material that is radiographically similar to, and that represents the specified percentage thickness of the material to be evaluated. The IQI's must be clean and properly identified. Blocks shall be available on which the IQI can be placed during the exposure, if required. The thickness of the blocks should be approximately equal to the thickness of the sections being radiographed and radiographically similar. When exposing nonhomogeneous specimens such as electronic components or other complex structured devices, IQI's shall be selected to produce similar image densities to that of the area of interest of the device being radiographed. Lead numbers and letters of adequate size and thickness should be available for film identification purposes. There should be a sufficient number of each letter and number to put all required identification on the film. However, alternative methods of permanent film identification are permitted. Examples are light box exposures and permanent white ink.

A1.3.4 *Imaging Systems*—The imaging system, that is, film, fluoroscope, and so forth, shall be capable of recording or displaying an image to the sensitivity and contrast required by the applicable specification, purchase order, or contract. Film, or paper if permitted, should be stored in a cool, dry place that is completely protected from direct or scattered radiation (background radiation excluded). Various types of intensifying screens are used in industrial applications, with the most common being lead compound (or lead oxide) and fluorescent. When intensifying screens are employed, they should be clean and free of scratches, wrinkles, surface contamination, and any other conditions that may interfere with the production of a quality radiograph.

A1.3.5 *Processing and Viewing Equipment*—Processing equipment, such as darkroom facilities, densitometers, and so forth, shall be adequate to ensure that the quality intent of the applicable specifications is maintained.

A1.3.5.1 A darkroom or other suitable facility must be available to handle film when loading exposure holders, cutting preloaded strip film, and when removing the film from the holder for processing. The darkroom should be equipped with both safe and white lights and a work area to handle the film.

A1.3.5.2 When hand-processing equipment is used, facilities must be available to process the film, in developer solution, stop bath or fresh water rinse, in fixer, and in a final fresh water rinse (preferably not the rinse used between develop and fix), and should include the use of a film dryer and a timer with an alarm. A time/temperature relationship for film processing must be maintained.

A1.3.5.3 When automatic processing equipment is used, it must be clean and time/temperature relationships and replenishment rates must be maintained.

A1.3.5.4 Facilities for viewing the radiograph and for measuring photographic or optical density must be available. The viewing equipment should include both high- and normal-intensity lights or separate viewers. A light transmission-type densitometer should be available to measure film density. A reflection-type densitometer should be available to measure the density of X-ray paper.

A1.3.6 *Reference Standards*—Reference standards must be in accordance with authority-furnished standards or specifications, or both, and when possible, should be established by the use of the applicable set of ASTM reference radiographs.

NOTE A1.3—See Guides E 94, E 431, and E 592, Practices E 747, E 801, E 1025, and E 1742, Test Methods E 746, E 1030, and E 1032, and Terminology E 1316 for additional information concerning radiographic examination, and Guides E 999 and E 1254 for information on film processing and storage.

A1.4 Neutron Radiographic Equipment

A1.4.1 *Neutron Beam*— The neutron beam shall consist mainly of collimated thermal neutrons, free of excessive scattered neutrons and, for the direct exposure method as defined in Practices E 748, free of excessive gamma radiation. The degree of collimation, (*L/D* ratio) and neutron to gamma ratio shall be sufficient to provide clear images of objects in the area of interest. Other standards or Method E 545, or combinations thereof, should be used as appropriate to verify sensitivity and beam quality.

A1.4.1.1 The neutron source shall provide adequate neutron flux to produce the specified radiographic quality in a timely exposure. The source aperture or other method of collimation must be well defined to provide the image sharpness required. Method E 803 can be used to make an analytical evaluation of *L/D* ratio. The neutron source may be a reactor, accelerator, or radioisotope provided the requirements of the specification can be met.

A1.4.2 *Safety and Monitoring Equipment*, consistent with good practice and current regulations should be available and normally includes area monitors, safety switches, survey meters, film badges, dosimeters, signs, personnel barriers, adequate gamma, and neutron shielding, etc., as appropriate to ensure the safety of operating and visiting personnel.

A1.4.3 *Recording Medium*—Normally, only single-emulsion film is used for direct neutron exposures. Other films that meet the requirements of the specification may be used. The film should be stored in a cool, dry place free of stray radiation. Conversion screens shall be of good quality and maintained in a clean condition. Vacuum cassettes used for exposure should be sufficiently vacuum-tight to maintain pressure contact between the film and conversion screen. Finished films should be free of lint images and excessive film or foil flaws in areas of interest with no scratches or mottling. A dust-free atmosphere, such as a filtered laminar flow work bench, is to be used for loading film into the cassette.

A1.4.4 *Processing Equipment*—Processing equipment, such as darkroom facilities, densitometers, etc., shall be adequate to ensure that the quality intent of the applicable specifications is maintained.

A1.4.4.1 A darkroom or other suitable facility must be available to handle film when loading exposure holders, cutting preloaded strip film, and when removing the film from the holder for processing. The darkroom should be equipped with both safe and white lights and a work area to handle the film.

A1.4.4.2 When hand-processing equipment is used, facilities must be available to process the film in developer solution stop bath or fresh water rinse, in fixer, and in a final fresh water rinse (preferably not the rinse used between develop and fix), and should include the use of a film dryer and a timer with an alarm. A time/temperature relationship for film processing must be maintained.

A1.4.4.3 When automatic processing equipment is used it must be clean and time/temperature relationships and replenishment rates must be maintained.

A1.4.4.4 Facilities for viewing the radiograph and for measuring photographic or optical density must be available. The viewing equipment should include both high- and normal-intensity lights or separate viewers. A light transmission-type densitometer should be available to measure film density.

A1.5 Liquid Penetrant Equipment

A1.5.1 Liquid penetrant inspection equipment consists of the necessary apparatus to apply the penetrant, wash the surface of the part, dry the part, and apply a developer, and a properly lighted area in which the part can be inspected. There are two basic liquid penetrant methods and three types of penetrant systems. Each system requires slightly different facilities and apparatus for proper processing of parts. The two liquid penetrant methods are fluorescent and visible. The three types of penetrant systems are water washable, post-emulsified, and solvent removable (see Test Method E 165).

A1.5.2 Equipment generally consists of either immersion dip tanks or spray apparatus (spray guns, aerosol cans, etc.) or brushing arranged in a logical order to allow for smooth flow of parts when the applicable sequence of operations (penetrant application, dwell, penetrant removal, drying, developing, examination) are followed as specified in Test Method E 165 or other contract documents.

A1.5.3 Adequate lighting shall be available when the parts are viewed for indications. When fluorescent dyed particles are used, ultraviolet light (3200 to 3800 Å (320 to 380 nm)) must be available. Adequate white light must be available when viewing visible dyed particles and should be available for use, as needed, when viewing fluorescent dyed particles.

NOTE A1.4—See Test Method E 165, Terminology E 1316, Reference Photographs E 433, and Practice E 1417 for additional information concerning liquid penetrant inspection.

A1.6 Ultrasonic Equipment

A1.6.1 *Ultrasonic Instrumentation*—The ultrasonic instrumentation shall be capable of generating and detecting pulsed ultrasonic energy over an adequate frequency and power range to ensure proper examination in accordance with the applicable governing specification. The instrumentation and accessories should include, when applicable, ultrasonic unit, search unit, tank, bridge, recorder, couplant, and reference blocks.

A1.6.1.1 *Ultrasonic Unit*— This unit should include a pulser circuit, receiver circuit, CRT display or acceptable equivalent signal display.

A1.6.1.2 *Search Unit*— The cable, search unit, and search tube (when immersion scanning is required).

A1.6.1.3 The ultrasonic unit and search unit as a system should meet the performance requirements of the authority as determined by Practice E 317.

A1.6.1.4 When immersion testing is required, a tank or bubbler system is necessary to furnish a water path between the search unit and the part. The tank should be equipped with a bridge and a manipulating system to hold the search unit. The bridge should be of sufficient strength to provide rigid support for the manipulator.

A1.6.2 *Reference Standards*:

A1.6.2.1 When reference blocks using flat-bottom holes are required, the holes should be processed and monitored in accordance with the requirements of Practices E 428 or E 127.

A1.6.2.2 When contoured surfaces are to be examined, reference standards conforming to the general geometry of the part or section should be used.

A1.6.2.3 Reference standards must be in accordance with authority-furnished standards or specifications, or both, and when possible, should be established by the use of the applicable ASTM standard.

NOTE A1.5—See Practices E 213, E 273, E 127, E 114, E 164, E 214, E 317, E 428, E 587, E 588, E 664, E 797, E 1001, and Terminology E 1316 for additional information concerning ultrasonic testing.

A1.7 Leak Testing

A1.7.1 *Equipment*:

A1.7.1.1 Helium leak testing requires a mass spectrometer that is peaked for helium and that has a sensitivity of at least one decade less than the minimum leakage rate being tested. Pressure chambers capable of withstanding positive and vacuum pressures may be required for some methods.

A1.7.1.2 Radioisotope leak testing requires a tracer gas pressurization system that has been approved and licensed by the appropriate state or federal agencies, or both. Also scintillation crystal detectors and Geiger Mueller counters are required which are capable of detecting emissions of the tracer being used.

A1.7.1.3 Halogen leak testing requires a standard probe-type halogen leak detector.

A1.7.1.4 Bubble leak testing requires baths of the appropriate size that are capable of heating the detector fluid to the specified temperature. Also, pressure vessels may be necessary for pressurization of the test specimens prior to immersion in the detector fluid.

A1.7.2 *Reference Standards*:

A1.7.2.1 The helium leak standard shall have a leak rate at least as small as the limit being tested.

A1.7.2.2 The Krypton 85 standard shall be encapsulated in the same type glass, wall thickness, and geometrical shape as the sample vials used to determine specific activity.

NOTE A1.6—See Practice E 427, Guide E 432, Test Methods E 493, E 498, E 499, and E 515.

A1.7.2.3 The halogen standard, with the response correction factor, shall be so contoured that the maximum leak will read on the upper 9⁄10 of the scale.

A1.8 Electromagnetic (Eddy-Current) Equipment

A1.8.1 *Electronic Apparatus*—The electronic apparatus shall be capable of energizing the test coils or probes with alternating currents of suitable frequencies and power levels and shall be capable of sensing the changes in the electromagnetic response of the sensors. Equipment may include a detector, phase discriminator, filter circuits, modulation circuits, magnetic-saturation devices, display (recorder, scope or meter, or both) and signaling devices as required by a particular application.

A1.8.2 *Test Coils*— 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 standard and sensing changes in the electric and magnetic characteristics of the specimen.

A1.8.3 *Standards*:

A1.8.3.1 *Sorting Standards*—In sorting, known reference standard(s) are required. Refer to Practices E 703 or E 566 for requirements.

A1.8.3.2 *Coating Thickness Measurements Standards*—Calibration standards of uniform thickness are available in either of two types: foil or coated substrate. Refer to Practice E 376 for requirements.

A1.8.3.3 *Conductivity Standards*:

(1) Primary Standards—Those standards which have a value assigned through direct comparison with a standard calibrated by the National Bureau of Standards or have been calibrated by an agency which has access to such standards or have been calibrated using equipment/methods which are traceable to NIST such as d-c resistance measurement techniques. The primary standards are usually kept in a laboratory environment and are used only to calibrate secondary standards.

(2) Secondary Standards—Those standards supplied with the instrumentation or standards constructed by the user for a specific test. These standards are used to calibrate the instrumentation during most examination of materials.

A1.8.3.4 *Discontinuity Standards*:

(1) The standard used to adjust the sensitivity of the apparatus shall be free of interfering discontinuities and shall be of the same nominal alloy, heat treatment, and dimensions as the products to be examined. It shall be of sufficient length to permit the spacing of artificial discontinuities to provide good signal resolution and be mechanically stable while in the examining position in the apparatus. Artificial discontinuities placed in the product to be examined shall be one or more of the following types:

(*a*)*Notches*—Notches may be produced by Electric Discharge Machining (EDM), milling, or other means. Longitudinal or transverse notches, or both, may be used. Orientation, dimensions, configuration, and position of the notches affect the response of the eddy-current system. Refer to Practices E 215, E 243, E 426, E 690, E 571, or E 309 when applicable.

(*b*) *Holes*—Drilled holes may be used. Care should be taken during drilling to avoid distortion of the piece and hole. Refer to Practices E 215, E 243, E 426, E 690, E 571, or E 309 when applicable.

A1.9 Acoustic Emission Equipment

A1.9.1 *Acoustic Emission Instrumentation*—The acoustic emission (AE) instrumentation shall be capable of detection of stress waves (acoustic emission) over an adequate frequency range and propagation distance to ensure a proper examination in accordance with the applicable governing specification. The instrumentation should include, when applicable, sensors, pre-amplifiers, filters, and a processing unit.

A1.9.1.1 *Sensors*—Sensors transform particle motion into electrical signals that can be processed by the instrumentation. Acoustic emission sensors are typically piezoelectric devices, but other types, for example, fiber optic or laser based, may also be used.

A1.9.1.2 *Pre-Amplifiers*—Pre-amplifiers are typically used between the sensors and the processing unit. Pre-amplifiers boost the AE signal from the sensor and provide the electronic drive necessary to assure signal integrity (through long cable distances) to the processing unit.

A1.9.1.3 *Filters*—Both analog and digital filtering can be used to eliminate noise and undesirable acoustic activity (for example, low-frequency machine vibrations), outside of the AE analysis frequency range. Filters can be used in both pre-amplifiers and the processing unit.

A1.9.1.4 *Processing Unit*—The processing unit includes 1 or more AE processing channels, each typically consisting of: a filter, amplifier, data acquisition circuitry, AE signal or feature processing, a user interface (for example, a keyboard or keypad input and display) and data storage or results output capability (for example, pass-fail indicator, bar graph, alpha-numeric readout). The processing unit must be capable of acquiring data and performing data analysis functions per the examination specifications.

A1.9.2 *Reference Standards*

A1.9.2.1 Because of the large variability of acoustic emission sources, due in part to material and loading, reference standards for acoustic emission examination should be specific. Material, geometry and loading conditions should be carefully controlled to provide reference signals for data analysis.

NOTE A1.7—See Practices E 569, E 650, E 749, E 750, E 751, E 1067, E 1118, E 1139, E 1211, E 1419, E 1781, E 1888, E 1930, E 1932, and E 2075 for additional information concerning acoustic emission examination.

APPENDIX

(Nonmandatory Information)

X1. Comparison of Selected NDE Methods

Method	Properties Sensed or Measured	Typical Discontinuities Detected	Representative Applications	Selected ASTM Standards	Advantages	Limitations
X and gamma radiography	Changes in density from voids, inclusions, material variations, placement of internal parts.	Voids, porosity, inclusions, cracks, corrosion.	Castings, weldments, assemblies, explosives, detection of corrosion/ material loss, location/ dimension of internal structures.	E 94 E 431 E 592 E 746 E 747 E 801 E 999 E 1030 E 1032 E 1316 E 1742	Detects internal discontinuities; useful on a wide variety of materials; portable; permanent record.	Relative insensitivity to thin or laminar flaws such as fatigue cracks or delaminations which are perpendicular to the radiation beam.
Neutron radiography	Compositional inhomogeneities; selectively sensitive to particular atomic nuclei.	Presence, absence, or mislocation of components or variations of suitable composition.	Examination of propellant or explosive charge inside closed ammunition or pyrotechnic devices; detection of corrosion.	E 545 E 748 E 803	Good penetration of most structural metals; high sensitivity to favorable materials; permanent record.	Cost; relatively unportable; health hazard.
Liquid penetrant examination	Surface openings.	Cracks, porosity, laps, and seams.	Castings, forgings, weldments, metallic and nonmetallic components.	E 165 E 433 E 1316 E 1417	Inexpensive; easy to apply; portable.	Discontinuity must be open to an accessible surface; false indications often occur.
Eddy current examnation	Changes in electrical and magnetic properties caused by surface and near-surface discontinuities.	Cracks, seams, laps, voids, and variations in alloy composition and heat treatment.	Bars, rods, wire, tubing, local regions of sheet metal, alloy sorting, and thickness gaging.	E 215 E 243 E 309 E 376 E 426 E 566 E 571 E 690 E 703 E 1004 E 1316	Moderate cost; readily automated; portable; permanent record if needed.	Conductive materials only; shallow penetration; geometry sensitive; reference standards often necessary.
Microwave examination	Anomalies in complex dielectric coefficient surface anomalies in conductive materials.	In dielectrics: disbonds voids, and cracks; in metal surfaces: surface cracks.	Glass-fiber-resin structures; plastics; ceramics; moisture content; thickness measurement.		Non contacting; readily automated; rapid inspection.	No penetration of metals; comparatively poor definition of flaws.
Magnetic particle examination	Leakage in magnetic field flux caused by surface or near-surface discontinuities.	Surface or near-surface cracks, laps, voids, and nonmetallic inclusions.	Ferromagnetic products such as weldments, castings, forgings, and extrusions, and other basic steel products.	E 125 E 709 E 1316 E 1444	Stable; inexpensive	Ferromagnetic materials only; surface preparation may be required; false indications often occur.
Magnetic flux leakage examination	Leakage in magnetic field flux caused by surface or near-surface discontinuities.	Surface or near-surface cracks, laps, voids, and nonmetallic inclusions.	Ferromagnetic products such as weldments, castings, forgings, and extrusions, and other basic steel products.	E 570	Sensitivity to typical discontinuities; readily automated; moderate depth penetration; permanent record, if needed.	Ferromagnetic materials only; proper magnetization of part sometimes difficult when parts do not have uniform cross section.
Ultrasonic examination	Changes in acoustic impedance.	Cracks, voids, porosity, lamination, delaminations, and inclusions.	Weldments, plates, tubes, castings, forgings, extrusions; thickness gaging.	E 114 E 127 E 164 E 213 E 214 E 273 E 317 E 428 E 494 E 587 E 588 E 664 E 797 E 1001 E 1316	Excellent penetration; readily automated; good sensitivity and resolution; requires access to only one side; permanent record, if needed.	Requires acoustic coupling to surface; reference standard usually required; highly dependent upon operator skill; relative insensitivity to laminar flaws which are parallel to the sound beam.
Sonic examination	Changes in acoustic impedance.	Disbonds, delaminations, cracks, or voids.	Laminated structures; honeycomb; small parts.		Simple to implement; readily automated; portable.	Geometry sensitive; poor definition.
Ultrasonic holography	Same as ultrasonic examination.	Used primarily for evaluation of discontinuities detected by other methods.	Examination of a limited region of the structure in each image.		Produces a viewable image of discontinuities.	Cost; limited to small regions of the structure; poor definition compared to radiography.

TABLE *Continued*

Method	Properties Sensed or Measured	Typical Discontinuities Detected	Representative Applications	Selected ASTM Standards	Advantages	Limitations
Infrared testing	Surface temperature; anomalies in thermal conductivity or surface emissivity, or both.	Voids or disbonds in nonmetallics; location of hot or cold spots in thermally active assemblies.	Laminated structures; honeycomb; electric and electronic circuits; insulated structures; refractory lined structures and machinery.		Produces a viewable thermal map.	Cost; difficult to control surface emissivity; poor definition.
Strain gages	Mechanical strains.	Not used for detection of discontinuities.	Stress-strain analysis of most materials.		Low cost; reliable.	Insensitive to preexisting strains; small area coverage; requires bonding to surface.
Brittle coatings	Mechanical strains.	Not commonly used for detection of discontinuities.	Stress-strain analysis of most materials.		Low cost; produces large area map of strain field.	Insensitive to preexisting strains.
Optical holography	Mechanical strains.	Disbonds; delaminations; plastic deformation.	Honeycomb; composite structures; tires; precision parts such as bearing elements.		Extremely sensitive, produces map of strain field; permanent record if needed.	Cost; complexity; requires considerable skill.
Leak detection	Pressure changes, bubbles, acoustic hiss, or the passage of a tracer fluid through a pressure boundary.	Leaks in closed systems.	Vacuum systems; gas and liquid storage vessels; piping.	E 427 E 432 E 479 E 493 E 498 E 499 E 515 E 908 E 1316	Good sensitivity; wide range of instrumentation available.	Requires internal and external access to system; contaminants may interfere; can be costly.
Acoustic emission	Stress wave energy generated by growing flaws, areas of high stress, leaks.	Cracks, structural anomalies, leaks, also delamination, fiber fracture and matrix failure in composite materials.	Crack detection and location during proof testing, crack propagation, composite, structures, metal structures, rotating equipment.	E 569 E 650 E 749 E 750 E 751	100% volumetric examination in real time, complicated geometries, very high sensitivity, permanent record, accurate flaw location.	Structure must be loaded, sensors must be in contact with structure.