CHAPTER 5. NONDESTRUCTIVE INSPECTION (NDI)

SECTION 1. GENERAL

5-1. GENERAL. The field of NDI is too varied to be covered in detail in this Advisory Circular (AC). This chapter provides a brief description of the various Nondestructive Testing (NDT) used for inspection of aircraft, powerplant, and components in aircraft inspection. The effectiveness of any particular method of NDI depends upon the skill, experience, and training of the person(s) performing the inspection process. Each process is limited in its usefulness by its adaptability to the particular component to be inspected. Consult the aircraft or product manufacturer's manuals for specific instructions regarding NDI of their products. (Reference AC 43-3, Nondestructive Testing in Aircraft, for additional information on NDI.

The product manufacturer or the Federal Aviation Administration (FAA) generally specifies the particular NDI method and procedure to be used in inspection. These NDI requirements will be specified in the manufacturer's inspection, maintenance, or overhaul manual; FAA Airworthiness Directives (AD); Supplemental Structural Inspection Documents (SSID); or manufacturer's service bulletins (SB). However, in some conditions an alternate NDI method and procedure can be used. This includes procedures and data developed by FAA certificated repair stations under Title 14 of the Code of Federal Regulations, (14 CFR), part 145.

5-2. APPROVED PROCEDURES. Title 14 CFR, part 43 requires that all maintenance be performed using methods, techniques, and practices prescribed in the current manufacturer's maintenance manual or instructions for continued airworthiness prepared by its manufacturer, or other methods, techniques, and practices acceptable to the administrator. If the maintenance instructions include materials, parts, tools, equipment, or test apparatus necessary to comply with industry practices then those items are required to be available and used as per part 43.

5-3. NDT LEVELS. Reference Air Transport Association (ATA) Specification 105-Guidelines For Training and Qualifying Personnel In Nondestructive Testing Methods.

a. Level I Special.

Initial classroom hours and on-the-job training shall be sufficient to qualify an individual for certification for a specific task. The individual must be able to pass a vision and color perception examination, a general exam dealing with standards and NDT procedures, and a practical exam conducted by a qualified Level II or Level III certificated person.

b. Level I/Level II.

The individual shall have an FAA Airframe and Powerplant Mechanic Certificate, complete the required number of formal classroom hours, and complete an examination.

c. Level III.

(1) The individual must have graduated from a 4 year college or university with a degree in engineering or science, plus 1 year of minimum experience in NDT in an assignment comparable to that of a Level II in the applicable NDT methods: or

(2) The individual must have 2 years of engineering or science study at a university, college, or technical school, plus 2 years of experience as a Level II in the applicable NDT methods: or

(3) The individual must have 4 years of experience working as a Level II in the applicable NDT methods and complete an examination.

5-4. TRAINING, QUALIFICATION, AND CERTIFICATION. The success of any NDI method and procedure depends upon the knowledge, skill, and experience of the NDI personnel involved. The person(s) responsible for detecting and interpreting indications, such as eddy current, X-ray, or ultrasonic NDI, must be qualified and certified to specific FAA, or other acceptable government or industry standards, such as MIL-STD-410, Nondestructive Testing Personnel Qualification and Certification, or Air Transport Association (ATA) Specification 105-Guidelines for Training and Qualifying Personnel in Nondestructive Testing Methods. The person should be familiar with the test method, know the potential types of discontinuities peculiar to the material, and be familiar with their effect on the structural integrity of the part.

5-5. FLAWS. Although a specific discussion of flaws and processes will not be given in this AC, the importance of this area should not be minimized. Inspection personnel should know where flaws occur or can be expected to exist and what effect they can have in each of the NDI test methods. Misinterpretation and/or improper evaluation of flaws or improper performance of NDI can result in serviceable parts being rejected and defective parts being accepted.

All NDI personnel should be familiar with the detection of flaws such as: corrosion, inherent flaws, primary processing flaws, secondary processing or finishing flaws, and in-service flaws. The following paragraphs classify and discuss the types of flaws or anomalies that may be detected by NDI.

a. Corrosion. This is the electrochemical deterioration of a metal resulting from chemical reaction with the surrounding environment. Corrosion is very common and can be an extremely critical defect. Therefore, NDI personnel may devote a significant amount of their inspection time to corrosion detection.

b. Inherent Flaws. This group of flaws is present in metal as the result of its initial solidification from the molten state, before any of the operations to forge or roll it into useful sizes and shapes have begun. The following are brief descriptions of some inherent flaws.

(1) Primary pipe is a shrinkage cavity that forms at the top of an ingot during metal solidification, which can extend deep into the ingot. Failure to cut away all of the ingot shrinkage cavity can result in unsound metal, called pipe, that shows up as irregular voids in finished products.

(2) Blowholes are secondary pipe holes in metal that can occur when gas bubbles are trapped as the molten metal in an ingot mold solidifies. Many of these blowholes are clean on the interior and are welded shut into sound metal during the first rolling or forging of the ingot. However, some do not weld and can appear as seams or laminations in finished products.

(3) Segregation is a nonuniform distribution of various chemical constituents that can occur in a metal when an ingot or casting solidifies. Segregation can occur anywhere in the metal and is normally irregular in shape. However, there is a tendency for some constituents in the metal to concentrate in the liquid that solidifies last.

(4) Porosity is holes in a material's surface or scattered throughout the material, caused by gases being liberated and trapped as the material solidifies.

(5) Inclusions are impurities, such as slag, oxides, sulfides, etc., that occur in ingots and castings. Inclusions are commonly caused by incomplete refining of the metal ore or the incomplete mixing of deoxidizing materials added to the molten metal in the furnace.

(6) Shrinkage cracks can occur in castings due to stresses caused by the metal contracting as it cools and solidifies.

c. Primary Processing Flaws. Flaws which occur while working the metal down by hot or cold deformation into useful shapes such as bars, rods, wires, and forged shapes are primary processing flaws. Casting and welding are also considered primary processes although they involve molten metal, since they result in a semi-finished product. The following are brief descriptions of some primary processing flaws:

(1) Seams are surface flaws, generally long, straight, and parallel to the longitudinal axis of the material, which can originate from ingot blowholes and cracks, or be introduced by drawing or rolling processes.

(2) Laminations are formed in rolled plate, sheet, or strip when blowholes or internal fissures are not welded tight during the rolling process and are enlarged and flattened into areas of horizontal discontinuities.

(3) Cupping is a series of internal metal ruptures created when the interior metal does not flow as rapidly as the surface metal during drawing or extruding processes. Segregation in the center of a bar usually contributes to the occurrence.

(4) Cooling cracks can occur in casting due to stresses resulting from cooling, and are often associated with changes in cross sections of the part. Cooling cracks can also occur when alloy and tool steel bars are rolled and subsequently cooled. Also, stresses can occur from uneven cooling which can be severe enough to crack the bars. Such cracks are generally longitudinal, but not necessarily straight. They can be quite long, and usually vary in depth along their length.

(5) Flakes are internal ruptures that can occur in metal as a result of cooling too rapidly. Flaking generally occurs deep in a heavy section of metal. Certain alloys are more susceptible to flaking than others.

(6) Forging laps are the result of metal being folded over and forced into the surface, but not welded to form a single piece. They can be caused by faulty dies, oversized dies, oversized blanks, or improper handling of the metal in the die. They can occur on any area of the forging.

(7) Forging bursts are internal or external ruptures that occur when forging operations are started before the material to be forged reaches the proper temperature throughout. Hotter sections of the forging blank tend to flow around the colder sections causing internal bursts or cracks on the surface. Too rapid or too severe a reduction in a section can also cause forging bursts or cracks.

(8) A hot tear is a pulling apart of the metal that can occur in castings when the metal contracts as it solidifies.

(9) A cold shut is a failure of metal to fuse. It can occur in castings when part of the metal being poured into the mold cools and does not fuse with the rest of the metal into a solid piece.

(10) Incomplete weld penetration is a failure of the weld metal to penetrate completely through a joint before solidifying.

(11) Incomplete weld fusion occurs in welds where the temperature has not been high enough to melt the parent metal adjacent to the weld.

(12) Weld undercutting is a decrease in the thickness of the parent material at the toe of the weld caused by welding at too high a temperature.

(13) Cracks in the weld metal can be caused by the contraction of a thin section of the metal cooling faster than a heavier section or by incorrect heat or type of filler rod. They are one of the more common types of flaws found in welds.

(14) Weld crater cracks are star shaped cracks that can occur at the end of a weld run.

(15) Cracks in the weld heat-affected zone can occur because of stress induced in the material adjacent to the weld by its expansion and contraction from thermal changes.

(16) A slag inclusion is a nonmetallic solid material that becomes trapped in the weld metal or between the weld metal and the base metal.

(17) Scale is an oxide formed on metal by the chemical action of the surface metal with oxygen from the air.

d. Secondary Processing or Finishing Flaws. This category includes those flaws associated with the various finishing operations, after the part has been rough-formed by rolling, forging, casting or welding. Flaws may be introduced by heat treating, grinding, and similar processes. The following are brief descriptions of some secondary processing or finishing flaws.

(1) Machining tears can occur when working a part with a dull cutting tool or by cutting to a depth that is too great for the material being worked. The metal does not break away clean, and the tool leaves a rough, torn surface which contains numerous short discontinuities that can be classified as cracks.

(2) Heat treating cracks are caused by stresses setup by unequal heating or cooling of portions of a part during heat treating operations. Generally, they occur where a part has a sudden change of section that could cause an uneven cooling rate, or at fillets and notches that act as stress concentration points.

(3) Grinding cracks are thermal type cracks similar to heat treating cracks and can occur when hardened surfaces are ground. The overheating created by the grinding can be caused by the wheel becoming glazed so that it rubs instead of cutting the surface; by using too little coolant; by making too heavy a cut; or by feeding the material too rapidly. Generally, the cracks are at right angles to the direction of grinding and in severe cases a complete network of cracks can appear. Grinding cracks are usually shallow and very sharp at their roots, which makes them potential sources of fatigue failure.

(4) Etching cracks can occur when hardened surfaces containing internal residual stresses are etched in acid.

(5) Plating cracks can occur when hardened surfaces are electroplated. Generally, they are found in areas where high residual stresses remain from some previous operation involving the part.

e. In-Service Flaws. These flaws are formed after all fabrication has been completed and the aircraft, engine, or related component has gone into service. These flaws are attributable to aging effects caused by either time, flight cycles, service operating conditions, or combinations of these effects. The following are brief descriptions of some in-service flaws.

(1) Stress corrosion cracks can develop on the surface of parts that are under tension stress in service and are also exposed to a corrosive environment, such as the inside of wing skins, sump areas, and areas between two metal parts of faying surfaces.

(2) Overstress cracks can occur when a part is stressed beyond the level for which it was designed. Such overstressing can occur as the result of a hard landing, turbulence, accident, or related damage due to some unusual or emergency condition not anticipated by the designer, or because of the failure of some related structural member.

(3) Fatigue cracks can occur in parts that have been subjected to repeated or changing loads while in service, such as riveted lap joints in aircraft fuselages. The crack usually starts at a highly-stressed area and propagates through the section until failure occurs. A fatigue crack will start more readily where the design or surface condition provides a point of stress concentration. Common stress concentration points are: fillets; sharp radii; or poor surface finish, seams, or grinding cracks.

(4) Unbonds, or disbonds, are flaws where adhesive attaches to only one surface in an adhesive-bonded assembly. They can be the result of crushed, broken, or corroded cores in adhesive-bonded structures. Areas of unbonds have no strength and place additional stress on the surrounding areas making failure more likely.

(5) Delamination is the term used to define the separation of composite material layers within a monolithic structure. Ultrasonic is the primary method used for the detection of delamination in composite structures.

5-6. SELECTING THE NDI METHOD. The NDI method and procedure to be used for any specific part or component will generally be specified in the aircraft or component manufacturer's maintenance or overhaul manuals, SSID's, SB's, or in AD's.

NOTE: Some AD's refer to SB's which may, in turn, refer to manufacturer's overhaul or maintenance manuals.

a. Appropriate Method. The appropriate NDI method may consist of several separate inspections. An initial inspection may indicate the presence of a possible flaw, but other inspections may be required to confirm the original indication. Making the correct NDI method selection requires an understanding of the basic principles, limitations, and advantages and disadvantages of the available NDI methods and an understanding of their comparative effectiveness and cost.

b. Other Factors. Other factors affecting the inspection are:

(1) The critical nature of the component;

(2) The material, size, shape, and weight of the part;

(3) The type of defect sought;

(4) Maximum acceptable defect limits in size and distribution;

(5) Possible locations and orientations of defects;

(6) Part accessibility or portability; and

(7) The number of parts to be inspected.

c. Degree of Inspection. The degree of inspection sensitivity required is an important factor in selecting the NDI method. Critical parts that *cannot* withstand small defects and could cause *catastrophic failure* require the use of the more sensitive NDI methods. Less critical parts and general hardware generally require less-sensitive NDI methods.

d. Material Safety Data Sheets (MSDS). The various materials used in NDI may contain chemicals, that if improperly used, can be hazardous to the health and safety of operators and the safety of the environment, aircraft, and engines. Information on safe handling of materials is provided in MSDS. MSDS, conforming to Title 29 of the Code of Federal Regulations (29 CFR), part 1910, section 1200, or its equivalent, must be provided by the material supplier to any user and must be prepared according to FED-STD-313.

e. Advantages and Disadvantages. Table 5-1 provides a list of the advantages and disadvantages of common NDI methods. Table 5-1, in conjunction with other information in the AC, may be used as a guide for evaluating the most appropriate NDI method when the manufacturer or the FAA has not specified a particular NDI method to be used.

5-7. TYPES OF INSPECTIONS. Nondestructive testing methods are techniques used both in the production and in-service environments without damage or destruction of the item under investigation. Examples of NDI methods are as follows:

a. Visual inspection

b. Magnetic particle

c. Penetrants

d. Eddy current

e. Radiography

f. Ultrasonic

g. Acoustic emission

h. Thermography

i. Holography

j. Shearography

k. Tap testing

TABLE 5-1. Advantages and disadvantages of NDI methods.

METHOD	ADVANTAGES	DISADVANTAGES
VISUAL	Inexpensive Highly portable Immediate results Minimum training Minimum part preparation	Surface discontinuities only Generally only large discontinuities Misinterpretation of scratches
DYE PENETRANT	Portable Inexpensive Sensitive to very small discontinuities 30 min. or less to accomplish Minimum skill required	Locate surface defects only Rough or porous surfaces interfere with test Part preparation required (removal of finishes and sealant, etc.) High degree of cleanliness required Direct visual detection of results required
MAGNETIC PARTICLE	Can be portable Inexpensive Sensitive to small discontinuities Immediate results Moderate skill required Detects surface and subsurface discontinuities Relatively fast	Surface must be accessible Rough surfaces interfere with test Part preparation required (removal of finishes and sealant, etc.) Semi-directional requiring general orientation of field to discontinuity Ferro-magnetic materials only Part must be demagnetized after test.
EDDY CURRENT	Portable Detects surface and subsurface discontinuities Moderate speed Immediate results Sensitive to small discontinuities Thickness sensitive Can detect many variables	Surface must be accessible to probe Rough surfaces interfere with test Electrically conductive materials Skill and training required Time consuming for large areas
ULTRASONIC	Portable Inexpensive Sensitive to very small discontinuities Immediate results Little part preparation Wide range of materials and thickness can be inspected	Surface must be accessible to probe Rough surfaces interfere with test Highly sensitive to sound beam - discontinuity orientation High degree of skill required to set up and interpret Couplant usually required
X-RAY RADIOGRAPHY	Detects surface and internal flaws Can inspect hidden areas Permanent test record obtained Minimum part preparation	Safety hazard Very expensive (slow process) Highly directional, sensitive to flaw orientation High degree of skill and experience required for exposure and interpretation Depth of discontinuity not indicated
ISOTOPE RADIOGRAPHY	Portable Less expensive than X-ray Detects surface and internal flaws Can inspect hidden areas Permanent test record obtained Minimum part preparation	Safety hazard Must conform to Federal and State regulations for handling and use Highly directional, sensitive to flaw orientation High degree of skill and experience required for exposure and interpretation Depth of discontinuity not indicated

5-8.—5-14. [RESERVED.]