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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Describes standard techniques and facilities for evaluating surface and subsurface characteristics of metallic/nonmetallic materials. Identifies current nondestructive test methods and ultrasonic test techniques applicable to cannon tubes, cast armor plate, welded joints, projectile fuzes, vehicle track shoes, and other items in which detection of cracks, voids, corrosion, and thickness variations is important. Keywords

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-102
*Test Operations Procedure 3-2-807 — 4 December 1985
AD No.

NONDESTRUCTIVE TESTING OF MATERIALS

1. SCOPE. This TOP describes standard techniques and facilities for conducting nondestructive tests (NDT) of material used in the manufacturing a test item, for determining surface/subsurface characteristics of the material without significantly affecting the item.

Nondestructive tests provide information about structural soundness of material, i.e., they reveal surface/subsurface discontinuities without altering the properties of or damaging the test item. These tests are therefore particularly beneficial during pre-test inspections. As the test progresses, re-examination of the test item will show whether there are any symptoms of failure or extensions of any discontinuities previously noted. Test item failure by fracture or deformation may be analyzed in the laboratory as described in TOP 3-2-806[1]** to determine the nature and cause of failure.

*This TOP supersedes TOP 3-2-807 dated 11 September 1972 and Change 1 dated 14 November 1975.

**Footnote numbers correspond to reference numbers in Appendix B.

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2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENT
Magnetic particles	dry powder; powder suspended in liquid; fluorescent powder suspended in liquid
X-ray machine	
Film and contact screens	

2.2 Instrumentation.

ITEM	PERMISSIBLE ERROR OF MEASUREMENT
Penetrameters	Not applicable
Ultrasonic unit	
Transducers	

3. REQUIRED TEST CONDITIONS. Nondestructive examination of test item material should be conducted in at least five situations:

a. To determine whether the test item is safe to test (e.g., armed fuze)

b. When there are recurring component failures or suspected deficiencies in structural integrity

c. When required by the test plan

d. For conformance with drawings and specification nondestructive test requirements for acceptance tests

e. When directed by higher headquarters

4. TEST PROCEDURES.

4.1 Magnetic Particle Inspection. This is performed to inspect material that can be magnetized for surface/subsurface discontinuities such as cracks, seams, porosity, and inclusions. This technique is limited to magnetic materials and is used for such items as gun tubes and associated components, vehicle track shoes, and high-speed rotors.

4.1.1 Method. The detection capability of this method depends on the intensity of the magnetizing current, the size of the magnetic particles, the size and orientation of discontinuities, and the permeability and retentivity of the material. Micro-cracks can be detected by this method under ideal conditions. Magnetic particle inspection is accomplished by creating an induced magnetic field in the part, applying the magnetic particles while current is flowing, visually inspecting the part, and de-magnetizing the part once the inspection is complete. Perform inspection as follows:

a. Induce a magnetic field in the material to be inspected by either direct magnetization or by placing the part in a magnetic field. Exercise caution when using direct magnetization on finished and hardened surfaces to prevent arcing or overheating at the contact points. This could result in hard spots or micro-cracks. Perform the magnetization of parts such as gun tubes to detect discontinuities perpendicular to the longitudinal and circumferential directions as follows:

(1) Longitudinal. Place the central conductor through the bore of the tube. A current passing through the central conductor sets up a magnetic field perpendicular to the direction of the current. This reveals longitudinal defects in the tube that are at right angles to the lines of force.

(2) Circumferential. Place the tube in a coil. Current passing through the coil induces a magnetic field whose lines of force are perpendicular to circumferential discontinuities. Consult applicable drawings or specifications for proper amperage or ampere turns. (Too low a current will not reveal significant discontinuities, while too high a current will reveal spurious patterns, e.g., flow lines.)

b. Apply the inspection medium of fine magnetic particles, in one of the following forms, to the magnetized surface while the magnetized current is momentarily flowing:

(1) Dry powder
(2) Powder suspended in liquid
(3) Fluorescent powder suspended in liquid

(The magnetic particles collect at the magnetic leakage field created by the discontinuity.)

c. Interpret the collected magnetic particles (referred to as indications) by visual examination under near ultraviolet or black light (approximately 3,650 Å) if a fluorescent powder suspension is used. Standard incandescent illumination is used for nonfluorescent powders.

d. Demagnetize the test item by alternately reversing the current direction and decreasing the amperage.

4.1.2 <u>Data Required</u>. Obtain the following:

a. Description of the item inspected
b. Configuration, size, and location of defects detected
c. Amount and length of time of current application during magnetization; for gun tubes, the number of turns in the coil

4.1.3 <u>Analytical Plan</u>. Compare surface/subsurface discontinuities with available evaluation criteria, e.g., drawing requirement, ASTM specification, military specification, SAE-ASME boiler code. If no acceptance/rejection criteria are available, continued inspection during testing will reveal extension of any previously noted defects. If no discontinuities are recorded during the initial inspection, interim inspections can be used as a tool to bracket the appearance of discontinuities found during subsequent testing.

4.2 <u>Liquid Penetrant Inspection</u>. This is used to inspect either magnetic or nonmagnetic material. Typically, this method is used for inspecting universal joints, machine gun parts, and aluminum mortar baseplates for discontinuities open to the surface of the test item.

4.2.1 <u>Method</u>. The detection capability of this method depends on the penetrant type, the surface condition, and the discontinuity dimension open to the part surface. Pinhole porosity and micro-cracking can be detected by this method. This method remains essentially same, regardless what penetrant is used. The basic steps include surface cleaning, application of the penetrant, removal of excess penetrant, application of the developer, inspection and interpretation. Perform the inspection as follows:

a. Cleaning. The item to be examined must be cleaned since anything that hinders the penetrant from entering the defects will defeat the inspection:

(1) Use a brush, buffer, etc., to remove scale and rust.

(2) Use a solvent to remove grease or oil deposits, e.g., vapor degrease, swab solvent on part.

(3) To avoid masking indications, do not sandblast or shotblast.

b. Penetrant application.

(1) Swab the item with or immerse it in penetrant; several types can be used: color-contrast or dyed kerosene, water wash fluorescent, post-emulsified fluorescent, or water base fluorescent penetrant.

(2) Dwell time, i.e., the time the liquid penetrant remains on the surface of the part, depends on the material, type of defect, and penetrant. Typical dwell times range between 2 and 30 minutes.

c. Removing excess penetrant. Excess penetrant must be removed so that no background penetrant remains to interfere with the defect indications; however, the cleaning operation must not remove the penetrant from the defects. Remove by using one of the following methods:

(1) Wipe the surface using a lint-free rag moistened with a suitable solvent.

(2) Spray solvent on the surface.

(3) Water wash.

(4) Dip in hydrophilic emulsifier (for post-emulsified penetrants).

(5) Immerse in agitated water bath; use coarse spray at 207-345 kPa (30-50 lb/in.^{2}); water temperature 16° to 43° C (60° to 110° F). Avoid overwashing.

(5) Once the excess penetrant is removed, allow the item to dry.

(6) Hot air dryer temperatures are usually maintained between 79° and 107° C (175° and 225° F). Part temperature should not exceed 52° C (125° F) and should be removed from heat when part surface is dry to touch. Excessive dryer time can cause damage to part and evaporation of penetrant.

d. Application of developer. The developer consists of a uniform thickness of fine powder applied over the surface of the part being inspected. Four types of developers are currently used: dry powder, water suspensions of powder, solutions in water, and solvent suspensions of powder. The uniform coating of developer acts as a blotter, absorbing penetrant from the defects and increasing visibility. Developers can be applied by brushing, spraying, or immersing.

e. Inspection and interpretation. Color contrast or dyed kerosene penetrants should be inspected under a standard incandescent "white" light. Fluorescent penetrants should be inspected using near ultraviolet or black light (approximately 3,650 Å). Highest illumination is obtainable by using a mercury vapor spot bulb with a blacklight filter. Both wetbench and portable models are available. Once inspection and interpretation are completed, discontinuities should be visibly marked, and the developer should be removed.

4.2.2 Data Required. Obtain the following:

a. Description of the item inspected

b. Configuration, size, and location of defects detected

c. Type penetrant used

4.2.3 Analytical Plan. Follow instructions specified in 4.1.3.

4.3 Radiographic Inspection. This is performed to inspect the interior conditions of metallic and nonmetallic items such as artillery projectile fuzes, explosive fillers, cast armor plate, and welded joints. This method employs penetrating radiation such as X-rays produced by machine or gamma rays emitted by radioactive isotope. Radiographic inspection is routinely used for detecting cracks, voids, hot tears, and separations, variations in material density, and shrink inclusions and corrosion. It is also used for examining the arrangement of interior components of items such as fuzes. Steel (or equivalent thicknesses of other materials) as thick as 25 cm (10 in.) can be inspected using 4000- and 11,000-kv X-ray machine. Sensitivity and exposure time vary, depending on material density, thickness, geometry of piece, and proper radiographic technique.

4.3.1 Method. Measure detection capability and technique sensitivity by using penetrameters. Normal requirements are 2% of the thickness for detail and contrast sensitivity. Under ideal conditions, sensitivities of 1/2% of thickness can be achieved.

a. Select an X-ray voltage, amperage, and exposure time to conform to the nature of the material to be examined. A long focal distance should be selected to minimize the distortion effect of focal spot size and distance of the defect to the film.

b. Select suitable film and contact screens. The finer grained films render better detail but require increased exposure. The use of chemical intensifying screens should be avoided, when possible, since they reduce detail quality.

c. Place appropriate penetrameters, usually 2% of the thickness of the test item, upon the corresponding part thickness so that they will be between it and the radiation source. Place the film behind the test object. Lead numbers or other means of identification should be used to identify the item and as an orientation device.

d. After exposure is completed, process the film according to the manufacturer's instructions. The processed film shows intensity variations as visible images.

e. When the inspection must be conducted in a remote location (i.e., no water or electricity available) or when the area to be inspected is inaccessible to the X-ray beam, gamma radiography should be employed. Gamma ray sources usually produce lower image contrast than X-rays, thus permitting a larger range of metal thickness to be recorded during one exposure. Lowered image contrast may be objectionable because it results in less than optimum capability to detect defects. Care must be taken in selecting gamma ray sources to ensure that the desired sensitivity can be achieved. Cobalt 60, Iridium 192, and Cesium 137 are examples of gamma ray sources useful for radiography. Permission must be obtained from NRC to acquire, store, and use gamma sources for radiography.

4.3.2 Data Required. Obtain the following:

a. Description of the item inspected

b. X-ray voltage, amperage, exposure time, focal distance, type of film, and screen type and thickness for each exposure

c. The nature and location of flaws in the interior of the test item as interpreted from the images on the film

4.3.3 Analytical Plan. Check subsurface and internal discontinuities (e.g., cavitation in ammunition, porosity in castings, cracks in weldments, shrink and porosity in castings, improper assembly or internal failures in fuzes and recoil mechanisms) for safety, or compare them with specifications for the test item. Internal discontinuities may also be correlated to their effects upon test item functioning or performance.

4.4 Pulse-Echo Ultrasonic Inspection. This method is used to examine subsurface areas of test items for discontinuities or to measure thickness. Examples of items inspected by this method include high-speed impellers, cannon tubes, breechblocks, and weldments. The technique is best suited for lamellar discontinuities oriented parallel to the surface or normal to the direction of sound propagation.

4.4.1 Method. This method can be used to detect discontinuities such as cracks, laminations, and unbonded areas, variations in microstructure or thickness, and lack of fusion. The detection capability depends on the part geometry and the location, size, and orientation of the discontinuity. The pulse-echo ultrasonic inspection can be thought of as complementary to radiographic inspection. Test as follows:

a. Obtain a time/distance calibration of the ultrasonic unit, using the search unit transducer selected for the thickness and type of material to be inspected. Use a calibration standard of known dimensions made of the same material as the test item for this.

b. Apply a suitable couplant (usually oil) for contact inspection, and scan the surface of the test item with the transducer.

c. Note the location of the reflected pulse between the initial pulse signal on the cathode ray tube (CRT) and back surface reflection signal from the test item. This reflected pulse will locate the material discontinuity relative to the front and rear faces of the material being examined.

4.4.2 Data Required. Obtain the following:

a. Description of the item being tested

b. Data necessary to document calibration of the ultrasonic test unit, such as search unit type and frequency, type of calibration block, etc.

c. Test item thickness and location and extent of defects detected by interpretation of the CRT image

4.4.3 Analytical Plan. Compare internal discontinuities in the test item with guidelines. If no guidelines are available, continue investigation during testing to reveal extensions of any previously noted discontinuities or time when they occur.

4.5 Ultrasonic Inspection of Gun Tubes - Normal Beam Technique. This method is used to locate and measure the depth of longitudinal cracks in gun tubes. This is a special application of the pulse-echo technique in which the crack direction is parallel to the direction of sound propagation instead of perpendicular as is normally the case. Ultrasonic inspection can be used for metals ranging from 0.01 cm thick to 1 meter, with sensitivity varying with the thickness. Transducers of lower frequencies are required for the greater thicknesses but result in loss of discontinuity detection capability.

4.5.1 Method.

a. Calibrate the ultrasonic inspection unit by using simulated area amplitude and distance amplitude reference standards made of the same material as the gun tube to be inspected. The reflected area amplitude and distance amplitude signals are displayed as vertical deflections along the horizontal time base line of the CRT.

b. Use a miniature search unit, couplant, and search unit holding device to preclude search unit wobble and to maintain the correct probe-to-test-item alignment.

c. With the sensitivity of the unit tuned to the highest level possible, scan the outer surface of the gun tube with a normal beam probe to detect internal discontinuities. Extreme care is required to note the small signal indications.

d. Supplement the pulse-echo ultrasonic technique with the transmit-and-receive method in order to detect discontinuities near the surface but hidden by the near-zone interference.

e. In many gun tubes, large hoops obscure areas likely to contain discontinuities. To facilitate inspection with ultrasonics, remove such barriers. When this is not feasible, supplement ultrasonic testing with magnetic particle inspection.

4.5.2 Data Required. Obtain the following:

a. Description of the item being inspected

b. For discontinuities (other than radial cracks) larger than the beam spread: depth, length, direction, and location

c. For discontinuities contained within the beam spread: location and equivalent flaw diameters

4.5.3 Analytical Plan. Compare internal discontinuities in the gun tube with available guidelines. If none is available, continue investigation during testing to reveal extensions of any previously noted discontinuities or time when they occur.

4.6 Miscellaneous Nondestructive Test Methods. The NDT methods described in paragraphs 4.1 through 4.5 are those most frequently used by Army test agencies. There are many others, however, used in industry and Government for special applications. These are all contained in Table 1 for quick reference and comparison. Some of these are not available at each TECOM proving ground. Specialized ultrasonic techniques occasionally used at proving grounds are described in Appendix A.

TABLE 1
CURRENT NONDESTRUCTIVE TESTING METHODS

Method	Measures or Detects	Applications	Advantages	Limitations
Acoustic emission	Crack initiation and growth rate. Internal cracking in welds during cooling. Boiling or cavitation. Friction or wear.	Pressure vessels. Stressed structures. Turbine or gear boxes. Fracture mechanics research. Weldments.	Remote and continuous surveillance. Permanent record. Dynamic (rather than static) detection of cracks. Portable.	Transducers must be placed on part surface. Highly ductile materials yield low-amplitude emissions. Part must be stressed or operating. Test system noise needs to be filtered out.
Acoustic-impact (tapping)	Debonded areas or delaminations in metal or nonmetal composites or laminates. Cracks under bolt or fastener heads. Cracks in turbine wheels or turbine blades. Loose rivets or fastener heads. Crushed core.	Brazed or adhesive structure. Bolted or riveted assemblies. Turbine blades. Turbine wheels.	Portable. Easy to operate. Can be automated. Permanent record or positive meter readout. No couplant required.	Part geometry and mass influences test results. Impactor and probe must be repositioned to fit geometry of part. Reference standards required.

TABLE 1 (continued)

Method	Measures or Detects	Applications	Advantages	Limitations
Eddy current	Surface and subsurface cracks and seams. Alloy content. Heat treatment variations. Wall thickness, coating thickness. Crack depth, Metal sorting.	Tubing. Wire. Ball bearings. "Spot checks" on all types of surfaces. Proximity gage. Metal detector.	No special operator skills required. High speed, low cost. Automation possible for symmetrical parts. Permanent record capability for symmetrical parts. No couplant or probe contact required.	Conductive materials. Shallow depth of penetration (thin walls only). Masked or false indications caused by sensitivity to variations, such as part geometry. Reference standards required. Permeability.
Electric current	Cracks. Crack depth, Resistivity. Wall thickness. Corrosion-induced wall-thinning.	Metallic materials. Electrically conductive materials. Train rails. Nuclear fuel elements.	Access to only one surface required. Battery or DC source. Portable.	Edge effect. Surface contamination. Good surface contact required. Difficult to automate. Electrode spacing. Reference standards required.
Electrified particle	Surface defects in nonconducting material. Through-to-metal pinholes on metal-backed material. Tension, compression, cyclic cracks. Brittle-coating stress cracks.	Glass. Porcelain enamel. Nonhomogeneous materials such as plastic or asphalt coatings. Glass-to-metal seals.	Portable. Useful on materials not practical for penetrant inspection.	Poor resolution on thin coatings. False indications from moisture streaks or lint. Atmospheric conditions. High voltage discharge.

TABLE 1 (continued)

Method	Measures or Detects	Applications	Advantages	Limitations
Holography (interferometry)	Strain. Plastic deformation. Cracks. Debonded areas. Voids and inclusions. Vibration.	Bonded and composite structures. Automotive or aircraft tires. Three-dimensional imaging.	Surface of test object can be uneven. No special surface preparations or coatings required. No physical contact with test specimen.	Vibration-free environment is required. Heavy base to dampen vibrations. Difficult to identify type of flaw detected.
Infrared (radiometers)	Lack of bond. Hot spots. Heat transfer. Isotherms. Temperature ranges.	Brazed joints. Adhesive-bonded joints. Metallic platings or coatings; debonded areas or thickness. Electrical assemblies. Temperature monitoring.	Sensitive to 1.5°F temperature variation. Permanent record or thermal picture. Quantitative. Remote sensing; need not contact part. Portable.	Liquid-nitrogen-cooled detector. Critical time-temperature relationship. Poor resolution for thick specimens. Reference standards required.
Leak testing	Leaks.	Joints: Welded. Brazed. Adhesive-bonded. Sealed assemblies. Pressure or vacuum chambers. Fuel or gas tanks.	High sensitivity to extremely small, tight separations not detectable by other NDT methods. Sensitivity related to method selected.	Accessibility to both surfaces of part required. Smeared metal or contaminants can prevent detection. Cost related to sensitivity.
Magnetic field	Cracks. Wall thickness. Hardness. Coercive force. Magnetic anisotropy. Magnetic field. Nonmagnetic coating thickness on steel.	Ferromagnetic materials. Ship degaussing. Liquid level control. Mine detection. Wall thickness of nonmetallic materials. Material sorting.	Measurement of magnetic material properties. Can be automated. Easily detects magnetic objects in nonmagnetic material. Portable.	Permeability. Reference standards required. Edge-effect. Probe lift-off.

TABLE 1 (continued)

Method	Measures or Detects	Applications	Advantages	Limitations
Magnetic particles	Surface and slightly subsurface defects; cracks, seams, porosity, inclusions. Permeability variations. Extremely sensitive for locating small tight cracks.	Ferromagnetic materials; bar, forgings, weldments, extrusions, etc.	Advantage over penetrant in that it indicates subsurface defects, particularly inclusions. Relatively fast and low cost. Can be portable.	Alignment of magnetic field is critical. Demagnetization of parts required after tests. Parts must be cleaned before and after inspection. Masking by surface coatings.
Microwave	Cracks, holes, debonded areas, etc. in nonmetallic parts. Changes in composition, degree of cure, moisture content. Thickness measurement. Dielectric constant.	Reinforced plastics. Chemical products. Ceramics. Resins. Rubber. Wood. Liquids. Polyurethane foam. Radomes.	Between radio waves and infrared in the electromagnetic spectrum. Portable. Contact with part surface not normally required. Can be automated.	Will not penetrate metals. Reference standards required. Horn to part spacing critical. Part geometry.
Neutron activation analysis	Radiation emission resulting from neutron activation. Oxygen in steel. Nitrogen in food products. Silicon in metals and ores.	Metallurgical. On-line process control of liquids or solid materials.	Automatic systems. Accurate (ppm range). Fast. No contact with sample. Sample preparation minimal.	Radiation hazard. Not portable. Fast decay time.
Penetrants	Defects open to surface of parts; cracks, porosity, seams, laps, etc. Through-wall leaks.	All parts with non-absorbing surfaces (forgings, weldments, castings, etc.) Note: Bleed-out from porous surfaces can mask indications of defects.	Low costs. Portable. Indications can be further examined visually. Results easily interpreted.	Surface films, such as coatings, scale, and smeared metal can prevent detection of defects. Parts must be cleaned before and after inspection. Defect must be open to surface.

TABLE 1 (continued)

Method	Measures or Detects	Applications	Advantages	Limitations
Radiography (thermal neutron)	Hydrogen contamination of titanium or zirconium alloys. Defective or improperly loaded pyrotechnic devices. Improper assembly of metal, nonmetal parts.	Pyrotechnic devices. Metallic, nonmetallic assemblies. Biological specimens.	High neutron absorption by hydrogen, boron, lithium, cadmium, uranium, plutonium. Low neutron absorption by most metals. Complements X-ray or gamma-ray radiography.	Nuclear reactor or accelerator required. Trained operators required for accelerators. Radiation hazard. Nonportable. Indium or gadolinium screens required.
Radiography (gamma rays)	Internal defects and variations, porosity. Inclusions, cracks, lack of fusion, geometry variations, corrosion.	Usually when X-ray machines are not suitable because source cannot be placed in part with small openings and/or power source not available.	Low initial cost. Permanent records; film. Small sources can be placed in parts with small openings. Portable. Low contrast.	One energy level per source. Source decay. Radiation hazard. Trained operators needed. Lower image resolution. Cost related to energy range.
Radiography (X-rays-film and image tubes)	Internal defects and variations; porosity, inclusions, cracks, lack of fusion, geometry variations, corrosion. Density variations.	Castings. Electrical assemblies. Weldments. Small, thin, complex wrought products. Nonmetallics. Solid propellant rocket motors.	Permanent records; film. Adjustable energy levels. High sensitivity to density changes. No couplant required. Geometry variations do not affect direction of X-ray beam.	Orientation of linear defects in part can not be favorable. Radiation hazard. Depth of defect not indicated. Sensitivity decreases with increase in scattered radiation.
Radiometry (X-ray, gamma-ray, beta-ray)	Wall thickness. Plating thickness. Variations in density or composition. Fill level in cans or containers. Inclusions or voids.	Sheet, plate, strip, tubing. Nuclear reactor fuel rods. Cans or containers. Plated parts.	Fully automatic. Fast. Extremely accurate. In-line process control. Portable.	Radiation hazard. Beta-ray useful for ultra-thin coatings only. Source decay. Reference standards required.

TABLE 1 (continued)

Method	Measures or Detects	Applications	Advantages	Limitations
Sonic	Debonded areas or delaminations in metal or nonmetal composites or laminates. Cohesive bond strength under controlled conditions. Crushed or fractured core. Bond integrity of metal insert fasteners.	Metal or nonmetal composite or laminates brazed or adhesive-bonded. Plywood. Rocket motor nozzles. Honeycomb.	Portable. Easy to operate. Locates far-side debonded areas. Can be automated. Access to only one surface required.	Surface geometry influences test results. Reference standards required. Adhesive or core thickness variations influence results.
Thermoelectric	Thermoelectric potential. Coating thickness. Physical properties. Thompson effect. P-N junctions in semiconductors.	Metal sorting. Ceramic coating thickness on metal. Semiconductors.	Portable. Simple to operate. Access to only one surface required.	Hot probe. Difficult to automate. Reference standards required. Surface contaminants. Conductive coatings.
Ultrasonic	Internal defects and variations; cracks, lack of fusion, porosity, inclusions, delaminations, lack of bond, texturing. Thickness or velocity. Poisson's ratio elastic modulus.	Wrought metals. Welds. Brazed Joints. Adhesive-bonded, joints. Nonmetallics. In-service parts.	Most sensitive to cracks. Test results known immediately. Automating and permanent record, capability. Portable. High-penetration capability.	Couplant required. Small, thin, complex parts can be difficult to check. Reference standards required. Trained operators for inspection.

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APPENDIX A

ADDITIONAL ULTRASONIC TEST TECHNIQUES

The following is a general description of ultrasonic test techniques other than the contact reflection and contact normal beam techniques discussed in paragraphs 4.4 and 4.5.

1. Transmission Technique. When both sides of the test item are accessible, the contact transmission technique can be used to inspect the test item. This method employs a transmitting crystal on one surface and a receiving crystal directly opposite on the other surface. The time delay between transmission and reception of pulse is calibrated in terms of the material thickness.

2. Resonance Technique. Ultrasonic resonance is used for measuring material thickness when access is possible from one or both sides. By varying the wavelength of the incident ultrasonic beam, one can establish points of material resonance. This facilitates thickness determination, since resonance occurs whenever the thickness of the specimen is equal to an integral number of half wavelengths of the ultrasonic wave.

a. Resonance instruments with direct-reading thickness scales will yield accurate results only when calibrated with test blocks of known thickness and alloy composition. Two or more test blocks within the range of the direct reading scale can be used for instrument calibration. The length and width of the test block should be at least twice and preferably five times the thickness. In case of thick test blocks, slots should be cut into the edges to avoid wave interference from side reflections.

b. Calibration is accomplished using tuned circuits and a matched set of transducers, coaxial cables, oscillator, and thickness reading screen. Only matched sets of components should be used for calibration and thickness measurements. The minimum thickness of resonance instruments is about 0.013 cm in steel and aluminum and 0.01 cm in brass and copper. The maximum thickness that can be measured depends upon inspection frequency and instrument design; it normally varies between 7.6 and 30 cm (3 and 12 in.).

3. Immersion Testing. Ultrasonic immersion testing is especially useful for inspecting weldments and parts with rough surfaces. The test item must be completely immersed in water or other suitable couplant. The transducer is then located some distance away from the part surface. Either the angle or normal beam inspection mode can be used in this technique depending on the geometry of the test item and suspected defect orientation. Irregularly shaped parts such as asymetrical forgings can be given a complete inspection, including fillet areas. This type of part cannot be inspected by the contact method by practical means. Two advantages of immersion testing (namely, c-scan mapping and speed of inspection) can be achieved during the inspection of symmetrical parts.

APPENDIX B

REFERENCES

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