U.S. Department
of Transportation
**Federal Aviation
Administration**

**AC 43-3
AC 43-7**

# NONDESTRUCTIVE & ULTRASONIC TESTING FOR AIRCRAFT

**Reprinted by Aviation Supplies & Academics, Inc.**

U.S. Department
of Transportation
**Federal Aviation
Administration**

**AC 43-3
AC 43-7**

# NONDESTRUCTIVE & ULTRASONIC TESTING FOR AIRCRAFT

AC 43-3
**Nondestructive Testing**

1 Introduction
2 Radiographic Inspection
3 Penetrant Inspection
4 Magnetic Particle Inspection
5 Eddy Current Inspection
6 Ultrasonic Inspection
7 Visual Inspection
8 New Applications for Nondestructive Testing
Appendices

AC 43-7
**Ultrasonic Testing**

1 Introduction
2 Transducers (Search Units, Probes, Crystals)
3 Wave Propagation
4 Ultrasonic Vibrations
5 Ultrasonic Systems
6 Presentation
7 Recorders
8 Electronic Gating
9 Delay Line
10 Couplant
11 Ultrasonic Reference Blocks
12 Testing Methods
13 Inspection of Intergral Fuel Tanks for Corrosion
14 Inspection of Representative Aircraft Parts

SAMPLE

**Reprinted by
Aviation Supplies & Academics, Inc.**
7005 132nd Place SE
Newcastle, WA 98059

**ASA-AC43-3-7**
ISBN 1-56027-106-X
978-1-56027-106-2

Printed in the United States of America

# TABLE OF CONTENTS

## Chapter 1. INTRODUCTION


| | Page |
|---|---|
| 1. Purpose | 1 |
| 2. Cancellation | 1 |
| 3. Types of Inspection | 1 |
| 4. Inspection Illustrations | 2 |
| 5. Common Failures | 2 |
| 6. Inspection Techniques | 3 |
| 7. Selecting Inspection Method | 3 |
| 8. Inspection of Airplane | 3 |
| 9. Inspection of Parts | 5 |


## Chapter 2. RADIOGRAPHIC INSPECTION


| | |
|---|---|
| 10. General | 6 |
| 11. Aircraft Preparation | 6 |
| 12. Radiographic Equipment | 6 |
| 13. Inspection Technique | 6 |
| 14. Principles of Radiography | 6 |
| 15. Safety | 8 |
| 16. Interpreting Film | 8 |


## Chapter 3. PENETRANT INSPECTION


| | |
|---|---|
| 17. General | 11 |
| 18. Penetrant Inspection Technique | 11 |


## Chapter 4. MAGNETIC PARTICLE INSPECTION


| | |
|---|---|
| 19. General | 15 |


## Chapter 5. EDDY CURRENT INSPECTION


| | |
|---|---|
| 20. General | 19 |
| 21. Types of Equipment | 19 |
| 22. Inspection Procedure | 20 |
| 23. Area Inspection | 21 |
| 24. Representative Eddy Current Inspections | 22 |
| 25. Eddy Current Guidelines | 22 |
| 26. Reserved. | |


## Chapter 6. ULTRASONIC INSPECTION


| | |
|---|---|
| 27. General | 23 |
| 28. Ultrasonic Equipment | 23 |
| 29. Components | 23 |
| 30. Applications | 23 |
| 31. Features | 23 |
| 32. Examples of Capabilities | 24 |
| 33. Limitations | 24 |
| 34. Requirements | 24 |
| 35. Aircraft Preparation | 24 |
| 36. Ultrasonic Inspection Requirements | 24 |


SAMPLE

| | Page |
|---|---|
| 37. Standard Block Test | 25 |
| 38. Transducer Mount | 26 |
| 39. Equipment Calibration | 27 |
| 40. Representative Inspections | 27 |
| 41. Fiberscopes (fiber optics) | 28 |
| 42.–45. Reserved. | |


### Chapter 7. VISUAL INSPECTION


| | |
|---|---|
| 46. Scope of Method | 30 |
| 47. Visual Inspection Aids | 30 |
| 48. Borescopes | 31 |
| 49.–50. Reserved | |


### Chapter 8. NEW APPLICATIONS FOR NONDESTRUCTIVE TESTING


| | |
|---|---|
| 51. Forecastings | 33 |
| 52. Industry Usage | 33 |
| 53. Priorities | 33 |
| 54. Future of NDT | 33 |


## APPENDICES


| | |
|---|---|
| APPENDIX 1 NONDESTRUCTIVE TESTING METHODS | 34 |
| APPENDIX 2. STANDARD ABBREVIATIONS | 36 |
| APPENDIX 3. TERMINOLOGY AND DEFINITIONS | 37 |
| APPENDIX 4. REFERENCES | 38 |


## LIST OF ILLUSTRATIONS


| *Figure* | *Page* |
|---|---|
| 1. Electron Cloud Around Hot Body | 7 |
| 2. Diagram of Radiographic Process | 9 |
| 3. Position of X-ray and Gamma Rays in Electromagnetic Spectrum | 10 |
| 4. Penetrant and Developer Action | 12 |
| 5. The Right Hand Rule | 15 |
| 6. Longitudinal Magnetism | 16 |
| 7. Circular Magnetism | 16 |
| 8. Prod Magnetization | 16 |
| 9. Main Landing Gear Trunnion Support Fittings Inspection | 18 |
| 10. Magnatest Conductivity Tester | 19 |
| 11. Magnatest Tester | 20 |
| 12. Types of Probes | 20 |
| 13. Standard Test Block | 25 |
| 14. Transducer Mount-Fastener Hole Inspection | 26 |
| 15. Main Landing Gear Torsion Link Lugs | 27 |
| 16. Main and Nose Landing Gear Wheels | 28 |
| 17. Main Landing Gear Torsion Link | 28 |
| 18. Inspecting for Cracks | 30 |
| 19. Typical Borescope Construction | 31 |
| 20. Types of Borescopes | 32 |
| 21. Temperature Dependence of Liquid Crystal State | 35 |


SAMPLE

# Chapter 1. INTRODUCTION

**1. PURPOSE.** This Advisory Circular reviews the basic principles underlying nondestructive testing. The information contained herein implements data currently available. It is hoped that interested parties will be stimulated by this publication and seek additional information in more extensive works on nondestructive testing.

**a.** One of the major dangers encountered in presenting data on nondestructive testing techniques is that the reader may be given the impression that a technique is a panacea for all problem solutions.

**b.** Let it be clear that each of the techniques to be discussed has application to certain requirements, but no one technique universally obviates the need for any of the others.

**c.** The most efficient testing system may include all known nondestructive techniques; however, until appropriate techniques for all applications have been developed, no system of evaluation can be completely efficient.

**2. CANCELLATION.** AC 20-61, dated April 29, 1969, Nondestructive Testing For Aircraft, is cancelled.

**3. TYPES OF INSPECTION.** This circular is divided into the commonly known types of inspections as follows: (See Appendix 1 for more detailed listing.)

**a. *Visual inspection*** is the most common form of examination, and consists of viewing the area with the eye, aided by magnifying glass, borescope, light source, etc.

**b. *Radiographic inspection*** will show internal and external structural details of all types of parts and materials. It is a nondestructive test method and is used for the inspection of airframe structure inaccessible or unsatisfactory for the application of other nondestructive test methods. It is accomplished by passing the X-ray or Gamma ray through the part of assembly being tested to expose a radiographic film. The processed film shows the structural details of the part or assembly by variations in film density. Interpretation of the radiograph will indicate defects or damage.

**c. *Magnetic particle inspection*** will indicate surface or near-surface defects in ferro-magnetic parts. It is a nondestructive test method and may be performed on assembled or disassembled parts. The test is accomplished by inducing a magnetic field in the part and applying a dry powder or liquid suspension of iron oxide particles. Local magnetic poles formed by defects in the part attract the oxide particles so they may be viewed and evaluated by color contrast or fluorescence under "black light." (See Appendix 3.)

**d. *Ultrasonic inspection*** is a nondestructive test method suitable for the inspection of most metals, plastics, and ceramics for surface or subsurface defects. Ultrasonic inspection requires at least one surface of the part to be accessible in the vicniity of the area in question. The inspection of airframe structure is accomplished by inducing the ultrasound into the part by a contacting probe and picking up reflections of this sound from within the part. The detected ultrasonic reflections are electronically displayed on an oscilloscope tube and interpreted for indications of defects.

**e. *Dye penetrant inspection*** is used to detect small cracks or discontinuities open to the surface and which may not be evident by normal visual inspection. Penetrant inspection can be used on most airframe parts and assemblies accessible for its application. The inspection is performed by applying a liquid which penetrates into surface defects. Excessive penetrating liquid is removed and suitable developers applied to draw the penetrant from the surface defects so that visual indications are obtained by color contrast or fluorescence of the penetrant under the influence of "black light." (See Appendix 3.)

**f. *Eddy current inspection*** is used to detect surface or near-surface cracks in most metals, and to separate metals or alloys and their heat treat conditions. It can be applied to airplane parts or assemblies where the defective area is accessible to contact by the eddy current probe. The inspection is performed by inducing eddy currents into a part and electronically observing variations in the induced field. The character of observed field change is interpreted to determine the nature of the defective condition.

**4. INSPECTION ILLUSTRATIONS.** Usually, inspection illustrations are provided by the manufacturer in manuals or service bulletins to cover each area of the aircraft that requires inspection. Areas are indexed on the major index charts and on the illustrated structure index. Each shows location of area, type of inspection, and directs the inspector to the inspection illustration for that area. This illustration shows the general area for inspection, the method of performing the inspection such as the type of dye penetrant to be used, type of film, kv. setting and exposure time for X-ray, or the type of optical equipment that may be used in a visual inspection. It also indicates the preparation of the part, such as cleaning, paint removal, corrosion removal, etc. When a particular type inspection has been completed, reference is made to a next step inspection. For example, if a visual examination has been performed, it may be necessary to confirm any suspected or visible cracks with a dye penetrant check.

**5. COMMON FAILURES.** The type of failures or defects the inspection personnel will encounter during the nondestructive inspection program follow. It is essential that the inspection personnel be skilled and well-trained in the field of nondestructive inspection to enable them to make sound decisions. Inexperienced personnel should not attempt to interpret the results of the nondestructive inspections. Misinterpretation can result in serviceable parts being rejected and defective parts being accepted.

**a. *Fatigue cracks*** only occur in parts that have been in service under repeated stress reversals or stress variations. The crack 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, such as fillets, poor surface finish, seams, grinding cracks, and from fastener holes that have poor surface finish or sharp burrs.

**b. *Heat-treat cracks*** are caused by faulty heat-treat processing of parts. They can be caused during the heating or quenching cycle or may be an enlargement of a fault existing from a previous operation. They generally occur in a sudden change of section which could cause an uneven cooling rate, or at fillets and notches which act as stress concentration points.

**c. *Grinding or plating cracks*—**

**(1) Grinding cracks** are caused by faulty grinding, and are quite critical as they generally occur on surfaces which are highly stressed. They are distinguished by very fine and sharp cracks at right angles to the grinding marks.

**(2) Plating cracks** are found only in areas where high residual stresses remain from some previous operation, such as hardening. When such parts are plated, the operation may cause those stresses to crack the surface.

**d. *Discontinuity is an interruption*** in the normal physical structure configuration of a part such as cracks, forging laps, folds, seams, porosity, etc. A discontinuity may or may not affect the usefulness of the part.

**e. *Inclusions are impurities*** embedded in the material in the forming stage. The inclusions can be deep in the part or near the surface. Normally, they will have no effect on the strength of the part, but when they occur in areas of high stress or in certain special locations or direction they may be cause for rejection of the part.

**f. *Corrosion.*** Almost all metals are subject to corrosion. The use of corrosive-resistant metals, such as aluminum clad sheet, minimize airframe corrosion. Many other factors contribute to the amount and degree of corrosion, such as the geographic location and fabrication process. Geographically, corrosion is caused by the presence of salts in moist air, or by some other abetment to corrosion present in the chemical content of the water or elements in the metal. Corrosion

caused by fabrication is dependent on such factors as protective coating, the type of metal used, treatment of parts, and dissimilar metal contacts. Stress corrosion is another common cause for cracking in metals.

**6. INSPECTION TECHIQUES—ADVANTAGES AND DISADVANTAGES.**

**a.** ***The various types of nondestructive inspections for aircraft application*** are described briefly. The advantages and disadvantages of each type are described in Table 1. These should be studied by personnel who are about to make an inspection of an area that is not covered in the specific inspection illustrations, or if the particular inspection equipment called for in the illustration is not available. The information should be used as a guide in choosing the best method, or best alternative method for the area, or equipment that is available.

**b.** ***Inspection access and provisions.*** The majority of the parts requiring inspection will be accessible from inside the airplane, or will be on the wings or empennage. The points for inspection in the fuselage will generally be underneath the soundproofing material. To locate these areas, the inspection team should have a good knowledge of the frame stations and stiffener positions (frame stations may be stenciled on soundproofing). Many areas to be inspected will be very difficult to get at and may necessitate removing doors or panels which are part of the structure.

**c.** ***Inaccessible inpection problems.*** In some cases, the method of inspecting an area will depend on the accessibility; it may be desirable to inspect by X-ray but not possible to get the unit near, or obtain the correct angle, for exposing the film. Also, it might be desirable to inspect an item by magnetic particle but not possible to get the coils around it, or probes to the part. The means of accessibility to the part will determine the best method for the inspection of it.

**7. SELECTING THE INSPECTION METHOD.** The method of inspection for the area will depend on several factors: accessibility, portability, type of defect sought, material of the part, and degree of sensitivity required. A typical example of determining which inspection method to use follows:

**a.** ***Example.*** In the lower wing skin, a fastener hole is found to have a fatigue crack radiating from it, the fastener is removed; a penetrant inspection is performed to determine the length of the crack on the surface, a section of the skin containing the hole and crack is cut out—(⅝" diameter section). It is required to check the skin around the cutout to determine that all of the crack has been removed. The following methods were considered: X-ray, eddy current, ultrasonics, and dye penetrant.

**(1) The penetrant method was considered** unsuitable because of the "smeared" nature of the saw-cut surface and excessive bleed back from the skin to doubler faying surface.

**(2) X-ray was considered** in evaluating the test standards, but was not considered feasible for the wing inspection because its sensitivity to a small tight crack is not as good as ultrasonics or eddy current.

**(3) Ultrasonic was considered;** however, it was rejected because it is less sensitive to small cracks of the size and type sought than eddy current inspection, and would require the preparation of a special transducer holder to obtain maximum sensitivity in suspected area.

**(4) Eddy current was chosen** as the best means for inspection because the inspection can be performed quickly with standard equipment and will obtain a high degree of sensitivity.

**8. INSPECTION OF AIRPLANE.** When an inspection of the airplane is to be performed, the airplane must be prepared to suit the type inspection being performed. For most methods of inspection, no special preparation is necessary, except in areas near or in fuel cells where the airplane would have to be defueled. In some areas parts of the structure may have to be removed to gain access to the area for inspection. For X-ray inspection, the plane may have to be defueled, X-ray tube leveled, and the area properly roped off with red rotating beacon lights at each corner to keep unauthorized personnel at a safe distance. After inspection, care must be taken to restore the airplane to original configuration, such as

TABLE 1. Comparisons of various inspection methods.

| *Method* | *Advantages* | *Disadvantages* |
|---|---|---|
| Visual | 1. Cheapness.<br>2. Portability.<br>3. Immediate results.<br>4. Minimum special skill.<br>5. Minimum part preparation. | 1. Suitable only for surfaces which can be viewed.<br>2. Generally detects only larger defects.<br>3. Misinterpretation of cracks and scratches. |
| Radiographic X-ray | 1. Ability to inspect for both internal and surface defects.<br>2. Ability to inspect parts covered or hidden by other parts or structure.<br>3. Permanent test record obtained.<br>4. Minimum part preparation required. | 1. Most expensive.<br>2. Airplane may have to be defueled.<br>3. Area must be cleared of other personnel to avoid X-ray exposure.<br>4. Test method is highly directional, depends on crack/X-ray source orientation.<br>5. High degree of skill required for varied technique development and radiographic interpretation. |
| Radiographic Isotopes | 1. It is portable.<br>2. Needs less area to gain access for energy source.<br>3. Can accommodate thicker material sources.<br>4. Less expensive than X-ray. | 1. Must conform to Atomic Energy Commission regulations for handling and use. |
| Eddy Current | 1. Portable.<br>2. Moderate cost.<br>3. Immediate results.<br>4. Sensitive to small indication.<br>5. Little part preparation. | 1. Essentially a surface inspection.<br>2. Surface to be inspected must be accessible to contact by the eddy current probe.<br>3. Rough surfaces interfere with test sensitivity.<br>4. Suitable for inspection of metals only.<br>5. No permanent test record.<br>6. Considerable skill and familiarity required in handling test equipment.<br>7. Time consuming to scan large areas. |
| Ultrasonic | 1. Suitable for surface and subsurface defects.<br>2. Sensitive to small defects.<br>3. Immediate test results.<br>4. Little part preparation.<br>5. Wide range of material thicknesses can be inspected. | 1. Surface of part to be inspected must be accessible to sonic probe.<br>2. Rough surfaces interfere with test results.<br>3. No permanent test record.<br>4. Test method is directional depending on sound beam—defect orientation.<br>5. High degree of skill and experience required to set up and interpret results for varied test conditions. |
| Dye Penetrant | 1. Cheapness.<br>2. Portable.<br>3. High sensitivity.<br>4. Immediate results.<br>5. Minimum skill required to perform. | 1. Can only inspect surface of parts accessible to penetrant application.<br>2. Defects must be open to surface.<br>3. Part preparation, such as removal of finishes and sealant required.<br>4. No permanent test results.<br>5. Direct visual detection of results required.<br>6. Requires a high degree of cleanliness for satisfactory inspection. |
| Magnetic Particle | 1. Semiportable.<br>2. Sensitive to small indications.<br>3. Detects surface and near-surface defects.<br>4. Sensitive to inclusions as well as cracks.<br>5. Moderate skill required to perform. | 1. Only suitable for ferro-magnetic material.<br>2. Part must be physically and visually accessible to perform test.<br>3. Removal of most surface coatings and sealant required.<br>4. Inspection is semidirectional requiring a general orientation of field to defect.<br>5. No permanent test results unless the indications from dry powder technique are recorded by pressing "scotch" tape on the surface.<br>6. Not usable in areas where a strong magnetic field may damage instruments.<br>7. Part must be demagnetized after inspection. |

SAMPLE