PART 1 - GENERAL

EDDY CURRENT

1. General

A. In recent years eddy current testing has gained a reputation as one of the most versatile and reliable inspection methods available. The development of small stable battery operated instruments has made eddy current inspection ideally suited to airplane maintenance.

2. Description of Method

A. To initiate eddy currents in a test object, an alternating current of selected frequency is applied to a test coil. The alternating current produces a varying magnetic field called the primary field around the test coil. When the test coil is placed next to a metal part, the primary magnetic field causes eddy currents to flow in the part. The depth to which the flow of eddy currents penetrate varies inversely with material conductivity and with the frequency applied to the test coil. This flow of eddy currents generates a second magnetic field (secondary field) which affects the initial field from the coil. The resultant magnetic field determines the coil electrical characteristics and becomes the source of information which is analyzed electronically to yield the required data. The condition of the part is determined from this data.

B. Eddy current instrumentation responds to changes in the electrical characteristics of the probe coil caused by secondary magnetic field changes which result from changes in the flow of the eddy currents. Changes in the flow of eddy currents result from:

(1) Changes in shape or dimension of the test part.

(2) Cracks, pits, porosity, voids, inclusions, seams.

(3) Variations in chemistry or alloy content.

(4) Heat treatment or mechanical working.

(5) Changes in spacing between test pieces and probe (Liftoff).

(6) Changes in magnetic permeability. (For practical purposes, permeability variations occur only in ferro-magnetic metals.)

C. There are two basic probe configurations used for eddy current testing, (1) absolute and (2) differential. The term absolute is used when there is only one probe used to inspect the test part. The term differential is used when two or more probes are used to inspect the part. Any difference between what the probes sense is monitored. Another application of the differential method is to place one probe in contact with a reference standard and the other in contact with the part being inspected.

The probes used for absolute and differential inspection may be made up of one or more coils, depending on the application. The wire is usually wound on a ferrite core or placed within a ferrite pot core which increases sensitivity and resolution.

D. A variety of specialized eddy current inspections are performed on airplane structure. The inspections listed below are the most commonly employed in aluminum or non-magnetic alloys.

(1) Detection of cracks in a wide variety of situations.

(2) Detection of corrosion and resultant metal loss between aluminum skins and/or mating members.

(3) Identification of alloy or heat treat condition.

(4) Evaluation of heat damage in structure exposed to fire or high temperatures.

E. Local permeability variations in low alloy steels produce corresponding large changes in the eddy current instrument read out. It is difficult to interpret these readings and distinguish between discontinuities and normal permeability changes. Eddy current inspection of ferromagnetic metals is not generally recommended unless there is no other practical inspection method available. See Part 6 for Eddy Current Inspection of Steel.

3. **Equipment**

A. The major objective in the design of suitable eddy current testing equipment is to achieve good sensitivity and flexibility at a reasonable cost. The equipment should be suitable for a variety of applications, and should be able to accommodate different types of coils. In general, versatility of equipment and ability to analyze signal data are proportional to complexity and cost.

B. An eddy current test system is actually a collection of subsystems working in conjunction with each other to extract specific data from a test. The components that make up the system are:

(1) Test coil (normally contained in a probe or fixture). There is no universal test coil. Test coils are made up to fit the needs of the particular job being performed. Coils of different designs, and in different combinations can be made to perform highly specialized tests. Specific probe types are discussed in Paragraph 6.

(2) Oscillator. The system should be capable of generating eddy currents over a wide, easily varied frequency range. The frequencies most commonly used for inspection of aluminum range from 100 Hz to 1 MHz.

(3) Balance and Processing System. This equipment should be as flexible as possible, within cost limitations of the individual operator, and be capable of obtaining all pertinent information from the test coil. This system detects changes in the flow of eddy currents. These changes are processed and amplified and presented for operator readout.

(4) Signal Readout System, or Display. The readout can be a cathode-ray tube, a meter, defect lights, or a recorder. The system also can include a means of automatic sorting and marking, and audible alarm auxiliaries. A meter readout normally is used in maintenance inspection equipment.

(5) Reference Standards. Reference standards are fabricated from material and to dimensions specified in individual test procedures. Electric discharge machining (EDM) may be substituted for jeweler's sawcuts in notch fabrication.

4. **Preparation for Inspection**

A. Normally it is not necessary to disassemble or remove a part from the airplane for eddy current inspection. However, it may be necessary to remove access doors, fairings, or some items of equipment to gain access to the inspection area. When inspecting fastener holes, the fastener will generally have to be removed. No other preparation of the airplane is necessary, except when inspection is conducted within the fuel tanks. Then the airplane fuel tanks must be drained and purged.

NOTE: It is the responsibility of the local fire department to approve conditions for use of specific eddy current instruments for use inside fuel tanks.

B. Parts being inspected require only minimum cleaning before inspection. Eddy current inspection can be performed through paint, oil, or any uniform nonconducting material.

5. **Application and Technique**

A. Eddy current applications can be classified into three general categories.

(1) High Frequency or Surface Inspection -

NOTE: Frequencies above 50 kHz are generally considered high frequency.

(a) Inspect for cracks or similar defects that are open to or just below an accessible surface. This includes fastener hole inspection with the fastener removed and a wide variety of surface crack inspections.

(2) Low Frequency or Subsurface Inspection

NOTE: Any frequency below 50 kHz is considered low frequency.

(a) Inspects for subsurface cracks or cracks in underlying structure using probes and equipment specifically designed for low frequency application.

(b) Inspects and estimates for corrosion loss on the inner surface of aluminum skins and mating members, if any.

(3) Conductivity Measurement -

(a) Use eddy current equipment calibrated to read electrical conductivity in IACS (International Annealed Copper Standard) or micro ohm centimeter units. Use to evaluate fire damage or determine heat treat condition of aluminum alloys.

B. Specific procedures are required for each of the general applications and in many cases special techniques are required for the part being inspected. The detailed procedures are contained in Part 6.

6. Probe Configurations

A. High Frequency Probes.

(1) Shielded pencil probes are recommended for surface eddy current inspection, particularly around fasteners, in radii, adjacent to steel or aluminum structure, or along edges of parts. Shielding restricts the magnetic field of the probe which reduces interference from adjacent structure. See Figure 1 for suggested pencil probe configurations.

(2) Nonshielded pencil probes are used for surface eddy current inspection of flat or moderately curved surfaces where no interference is anticipated from adjacent structure, radii, or close edge margins. See Figure 1.

(3) Spring-loaded surface probes are used for inspection of large flat surfaces where no interference is anticipated from adjacent structure, radii, or close edge margins.

(4) Bolt hole probes are used when it is necessary to detect small cracks initiating at the surface of a fastener hole.

(a) Probe diameter should be adjustable to obtain a snug fit in the hole. See Figure 2 for sample probe design.

(b) Probe should have an adjustable collar which controls the depth penetration in the hole. The collar is used as a guide when probe is rotated inside the hole.

(5) Probes must meet sensitivity, liftoff and performance requirements of the Part 6 procedure being performed.

B. Low Frequency Probes

(1) Ring (encircling) probes are usually centered over a fastener. A crack which propagates in any direction out of the fastener hole would be detectable. The inside diameter (ID) of the probe must be large enough to fit around steel or protruding head fasteners. The outside diameter (OD) should not be so large that adjacent fasteners and structure interfere with the inspection. Generally, crack sensitivity is improved if the ring probe ID is closely matched to the steel fastener head OD. The probe operating frequency is selected to optimize the crack sensitivity and signal-to-noise ratio for the structure being inspected.

(2) Spot probes are usually placed or scanned adjacent to a fastener or scanned at a specified location such as a skin splice gap. Spot probes are sometimes placed directly on countersunk aluminum and titanium fasteners. A crack would be detected only if the probe was scanned or placed directly over it. The probe OD and operating frequency selected depend on the structure in the area to be inspected.

NOTE: Ring and spot probes can be used interchangeably for some applications.

(3) Factors which must be considered when probe type, size and frequency is selected are:

(a) Material type (alloy, heat treat condition).

(b) Thickness of material or layer(s) above the expected crack location.

(c) Thickness and material of the layer(s) to be inspected for possible cracks.

(d) Whether layers beneath those to be inspected will interfere with the inspection; either by decreasing the crack sensitivity, or by changing the eddy current response.

(e) Expected crack direction.

(f) Fastener type, material, size and spacing.

(g) Edge margins, both surface and subsurface.

(h) Adjacent structure which may restrict probe access or cause interfering signals.

(i) Signal-to-noise ratio. It is desirable to maintain at least a 3:1 signal noise ratio between the amount of meter deflection obtained from the reference standard notch and the amount of variation in response caused by changes in structure other than cracks.

(4) Probe dimensions for Part 6 procedures are specified in several different ways depending on their design and application. See Figure 3.

(a) The diameter of the coil shielding may be specified. Coil shielding is commonly achieved by use of a ferrite pot or soft iron core.

(b) The active coil diameter may be specified.

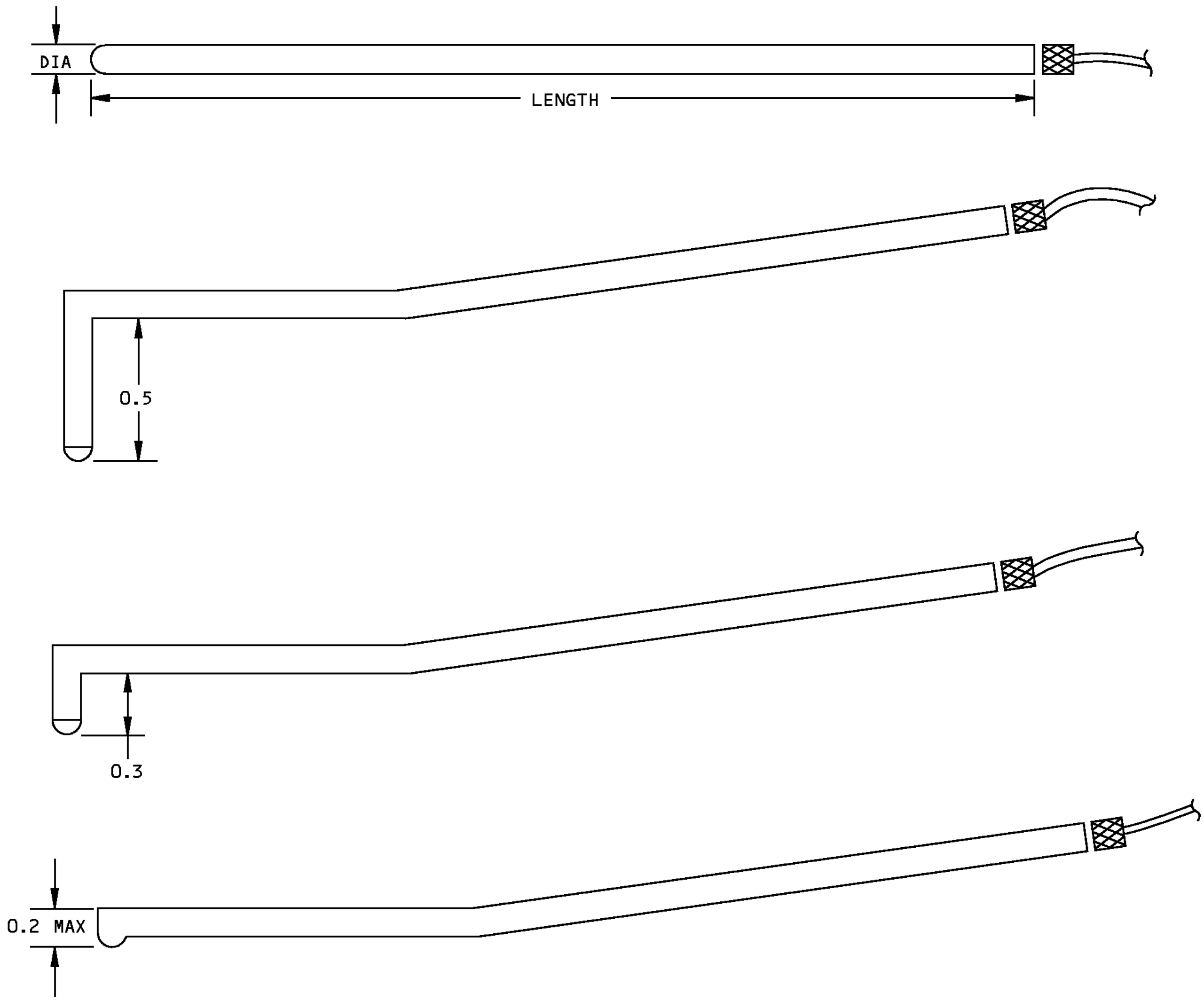
(c) The probe case diameter and height may be given in addition to Paragraph 6.B.(4)(a) or Paragraph 6.B.(4)(b) where an access problem exists.

NOTE: The diameter of the shielding and coil may be obtained from the manufacturer or determined by X-raying the probe.

(5) Any low frequency probe which meets the performance requirements of the Part 6 procedure being performed may be used. See Figure 3 for typical probe configurations used in the Part 6 detailed procedures.

7. Equipment Manufacturers

A. Refer to Part 1, 51-01-00 for information about some of the manufacturers of eddy current equipment.



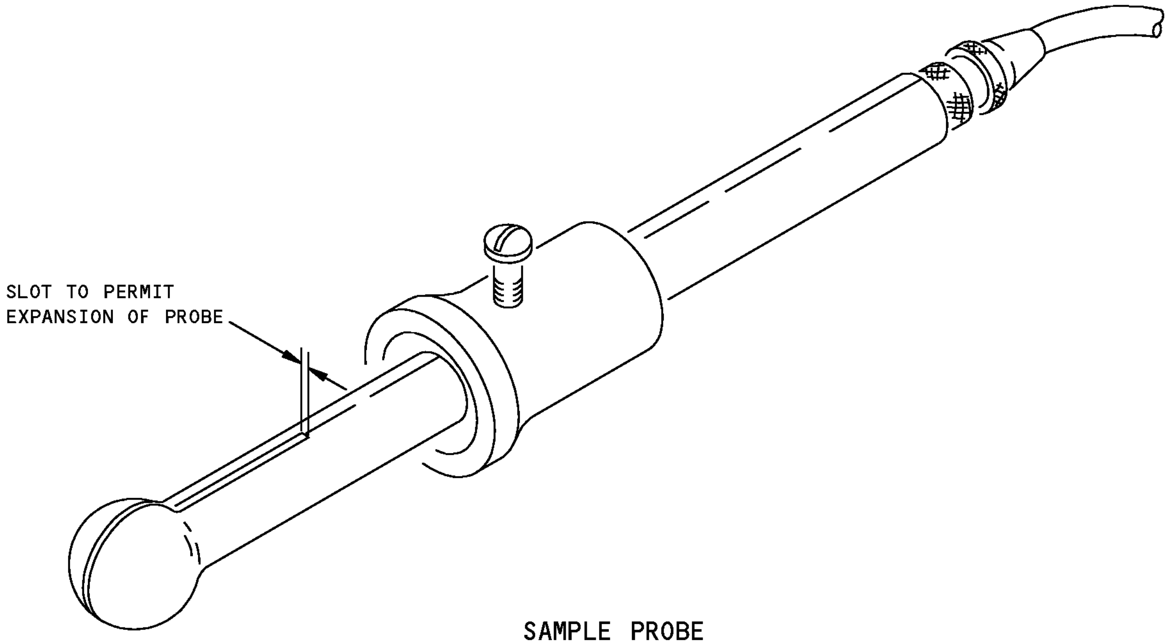
NOTES

- ALL DIMENSIONS ARE IN INCHES
- THE FOUR PROBE CONFIGURATIONS SHOWN WILL PERMIT ACCESS FOR MOST INSPECTIONS IDENTIFIED IN PART 6 WHICH REQUIRE PENCIL PROBES. SHIELDED PENCIL PROBES ARE RECOMMENDED

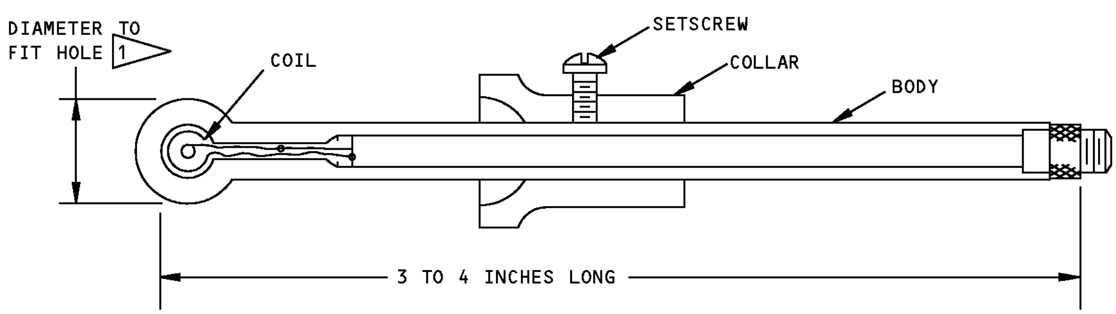
  LENGTH: 3 TO 5 INCHES

  DIAMETER: 0.2 INCH MAXIMUM. 0.12 INCH DESIRABLE FOR AREAS OF RESTRICTED ACCESS

Typical Pencil Probe Configuration
Figure 1



SAMPLE PROBE

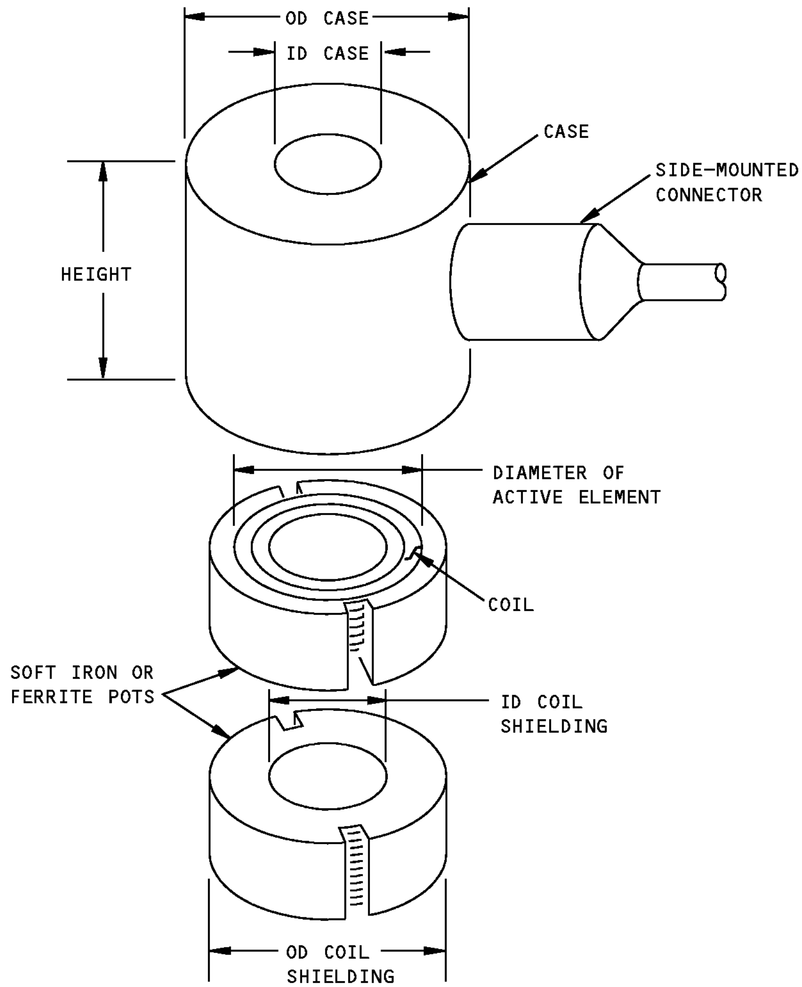


CROSS SECTION THROUGH CENTER OF PROBE

NOTE

1 STANDARD PROBE DIAMETERS
0.187 INCH
0.250 INCH
0.312 INCH
0.375 INCH
0.437 INCH
0.500 INCH

Typical Eddy Current Bolt Hole Probe
Figure 2



NOTES

- ALL DIMENSIONS ARE IN INCHES
- SIDE-MOUNTED CONNECTOR IS DESIRABLE FOR AREAS OF RESTRICTED ACCESS
- GENERALLY, PROBE CASE DIAMETER AND HEIGHT IS SPECIFIED ONLY FOR AREAS OF RESTRICTED ACCESS

TYPICAL PROBE CONFIGURATIONS			
OPERATING FREQUENCY RANGE	PROBE SHIELDING DIMENSIONS (INCHES) OD	ID	PROBE TYPE
100 TO 500 Hz	1.0	0.5	RING
100 TO 400 Hz	1.25	0.62	RING
200 TO 2000 Hz	0.75	0.3	RING
100 TO 500 Hz	1.25	0.8	RING
100 TO 500 Hz	1.0		SPOT
400 TO 4000 Hz	0.55		SPOT
1000 TO 4000 Hz	0.35		SPOT
1 TO 20 kHz	0.27		SPOT
20 TO 40 kHz	0.27		SPOT

Low Frequency Probes
Figure 3

PART 1 - GENERAL

RIVET FINISH IDENTIFICATION IN REFERENCE STANDARDS

1. **Purpose**

A. Use this procedure to identify the type of finish that is on fasteners that are installed in eddy current reference standards. Use this procedure only if the use on conversion coated (Alodined) rivets is specified in the reference standard drawing.

B. Anodized fasteners are not electrically connected to the structure around the fastener hole. Eddy current calibration with a reference standard that contains anodized fasteners can decrease the inspection sensitivity if the airplane structure to be examined has Alodined rivets.

C. Alodined rivets are electrically connected to the structure around the fastener hole. Eddy currents can flow through the fastener. Calibration on a reference standard with Alodined rivets permits sufficient sensitivity for inspection of airplane structure with Alodined and anodized rivets.

D. This procedure cannot be used to identify the finish on rivets installed on airplanes. The rivet heads on in-service airplanes can have paint coatings. If the paint has been removed, the removal process can also remove the rivet finish.

2. **Equipment**

A. General

(1) Use equipment that can be calibrated as specified in Paragraph 4.

(2) The multimeters that follow were used to help prepare this procedure:

(a) Model 77 Digital Multimeter, with continuity mode; Fluke

(b) Model 89IV Digital Multimeter, with continuity mode; Fluke

(c) Model 630A Analog Multimeter; Triplett

(d) Model 260 Analog Multimeter; Simpson

NOTE: Multimeters are instruments that can measure resistance, current and voltage. Many multimeters have an electrical continuity mode with a horn that makes the inspection easier.

B. Reference Standard

(1) All eddy current reference standards can be used during calibration for this inspection procedure.

3. **Prepare for the Inspection**

A. Identify the eddy current reference standards that must be examined.

(1) The eddy current reference standards that must be examined are those for which the reference standard drawing specified the use of conversion coated (Alodined) rivets.

B. Clean the heads and tails of the reference standard fasteners with solvent. It is only necessary to clean the heads and tails of the fasteners that the multimeter probes will touch during the inspection. Do not use abrasive material.

4. **Instrument Calibration**

A. Energize the multimeter.

B. Put the multimeter in the correct mode:

(1) Put the multimeter in the electrical continuity mode if possible and if the multimeter has a horn.

(2) Set the multimeter in the R1 or the equivalent lowest resistance range if the multimeter does not have a continuity mode.

C. Hold the probe tips together so they touch each other.

D. Monitor the resistance value that is measured by the multimeter. The resistance value must be less than 5 Ohms.

E. If you use an analog multimeter, adjust the multimeter balance point to the lowest possible resistance value.

NOTE: If the multimeter has an electrical continuity mode, make sure that the horn operates when the probe tips touch.

F. Lightly touch the probe tips to the surface of the reference standard at a location that is away from a fastener. Do not touch the fastener heads for this calibration step. Make sure that the probe tips do not touch each other.

(1) Make sure the resistance value that you measure is less than 5 Ohms.

(2) Make sure that the horn can be heard if the instrument is equipped with a continuity mode.

G. If the resistance is more than 5 Ohms, or the horn cannot be heard, do Paragraph 4.A. thru Paragraph 4.F. again or use a different multimeter.

5. **Inspection Procedure**

A. Find a reference standard that must be examined.

(1) The eddy current reference standards that must be examine are those for which the reference standard drawing specified the use of conversion coated (Alodined) rivets.

B. Do a visual check of the tail of the rivet. If you can see a "C" on the tail of the rivet, identify it as an Alodined rivet.

C. Calibrate the equipment as specified in Paragraph 4.

D. Lightly touch the multimeter probe tips to the head of one fastener on the reference standard. Make sure that the probe tips touch only the rivet head and do not touch each other.

NOTE: Only the rivet is to be measured for resistance. Identification of the resistance between the rivet and the reference standard structure is not a good procedure to use to identify the rivet finish.

E. Identify the rivet type:

(1) If the rivet has an anodized finish, the resistance value on the multimeter will not change when the probe tips are put on the rivet. A high resistance value (open circuit) will occur.

(2) If the rivet has an Alodine finish, it will cause a resistance value that is less than 5 Ohms and the horn (if the multimeter has the continuity mode) will be heard.

F. If the resistance value is more than 5 Ohms or the horn is not heard, the rivet has an anodized finish. Make a mark on the rivet in the reference standard to identify it as an anodized rivet.

G. Examine all aluminum rivets in the reference standard.

H. Do Paragraph 5.C. thru Paragraph 5.G. again to measure the resistance on the tail of the rivets. If the resistance measured on the tail is more than 5 Ohms, identify the rivet as anodized even if the resistance value that occurred when the probe tips were on the rivet head is less than 5 Ohms. This will make sure that an anodized rivet is rejected if the finish on the rivet head is gone because of wear.

6. **Inspection Results**

A. All anodized rivets must be replaced with Alodined rivets.

B. Refer to Part 1, 51-01-04 for the instructions on how to install Alodined rivets.

C. Reference standards with Alodined rivets can be used to examine airplane structure with anodized or Alodined rivets.