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Miramar, FL 33025
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Fax: 954-443-4963
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# Revision History

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<td>B</td>
<td>Complete revision of section 51-EQ-03/301.</td>
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# RECORD OF REVISIONS

Retain this record in the front of the manual. On receipt of revisions, insert pages in the manual. Enter revision number, date issued, date inserted and initials.

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## RECORD OF TEMPORARY REVISIONS

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# LIST OF EFFECTIVE PAGES

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<td>Title Page</td>
<td>TP-1</td>
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<td>Equipment Suppliers</td>
<td>112</td>
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<td>101</td>
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<td>Aluminum part subsurface inspection-Multilayer</td>
<td>116</td>
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</tr>
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Manual No.: 2-120483-800
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<td>51-EQ-04</td>
<td>305</td>
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<td>Mar 29/16</td>
<td>506</td>
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<td>306</td>
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<td>507</td>
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<td>307</td>
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<td>310</td>
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<td>Mar 29/16</td>
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<td>51-EQ-08</td>
<td>311</td>
<td>R</td>
<td>Mar 29/16</td>
<td>502</td>
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Manual No.: 2-120483-800

LEP-2
Mar 29/16
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<td>Method of Inspection</td>
<td>901</td>
<td>R</td>
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</tbody>
</table>
# TABLE OF CONTENTS

INTRODUCTION .................................................................................................................. 1

EDDY CURRENT

- GENERAL INFORMATION ........................................................................................... 101
- EQUIPMENT SUPPLIERS ............................................................................................ 201
- ALUMINUM PART SUBSURFACE INSPECTION – MULTILAYER .................................. 301
- ALUMINUM PARTS SURFACE INSPECTION (METER DISPLAY) ................................. 401
- ALUMINUM PARTS FASTENER HOLE INSPECTION (IMPEDANCE PLANE DISPLAY) 501
- ALUMINUM PART FASTENER HOLE INSPECTION (ROTARY SCANNER) ..................... 601
- SURFACE CRACK INSPECTION OF FAYING SURFACE ............................................... 701
- DETECTION OF CRACKS AT EDGE OF CUTOUTS ....................................................... 801

PENETRANT

- METHOD OF INSPECTION .......................................................................................... 901
INTRODUCTION

1. General
   A. Detection of structural damage and defects before they deteriorate to a critical state is a necessity to assure structural integrity of the aircraft. Inspection techniques to discover such defects are presented in this manual; Eddy Current & Penetrant. As other methods of tests are found adequate, they will be added to this manual.
   B. The intent of this manual is to provide nondestructive testing methods to support B/E Aerospace Design Approvals (e.g. Supplemental Type Certificates (STC)) only.

2. Manual Arrangement
   A. This manual is broken into two separate parts, Eddy Current test and Penetrant test. They contain specific information and procedures pertaining to each test method. The aircraft maintenance personnel performing these tests are required to be adequately trained in the test methods and test equipment described in this manual, no effort is being made to include instructions for operating the various types of equipment used for the tests. However, where needed specific operating procedures are suggested.

3. Subject Numbering
   A. Each part of this manual is subdivided by the use of the three-element pseudo ATA-100 numbering system (e.g. 51-EQ-08). First number denotes the ATA chapter the second denotes it is a B/E Aerospace procedure, and the third denotes the subject number.

4. List of Effective Pages
   A. A List of Effective Pages at the front of the manual lists all of the pages contained in the manual and indicates the date of which the page was last revised.
1. General
A. This subject describes the functions and features of equipment and materials necessary to conduct Eddy Current tests. Equivalent test instruments, (Table 101), are allowable provided that all tests, as defined in each procedure, can be performed with the same results. Other equivalent material and equipment substitutes may also be used. Specific inspections may require equipment and materials not listed here, but described in the specific document.
B. The requirements of this subject should be followed unless otherwise noted by a specific document.

2. Flaw Detection Systems
A. Meter Display Instrument (Ref. Figure 101)
   (1) Description
      (a) Meter display instruments feature a scale usually graduated in milliamperes and movable meter needle. The amplitude of needle movement is proportional to the impedance of the test circuit. The electronics of some instruments can be switched to allow the meter to indicate Phase angle. Some instruments have dual meters, one indicating milliamperes and one indicating phase angle.
      NOTE: Meter display instruments are acceptable for flaw detection only when used in conjunction with an appropriately adjusted audio or visual flaw alarm.
   (2) Required Features
      (a) Frequency range and sensitivity required by specific test.
      (b) Adjustable Audio or Visual defect alarm.
         1) Alarm activation must not affect the display needle position.
      (c) Lift-off effect suppression to not more than 10% of reference standard notch response.
      (d) Circuitry to support reflectance (Driver/Receiver) probes if instrument is to be used for such tests.
   (3) Desirable Features
      (a) Indication recording capability.
      (b) Phase rotation capability.

B. Impedance Plane Display Instrument (Ref. Figure 101)
   (1) Description
      (a) Impedance plane display instruments feature a “flying dot” on a CRT, LCD, or video display. The position of the flying dot indicates the impedance of the test circuit, but also displays the effect of both resistance and reactance presenting both phase and amplitude information. The resultant information often creates unique signatures of different conditions influencing the sensor, such as conductivity, permeability, cracks, liftoff, spacing, and thinning, making recognition of defects easier and more reliable. Indications are displayed in “real Time” and can be stored for variable lengths of time to reduce the risk of missing defect indications.
   (2) Required Features
      (a) Frequency range and sensitivity required by specific test
      (b) Display presentation storage capability
(c) Phase rotation capability
(d) Circuitry to support reflectance (Driver/Receiver) probes if instrument is to be used for such tests.

(3) Desirable Features
(a) Separately adjustable X and Y gain in .5V per division steps.
(b) Indication recording capability.
(c) Motorized open hole probe scanner with time base display.

C. Linear Time Base Display Instruments (Ref. Figure 103)

(1) Description
(a) Linear time base display instruments are usually used with rotating open hole probe scanners. The horizontal position of the signal on the display indicates sensor clock position in the hole and the vertical peak of the signal indicates amplitude of the response.

(2) Required Features
(a) Same as those of the impedance plane display instrument.
(b) Adjustable filters for noise reduction.

(3) Desirable Features
(a) Indication recording capability
(b) Switchable to impedance plane display for further signal analysis

D. Bargraph Display Instruments (Ref. Figure 104)

(1) Description
(a) Bargraph display Instruments feature an LCD readout bar scale graduated in voltage sensitive increments. The position of the display indication is adjustable from one bar to full scale.

(2) Required Features
(a) Frequency range and sensitivity required by a specific test.
(b) Signal-to-noise ratio of at least 3-to-1

(3) Desirable Features
(a) Adjustable audio or visual defect alarm
   1) Alarm activation must not affect display bar scale position.

E. Probes

(1) Required Features
(a) Compatibility with instrument used (indicated by sensitivity, stability and lift off characteristics).
   1) Many probes work equally well with instruments marketed by several different manufacturers (sometimes requiring only connector adapters).
   2) Some probes work only with an instrument produced by one manufacturer, but the probes are manufactured by several sources.
   3) Some probes are designed for a particular instrument, but will work with others if used with special adapters incorporating balance or trimmer coils.
4) If doubt exists about applicability, contact the probe and instrument manufacturers.
   
   (b) Manufacturer part number and nominal frequency range marked on probe (or on integral
       instrument connector/lead assembly if probe marking not practical).
   
   (c) Stability and low noise throughout usable frequency range, producing at least a 3 to 1 system
       signal to noise ratio.

(2) Desirable Features

(a) Probes incorporating removable leads are often preferred for the following reasons:
   
   1) Reduce storage space required and less storage damage.
   
   2) Promote prompt correction of system noise caused by faulty leads (system weak link).
   
   3) Easier and more economical to repair in the field than integral leads.

(b) Probe coil(s) should be shielded whenever possible to reduce effects of proximate structural
    variables. (See Figure 106).
   
   1) Ferrite shielded coils are usually preferred over Mu metal shielded coils.
   
   2) Some specific inspections may require shielded coil(s).
   
   3) Some specific inspections may require unshielded coil(s).

(3) Probe Types

(a) High Frequency Surface Probes (Ref. Figure 107)
   
   1) Coils are usually wound as absolute sensors or differential sensors. The choice of
      absolute or differential probes is generally based on operator preference. The absolute
      probes are most commonly used. In some cases, the differential probes are selected to
      improve signal to noise ratio in difficult inspection applications.
   
   2) The specimen contact surface (tip) of a high frequency surface probe may be flat,
      rounded, or pointed. The flat probes offer more stability and effective shielding; the
      rounded tips are usually preferred for versatility since they can be scanned closer to
      edges, fasteners and corners and produce less lift-off effect from probe wobble during
      scanning. Rounded tips are also better suited for scanning along and across radii. The
      Pointed tips are usually used for scanning thread roots and splines.

(b) High Frequency Bolt Hole (Open Hole) Probes (Ref. Figure 108)
   
   1) Probe coils are wound similar to High frequency surface probes. See item a.1) above.
   
   2) The specimen contact surface (tip) of open hole probes are rounded to match the hole
      diameter to be tested. Probes are normally manufactured in 1/16 inch increments, but
      can usually be purchased in any size required. The tips are usually split to allow
      expansion inside the hole and cause the sensor coil to intimately contact the specimen
      bore wall at a 90 degree angle. The expandable tip allows testing of hole sizes which my
      fall between the nominal probe tip diameters.
      
      i. Early model probe tips for motorized probe scanners are usually fabricated from low
         permeability corrosion resistant steel to resist wear and are not split to allow
         expansion for different size holes. Complete wraps of Teflon tape are added to
         probe tip to compensate for intermediate hole sizes
      
      ii. Later model probe tips for motorized probe scanners are made of Teflon or Delrin
           and are split to allow expansion for different size holes. The tips of these probes
usually wear out faster, but usually are more versatile. Tip wear can be slowed by wrapping Teflon tape around sensor portion of tip.

3) Probes used for manual scanning, must be equipped with a movable collar to adjust the depth of probe insertion along the axis of the hole.

(c) High Frequency Special Application Probes

1) Countersink Probes (Ref. Figure 109)
   i. The probe tips are designed to resemble the shank and head of a flush head fastener. The sensor coil is located in the shank/head transition area to detect very short cracks originating in the fastener hole which do not emerge beyond the head countersink area.
   ii. The fastener must be removed for this inspection.
   iii. The countersink probe is most useful for inspection of thin plating where insufficient cross section remains after countersinking to allow use of a conventional open hole probe.
   iv. An adjustable guide collar should be used with manual scan probes to reduce noise caused by probe tipping during rotational scanning.
   v. Countersink probes are designed to fit each nominal fastener hole size and will not compensate for out-of-round holes. Since their sensor is positioned very close to the hole edge, any burrs, nicks or other variables in material edge profile cause noisy responses which may necessitate careful hole oversizing and/or de-burring to allow inspection.

2) Plug Probes (Ref. Figure 110)
   i. The type A plug probes are designed to place the sensor coil at a fixed angle and position relative to the bottom radius of a spotface or counterbore. The fastener must be removed to allow its use.
   ii. The Type B plug probe tips are designed to position the sensor coil at the edge of an open hole to detect very short cracks originating in the fastener hole. These cracks do not emerge beyond the protruding head, or locking device (or upset end) of any fastener. The fastener must be removed for this inspection.
   iii. The Type B plug probe is most useful for inspection of thin plating where insufficient cross section exists to allow use of a conventional open hole probe.
   iv. Item 1)i, above also applies to the Type B plug probe.

3) Shaped Probes (Ref Figure 111)
   i. The bodies of the probes are designed to position the sensor coil at a particular position relative to an edge or structural feature such as spotface radii, grooves, splines and lugs. The special configuration is usually attained by molding or machining the body of the probe around the sensor(s) in a manner which uses a portion of the body as a scanning or positioning guide.
   ii. The fixed relative position during scanning reduces noise or erratic Indications caused by edge effect, wobble and profile changes. This allows use of high gain settings and detection of very small defects originating at such areas. The same effect may sometimes be attained by fabrication of guide fixtures to be used in conjunction with regular high frequency surface probes.
iii. Shaped probes can be manufactured in very low profile to allow access under obstructions. Attachment of a handle can allow access to even more restricted areas while maintaining good control during scanning.

iv. Heavy reliance on shaped probes is discouraged due to extra cost, poor cross utilization. When such a tool malfunctions, the inspection cannot be accomplished as written.

(d) Low Frequency Spot Probes (Ref. Figure 112)
   1) Coils are usually wound as absolute sensors or reflectance sensors. The reflectance probes are becoming most commonly used due to their better electrical stability at lower frequencies, allowing use of higher instrument gain settings.
   2) The specimen contact surface (tip) of a low frequency surface probe is usually flat, but may be slightly chamfered at edges to allow placement or scanning closer to radii and corners.

(e) Low Frequency Encircling (Ring) Probes (Ref. Figure 113)
   1) Ring probes (Sometimes referred to as Donut probes) are very similar to spot probes, except that the ring probes are hollow in the center to allow placement and alignment centered over fastener heads.
   2) When the ring probe is placed over a fastener made of a high permeability material, the fastener acts like an extension of the coil core, driving the magnetic field (and eddy currents) deeper into the material being tested. This feature generally allows testing of thicker materials containing magnetic steel fasteners than usually possible with the spot probe.
   3) The ring probe sometimes allows testing of structures where conventional probes cannot be used due to the effects of surface and/or subsurface edges and corners close to fasteners. If such features are too close to the fasteners they will also prevent use of these probes.
   4) Ring probes may be used for scanning structure (like spot probes) not affected by fasteners. Their outer diameters are usually larger than spot probes of the same frequency range. This larger diameter may be detrimental when the probe physical size is critical, but can sometimes be advantageous by allowing greater depth of eddy current penetration.
   5) The major disadvantage of the ring probe is when placed over protruding fasteners; the probe cannot be scanned over the structure allowing dynamic comparison of defective vs. non-defective structure. This technique allows only absolute comparison of conditions. The absolute reading is affected by structure thickness changes, fastener permeability/ conductivity differences, fastener diameter, length, and configuration, and other hardware differences.

   Where such differences are encountered, false defect indications may be obtained, or actual defects may be masked by those variables. If such structural differences exist in the inspection area, they must be represented in the reference standard and additional methods should be provided to evaluate inspection results.

(f) Low Frequency Special Application Probes
   1) Shaped Probes (Ref. Figure 111, 112, 113, 114)
      i. Low frequency Shaped probes are similar to, and offer the same advantages/disadvantages as high frequency shaped probes. See item (c) 3)
proceeding, and Figure 111 and 112. The major difference is the operating frequency and physical probe size.

(g) Sliding Probes (Ref. Figure 115)

1) The sliding probe is a driver / receiver (reflection) probe system exhibiting a wide range of usable frequency. Some probes are usable in both the low frequency range and low end of the high frequency range. They provide good defect sensitivity and reliability. The driver and receiver coils are not stacked Piggy-back or concentrically as in other probes, but located in tandem next to the inspection surface.

2) The tandem driver and receiver coil system allows detection of cracks at flush head fastener locations by sliding the probe (hence the name sliding probe") over the fastener heads without saturating the instrument display with the fastener signal. Impedance plane display instruments allow manipulation of the signal response to enhance discrimination between fastener and defect signals.

3) Prior to the development of the sliding probe, inspection at fastener locations was usually accomplished by the more tedious method of scanning a probe between each fastener or by placing a ring probe over each fastener in the inspection area. Such methods are still used in situations not adaptable to the faster sliding probe methods.

4) Direction Sensitive - Probe will detect linear type defects (such as cracks) only when the defect length is oriented parallel (or within 45 degrees from parallel) to the tandem axis of the driver and receiver coils. The tandem axis of the probe assembly is usually indicated by a green line etched on the probe. Since potential crack direction is normally known by the stress orientation in a given structure, the sliding probe can usually be scanned in the proper orientation to detect such cracks. The direction sensitive disadvantage is most troublesome when cracks must be found which radiate in all directions or when the direction is not known. When this occurs, probe scanning must be conducted twice along each fastener row or scan path. One scan must be performed with the probe tandem axis parallel to the fastener row or scan path, and the second scan with the probe tandem axis perpendicular to the fastener row or scan path.

5) Sliding probes will work only with instruments incorporating circuitry designed for (or adaptable to) reflectance probes.

6) Some advantages of the sliding probe are:

   i. Rapid inspection at installed flush head fasteners, as well as areas without fasteners.
   ii. Can be manufactured for large area coverage, reducing probe scan repetition.
   iii. Can be manufactured to allow adjustable spacing between driver and receiver coils for modification of signal response from troublesome fastener types, patterns and structural details. Variable coil spacing can also modify depth of eddy current penetration.
   iv. Improved depth of penetration compared to most other probes for a given frequency.
   v. Useable over a wide range of operating frequencies.

7) Some disadvantages of the sliding probe are:

   i. Very alignment sensitive - Probe must be properly aligned over fastener row to maintain consistent, reliable indications.

(h) Rotating Probes (Ref. Figure 117)
1) Rotating probes are used to detect short cracks under installed flush head fasteners. First layer cracks 0.032 inch long were detected at Sandia Laboratories using the NASA Self-Nulling Rotating Probe System with a 90/95% PoD in 0.040 inch thick skins at 60 kHz. First layer cracks 0.040 inch long have been detected in 0.063 inch thick skins at 35 kHz. Second layer cracks 0.100 inch long have been detected in 0.063/0.063 inch thick skins at 6 kHz. Third layer cracks 0.150 inch long have been detected in 0.040/0.040/0.040 inch thick skins at 3.5 kHz.

2) The rotating probe of the NASA system holds the sensor element, the self-nulling probe, in addition to housing a drive motor for probe rotation, an angular position sensor, and associated electronics. A button for controlling data acquisition is located on the frontend of the head. The circular front foot of the head is designed to be placed directly on the part surface under test allowing for controlled lift-off of the sensor. Adjustments to the probe rotation radius and lift-off heights are made at the rotating probe head. The data acquisition will not activate until the probe is properly centered over the fastener.

3) The Staveley/Nortec EddyScan 30 consists of a compact scanner and a portable instrument. Pulsed eddy current techniques and a broadband Hall Effect Sensor allow complete inspection of the hole from the surface to the maximum depth capability of the system. During inspection, the scanner is centered over the fastener. The Hall Effect Sensor and driving coil are rotated by the scanner about the fastener head. The signal induced into the part under test is a sharp edged magnetic pulse, providing a wide range of multi-frequency excitation. Due to the phase velocity effects, the lower frequency components propagate at slower rates through the material, while the higher frequency components take less time. Thus, effects from cracks that are shallower appear at an earlier time on the detected waveform. Depending upon the material under test and the expected depth of the crack, a "gate" is set to start a certain time after the start of each pulse with a width that covers the desired range of depth. The displayed signal is a comparison between the measured field strengths around the circumference of the fastener, and thus becomes rather insensitive to change in lift-off, conductivity, or permeability from one fastener to the next.

4) The basic operation of the Hocking Fast Scan Probe is that a driver coil induces eddy currents to circulate around the fastener. A series of pickup coils are arranged to operate with the generated eddy current field. In a typical arrangement four of these pick-up coils are arranged equally spaced at a set diameter. The pick-up coils are wired to reduce the effect of lift-off. The probe is centered over the fastener to be inspected and is manually twisted through 90-degrees. This allows each of the coils to traverse 90-degrees of the circumference of the fastener. As there are four pick-up coils, the full 360 degrees around the fastener is inspected. Should any cracks be encountered in the field of the eddy currents, the flaw signal will be displayed on the screen. To allow for easy operation of the Fast Scan Probe a guide has been produced that contains a bearing to allow an easy twist of the wrist operation from the operator and a guidance hole that is larger than the fastener head to allow a perfect concentricity to be obtained around the fastener. The FastScan Probe can be used in a single frequency mode, but is far more effective as a dual frequency technique, giving a very clear indication of small cracks in the second and third layers.

(4) Probe Ordering Information

(a) Probe operating frequency will be based on the instrument used and the type of test required. Specify operating frequency range when ordering.

(b) When ordering probes, specify the instrument for which the probe is being used so that probe connection can be made to the instrument. Specify probe size, shielding requirements, and lead preference (Separate, or Integral).
Bolt hole probes shall be selected based on the minimum diameter of the holes to be inspected. Particular size holes are specified for detailed inspections. However, some holes may be found to be oversized upon teardown, necessitating additional oversized probes.

F. Connectors, Leads and Adapters (Ref. Figure 116)
   (1) Many instrument and probe manufacturers use unique connectors for probes and accessories. Probes manufactured by one company may work on several instruments manufactured by various companies. To eliminate the need to purchase duplicate probes for each different instrument used, contact the instrument or probe manufacturer for a list of available adapters.
   (2) Specify desired connectors when ordering probes from vendors.
   (3) All leads should be shielded and have a nominal length of 72 inches.
   (4) Some flaw detectors were manufactured before reflectance probes were developed, but have the capability of operating them by utilizing external adapters. Contact the instrument manufacturer for applicability and availability of adapters.

G. Reference Standards
   (1) General
      (a) Reference standards must be used for all eddy current inspections. They must be designed to accurately represent all structural conditions and variables present in the inspection area that may affect the test results.
      (b) Reference standards should be designed to be as simple as practicable and still accomplish the desired effect. Structural details and hardware, multiple layers and extra cross section thickness which do not affect the test should be omitted when possible to reduce cost, size, and weight.
   (2) Surface Crack Standards (Ref. Figure 118)
      (a) Are used for equipment adjustment when inspection is required for defects which intersect the surface of the part.
   (3) Countersink Surface Crack Standards (Ref. Figure 119)
      (a) Are used for equipment adjustment when inspection is required for defects which intersect the surface of the part at the juncture of the open hole and the countersink. They are most commonly used when inspection of the interior of the hole is impractical as in thin materials.
   (4) Plug Probe Surface Crack Standards (Ref. Figure 120)
      (a) Are used for equipment adjustment when inspection is required for defects which intersect the surface of the part and inspection of the interior of the hole is impractical as in thin materials.
   (5) Open Hole Crack Standards (Ref. Figure 121)
      (a) Are used for equipment adjustment when inspection is required for defects originating in holes and must be detected before they reach the part surface.
   (6) Subsurface Crack Standards (Ref. Figure 122)
      (a) Are used for equipment adjustment when inspection is required for defects originating on surfaces or layers which are not accessible for other inspection methods. They are also used when inspection at fasteners must be conducted without their removal.
   (7) Material Thinning Reference Standards (Ref. Figure 123) (Applicable to nonmagnetic materials only)
(a) Most commonly used to simulate thinning of material by corrosion, erosion, abrasion, or mechanical rework for single layer structures

(b) Can be used to simulate thinning at faying surfaces of multiple layer structure, but such procedures are susceptible to false defect calls if on aircraft plate spacing variables are not eliminated, or mitigated by use of special equipment or processes.

(8) Stackable Reference Standards (Ref. Figure 124)

(a) Are multiple layer arrangements of plates or panels with slightly oversize fastener holes which may be easily disassembled and reassembled in different thickness or material combinations and/or utilizing different types of fasteners.

(b) Used to simulate structure where variables such as material type, thickness and fastener type are too numerous to allow economical or practical fabrication of permanently fastened reference standards simulating all the variables.

(c) Should be used only after verification that oversize holes used to allow fastener interchangeability does not affect instrument signal response at fasteners.

H. Fixtures (Ref. Figure 125)

(1) Some fixtures (Probe Guides) are useful to stabilize test probes during scanning to prevent tipping and resulting noise and to maintain the probe at a constant position relative to edges and other details. Other fixtures may be fabricated to control the index interval between multiple probe scans to ensure consistent coverage of large inspection areas.

3. Conductivity Measuring Systems

A. Conductivity Measuring Instruments (Ref. Figure 105)

(1) Description

(a) Dedicated conductivity measuring instruments are usually meter display or digital readout instruments capable of indicating measurement results in percent IACS for conductivity or its reciprocal resistivity in micro-ohm millimeter.

(b) Relative readings for sorting purposes maybe obtained using impedance plane display or meter display defect detection instruments after careful calibration using NIST traceable reference standards. It is also recommended that results be compared with those from similar parts of known values. Use of impedance plane display instruments is particularly helpful when troublesome nonconductive coatings cannot be removed for sorting tests.

(2) Required Features

(a) Frequency range required to maintain depth of penetration at less than the effective depth of penetration (EDP) (or 3 standard depths) for the material being tested. Most portable instruments for testing aluminum operate at 60 kHz and/or 100 kHz which limits the minimum thickness of the material which may be tested.

(b) Some form of lift-off effect suppression is needed if coated materials are to be tested without removal of coating. Some direct reading instruments incorporate automatic lift off compensation for up to 0.003 inch (0.08 mm) nonconductive coating thickness.

(3) Desirable Features

(a) Indication recording capability.

(b) Frequency range for impedance plane display instruments should be adjustable between 20 kHz and 100 kHz for sorting aluminum alloy. This would allow optimum separation of lift off effects from conductivity effects.
B. Conductivity Measuring Probes (Ref. Figure 126)
   (1) Description
      (a) Coils are usually wound as absolute sensors
      (b) The specimen contact surface (tip) of a conductivity probe is usually flat, but maybe slightly chamfered at edges.
   (2) Required Features
      (a) Compatibility with instrument used (indicated by sensitivity, stability and lift off characteristics).
         1) Most conductivity measuring systems utilize probes which are matched with the instrument.
      (b) Manufacturer part number and nominal frequency range should be marked on probe (or on integral instrument connector/lead assembly if probe marking not practical).
   (3) Desirable Features
      (a) Same as those for flaw detection probes.
C. Connectors, Leads and Adapters (Ref. Figure 116)
   (1) Specify desired connectors when ordering probes from vendors.
   (2) All leads should be shielded and have a nominal length of 72 inches.
   (3) Most probes used with conductivity measuring instruments are made by the same company who manufactured the instrument, so adapters are usually not required. If flaw detectors are used for material sorting, see paragraph 2 D.
D. Conductivity Reference Standards (Ref. Figure 127)
   (1) General
      (a) Reference standards must be used to calibrate equipment for all eddy current conductivity measurements.
         1) A set of two or more primary reference standards must be maintained, one of which is in the range of 25 to 32% IACS, and one in the range of 38 to 50% IACS. Primary reference standards must be traceable to the National Institute of Standards and Technology (NIST), and be certified to be accurate within ±0.35% IACS, or 1% of value, whichever is less, at 68° ± 5° F. Primary reference standards must be protected from heat and corrosion.
         2) Special secondary reference standards maybe manufactured locally and marked with their conductivity values as compared to those of primary standards.
         3) Actual parts may be used as "go, no-go" standards for heat treat, and material sorting if their authenticity is verified by hardness testing and conductivity test. Their conductivity readings must legibly marked on the parts.
      (b) Reference standards should be large enough to eliminate all edge effects during calibration. They must be thicker than the effective depth of penetration (EDP) for the frequency and probe used.
   (2) Material (Nonmagnetic Only)
      (a) Material used to manufacture reference standards should exhibit conductivities both greater and less than that of the part or structure being evaluated. Additional reference standards manufactured from the actual materials being sorted may also be helpful.
E. Conductivity Measurement Fixtures (Ref. Figure 125)
   (1) Some fixtures (Probe Guides) are useful to stabilize test probes during sampling positioning to prevent tipping and resulting lift off errors. Other fixtures may be fabricated to maintain the probe at a constant position relative to edges and other details.

4. Foerster Rivet Check System
   A. The Foerster Rivet Check System is designed to detect small cracks under installed fasteners in the thin outer layers of and below airframe fuselage skin. The instrument uses a patented rotating self-nulling eddy current probe. The unique eddy current distribution and simple flaw signature from this probe and the associated computer signal processing provides a simple to use and highly accurate fatigue crack detector. The results are superior to those obtained from other instruments of its type. Figure 129 shows an illustration of the system.
   B. The main features of the Rivet Check System are
      (1) Simple setup
      (2) Ease of operation
      (3) Lightweight test head
      (4) Guided probe centering
      (5) Ability to find small flaws (0.030 or longer) in aluminum first layers under nonferrous rivets.
      (6) Automatic data storage and display
      (7) Can be optimized for first, second or third layer tests
   C. Centering
      (1) The Rivet Check System software allows the user to easily center the inspection probe over the rivet head and then presents any defect signal on a separate display. The user can easily adjust for both probe liftoff and rivet head radius to quickly perform various inspection tasks.
   D. Testing
      (1) Testing for cracks can be performed either with or without the aluminum or titanium fasteners in place. Testing can be optimized for crack detection in the first, second or third layers of riveted joints with layer thickness ranging from 0.040" to 0.080". The Rivet Check System includes a test head with rotating self-nulling probe, data acquisition PC card and laptop computer. The laptop computer provides power to the test head, making the system portable and battery operated. The results can be reviewed layer using a viewer mode, which also permits printing of the test results.
   E. Reference Standards
      (1) The calibration standard included with the test system consists of three aluminum plates 0.040 inches thick. The plates are made of 2024-T3 aluminum. Each plate has 15 positions of rivets (3 rows of 5 rivets). The rivet head diameter is 0.236". The standard contains EDM notches under several of the rivets. The geometry of the notches is illustrated in Figure 130.

5. Magneto-optic/Eddy Current System
   A. Flaw Detection Instruments (Ref. Figure 128)
      (1) Description
         (a) The Magneto-optic / Eddy Current Imager (MOI) is a flaw detector which combines eddy current induction principles and real time magneto-optic imaging principles. The MOI is capable of inducing eddy currents in the frequency range from 1.6 to 100 kHz. At the higher frequencies, the instrument can image and detect surface and near-surface cracks and some
forms of corrosion in aluminum structures near fasteners. At lower frequencies, the instrument can detect and image second and third layer cracks and some types of corrosion in aluminum structures.

(b) The magneto-optic /eddy current technique induces currents to flow with a thin planar foil placed near, and parallel to, the surface of the test piece. Disruption of induced eddy currents produced by intervening fasteners, cracks, corrosion, and other defects are detected by a sensor which exhibits the Faraday magneto-optic effect. The sensor consists of a specially engineered magnetic garnet film. Images appear directly at the sensor and can be viewed by eye, or as an option, the output can be converted to standard television format using small CCD TV camera for viewing on a monitor and/or recording with a standard VCR. The MOI shown in Figure 26 consists of a control unit, optional CCD TV camera and monitor, and a hand-held imaging head. The monitor and imaging head can be located up to 30 feet from the control unit.

NOTE: The video camera and monitor are usually necessary to perform an inspection on the aircraft. The video equipment is usually not necessary if the inspection is accomplished on a subassembly in a shop environment.

B. Probes
   (1) The MOI sensor is an integral part of the scanning head, so separate probes are not required.

C. Connectors, Leads and Adapters
   (1) All required leads and adapters are supplied with the MOI instrument.

D. Reference Standards
   (1) The Reference standards required for the MOI are similar to those for other flaw detectors, except that the overall dimensions must be larger to prevent edge effects from affecting the instrument adjustment.

E. Fixtures
   (1) If the Direction of expected cracks is known, fixtures may be useful to maintain the probe at a constant position relative to edges and other details.
Table 101: Eddy Current Instrument Type (Example)

<table>
<thead>
<tr>
<th>Type</th>
<th>Used for Procedure Development</th>
<th>Example of Equivalent Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Impedance Plane Display (RP)</td>
<td>Staveley (Nortec) NDT18</td>
<td>Foerster: Detectoskop – S2830</td>
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<tr>
<td></td>
<td></td>
<td>Hocking: Phasec D5A &amp; D6A, AV10, AV100</td>
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<td></td>
<td>Magnaflux: ED 810</td>
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<tr>
<td></td>
<td></td>
<td>Rohmann: Elotest B1 &amp; B2</td>
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<td>Staveley: NDT 19, NDT 25, NDT 23ST</td>
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<td></td>
<td></td>
<td>Zetec: MIZ 17, MIZ 20A</td>
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<td>2. Impedance Plane Display</td>
<td>Automation Industries EM 3300</td>
<td>(Any Type 1 may be substituted for Type 2)</td>
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<tr>
<td></td>
<td></td>
<td>Magnaflux: ED 800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staveley: NDT 6D, NDT 15, NDT 16</td>
</tr>
<tr>
<td>3. Meter Display (RP) (A)</td>
<td>Zetec MIZ 10B</td>
<td>Hocking Super Halec A04-002*</td>
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<tr>
<td>4. Meter Display (A)</td>
<td>Zetec MIZ 10B</td>
<td>(Any Type 3 may be substituted for Type 4)</td>
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<td>Foerster: Defectometer 2.164, 2.835</td>
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<td></td>
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<td>Hocking: Halec MKII, Locator UH</td>
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<td>Magnaflux: ED 530</td>
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<tr>
<td>5. Motorized Hole Inspection</td>
<td>Gulton FD-100</td>
<td>Hocking Aeromaster – R</td>
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<td>Rohmann: Rototest B500</td>
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<td>Staveley: Rechii-l</td>
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<td></td>
<td></td>
<td>Zetec: MIZ 20B</td>
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<tr>
<td>6. Conductivity Measuring</td>
<td>Magnaflux FM120</td>
<td>Hocking Autosigma 2000</td>
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<tr>
<td>7. Bargraph Display (RP)</td>
<td>KB Instruments CrackFinder*</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

(A) Meter Display instruments are acceptable for flaw detection only when used in conjunction with an appropriately adjusted audio or visual flaw alarm.

(RP) Reflection eddy current probe capability

* Requires special eddy current probes matched for instrument manufacturer

Individual instrument suitability must be determined by the operator for each inspection. Other instruments not listed here may be used if performance, (sensitivity and signal to noise ratio) equals or exceeds the requirements of the applicable inspection procedure.
Typical Meter Display Instrument
Figure 101
Typical Impedance Plane Display Instrument
Figure 102

TYPICAL DUAL COIL TRACE

TYPICAL ABSOLUTE COIL TRACE
Typical Linear Timebase Display Instrument
Figure 103
Typical Bargraph Display Instrument
Figure 104

"NO CRACK" INDICATION

"CRACK" INDICATION
- OR -
"LIFT-OFF" INDICATION
A. METER DISPLAY INSTRUMENT

B. DIGITAL READOUT DISPLAY INSTRUMENT

Typical Conductivity Measuring Instrument
Figure 105
Typical Coil Types
Figure 106
Typical Surface Probes (High Frequency)
Figure 107 (Sheet 1 of 2)

* = 1/8 INCH DIAMETER SHAFT - MAY BE COPPER FOR FLEX
Typical Surface Probes (High Frequency)
Figure 107 (Sheet 2 of 2)
Typical Open Hole Probes (High Frequency)
Figure 108
Typical Countersink Probes (High Frequency)

Figure 109
Typical Plug Probe (High Frequency)
Figure 110

TYPE A - USED TO INSPECT COUNTERBORE OR SPOT FACE CORNER RADIUS AT OPEN HOLES. SPECIFY NORMAL HOLE DIAMETER, SPOTFACE DIAMETER AND CORNER RADIUS (R).

TYPE B - USED TO INSPECT SURFACE AT OPEN EDGE. SPECIFY NORMAL HOLE DIAMETER.
Typical Shaped Probes (High Frequency)
Figure 111
Typical Spot Probes (Low Frequency)
Figure 112
Typical Encircling (Ring) Probe (Low Frequency)
Figure 113
Typical Shaped Probe
Figure 114
Typical Sliding Probes
Figure 115
Typical Connectors, Adapters and Leads
Figure 116

NOTE:
SOME CONNECTORS FOR PROBES WITH INTEGRAL LEADS
AND SOME ADAPTERS CONTAIN IMPEDANCE MATCHING CIRCUIT FOR ABSOLUTE PROBES

CANNON 3 PIN
BNC
MICRODOT (MD)
BURNDY
ADAPTER BURNDY TO BNC
Rotary Probe
Figure 117
A. SINGLE NOTCH REFERENCE STANDARD

B. REFERENCE STANDARD DAC GS55T XX.01

Typical Surface Crack Reference Standard
Figure 118
SECTION A–A

Typical Countersink Crack Reference Standard
Figure 119
Typical Surface Crack Reference Standard for Plug Probes
Figure 120

SECTION A-A
A. SINGLE HOLE REFERENCE STANDARD

B. MULTIPLE HOLE REFERENCE STANDARD

Typical Open Hole Crack Reference Standard
Figure 121
Notes:

1. Crack orientation is related to a particular condition of loading as determined by stress and loading analysis.
2. Artificial defects should be oriented relative to the applicable crack propagation condition.

Typical Multi-layer (Subsurface) Crack Reference Standard
Figure 122
Typical Material Thinning Reference Standard
Figure 123

A. TAPERED REFERENCE STANDARD

INDEX MARKS
PLACED AT 0.005 INCH
INCREMENTS ALONG TAPER

B. STEPPED REFERENCE STANDARD

STEPS MILLED IN EACH STOCK SHEET THICKNESS
Notes:

1. Crack orientation is related to a particular condition of loading as determined by stress and loading analysis.
2. Artificial defects should be oriented relative to the applicable crack propagation condition.

Typical Stackable Reference Standard
Figure 124
Figure 125

DRAFTSMAN CIRCLE TEMPLATE (TYPICAL)

ADJUSTABLE PROBE COLLAR FOR FLAT SURFACES

ADJUSTABLE PROBE COLLAR FOR CONVEX SURFACES OR ROUND STOCK

Fixtures
Figure 125
Typical Conductivity Testing Probes
Figure 126

Spring loaded probe for flat surfaces
Spring loaded probe with "V" notched collar for convex surfaces
Typical Conductivity Reference Standards
Figure 127
Magneto-optic/Eddy Current Imaging System
Figure 128
NASA Self-Nulling Rotating Probe System
Figure 129
Foerster Rivet Check System Reference Standard
Figure 130
EQUIPMENT SUPPLIERS

1. General
   A. This subject provides supplier/vendor information for equipment and materials applicable to the Non-destructive Testing, Eddy Current, and methods.
   B. Table 202, lists general categories of equipment and materials followed by the product code number assigned to each category.
   C. Table 203, provides the address, product category and product line names available from each listed supplier.
   D. The equipment and addresses are listed only as examples and should not be considered as approval or disapproval of any product or supplier.
   E. Description of equipment and materials and examples are provided in B/E Aerospace NDT Manual 51-EQ-101/101.

<table>
<thead>
<tr>
<th>Vendor Name and Address</th>
<th>Use</th>
<th>Trade Name</th>
</tr>
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<tbody>
<tr>
<td>Ardox, Inc.</td>
<td>Paint Removal</td>
<td>Ardrox</td>
</tr>
<tr>
<td>16961 Knott Avenue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Mirada, CA 90638</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsalt Corporation</td>
<td>Paint Removal</td>
<td>E-Z Strip</td>
</tr>
<tr>
<td>3 Penn Center</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philadelphia, PA 19102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turco Products Div.</td>
<td>Paint Removal</td>
<td>Turco</td>
</tr>
<tr>
<td>Purex Corporation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24600 South Main</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilmington, CA 90744</td>
<td></td>
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Table 202: Product Codes for Supplier Information

<table>
<thead>
<tr>
<th>Equipment/Materials</th>
<th>Product Code</th>
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<tbody>
<tr>
<td>Conductivity Testers</td>
<td>1</td>
</tr>
<tr>
<td>Flaw Detectors</td>
<td>2</td>
</tr>
<tr>
<td>Motorized Open Hole Scanners</td>
<td>3</td>
</tr>
<tr>
<td>Probes, Leads, Adapters &amp; Fixtures</td>
<td>4</td>
</tr>
<tr>
<td>Reference Standards</td>
<td>5</td>
</tr>
<tr>
<td>SID Document Reference Standards</td>
<td>6</td>
</tr>
<tr>
<td>(Have Previously Expressed Interest)</td>
<td></td>
</tr>
<tr>
<td>Magneto-optic / Eddy Current Imager</td>
<td>7</td>
</tr>
<tr>
<td>Crack Finder</td>
<td>8</td>
</tr>
<tr>
<td>Rivet Check System</td>
<td>9</td>
</tr>
</tbody>
</table>
## Table 203: Supplier/Vendor Information

<table>
<thead>
<tr>
<th>Vendor Name and Address</th>
<th>Product Code</th>
<th>Product Line Name</th>
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<tbody>
<tr>
<td>Electro-Spezial Rohmann Koningsverger Staussie 13</td>
<td>2, 3, 4, 5</td>
<td>Rototest</td>
</tr>
<tr>
<td>6711 Beidersheim W. G.</td>
<td></td>
<td>Elotest</td>
</tr>
<tr>
<td>Foerster Instruments, Inc. 202 Rosemont Drive</td>
<td>2, 3, 4, 5, 9</td>
<td>Defectometer</td>
</tr>
<tr>
<td>Corapolis, PA 15108</td>
<td></td>
<td>Defectoscop</td>
</tr>
<tr>
<td>Gulton Industries</td>
<td>3</td>
<td>Rivet Check</td>
</tr>
<tr>
<td>Gulton Industries Park</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Greenwich, RI 02818</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hocking NDT, Ltd.</td>
<td>1, 2, 3, 4, 5</td>
<td>Locator</td>
</tr>
<tr>
<td>St. Albens England (or Krautkramer)</td>
<td></td>
<td>Aeromaster</td>
</tr>
<tr>
<td>Krautkramer-Branson Mifflin County Industrial Park</td>
<td>1, 2, 3, 4, 5</td>
<td>Locator</td>
</tr>
<tr>
<td>P.O. Box 350</td>
<td></td>
<td>Aeromaster</td>
</tr>
<tr>
<td>Lewistown, PA 17044</td>
<td></td>
<td>Halec, AV</td>
</tr>
<tr>
<td>Ideal Speciality Company</td>
<td>4, 5, 6</td>
<td>Ideal Speciality</td>
</tr>
<tr>
<td>2531 East Independence Tulsa, OK 74110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KB Instruments</td>
<td>2, 4, 5</td>
<td>CrackFinder</td>
</tr>
<tr>
<td>50 Industrial Park Road Lewistown, PA 17044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnaflux Corporation</td>
<td>1, 2, 3, 4, 5</td>
<td>ED</td>
</tr>
<tr>
<td>7300 W. Lawrence Avenue Chicago, IL 60650</td>
<td></td>
<td>Elotest</td>
</tr>
<tr>
<td>NDT Product Engineering</td>
<td>4, 5</td>
<td>NDT Prod.</td>
</tr>
<tr>
<td>7056 S. 220th St. Kent, WA 98032</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH Tool</td>
<td>5, 6</td>
<td>PH</td>
</tr>
<tr>
<td>10 Callow Hill Road New Britain, PA 18901</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRI Instrumentation</td>
<td>7</td>
<td>MOI</td>
</tr>
<tr>
<td>25500 Hawthorne Blvd. Suite 2300 Torrance, CA 90505</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Monitoring Inspection (QMI)</td>
<td>5</td>
<td>QMI</td>
</tr>
<tr>
<td>919 Sunset Drive Costa Mesa, CA 92627</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vendor Name and Address</td>
<td>Product Code (Ref: Table 202)</td>
<td>Product Line Name</td>
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<tr>
<td>---------------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Staveley Instruments, Inc.</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>NDT</td>
</tr>
<tr>
<td>421 N. Quay Street Kennewick, WA 99336</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyvin Inc.</td>
<td>4, 5, 6</td>
<td>Tyvin</td>
</tr>
<tr>
<td>4418 Auburn Way North #4j Auburn, WA 98002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniwest</td>
<td>2, 3, 4, 5</td>
<td>Eagle</td>
</tr>
<tr>
<td>1021 N. Kellogg Kennewick, WA 98373</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VM Products</td>
<td>4, 5, 6</td>
<td>VM</td>
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<tr>
<td>11208 62nd Ave Puyallup, WA 98373</td>
<td></td>
<td></td>
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<tr>
<td>Xactex Corp.</td>
<td>2, 4</td>
<td>Xactex</td>
</tr>
<tr>
<td>3704 Steawrman Ave. Pasco, WA 99301</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zetec Inc.</td>
<td>2, 3, 4, 5</td>
<td>MIZ</td>
</tr>
<tr>
<td>1370 N.W. Mall Issaquah, WA 98027</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. **General**
   A. Use this Low Frequency Eddy Current (LFEC) procedure to do an inspection for cracks on the aluminum parts that are behind other layers.
   B. The thickness of the layers in front of the parts to be examined must be between 0.036 inch (0.91 mm) and 0.250 inch (6.35 mm).
   C. This procedure uses an impedance plane display instrument.

2. **Equipment**
   A. **General**
      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.
      (2) Refer to 51-EQ-01 for data about the equipment manufacturers.
   B. **Instrument**
      (1) Use an eddy current instrument that:
         (a) Has an impedance plane or meter display.
         (b) Operates at a frequency range of 300 Hz to 9 kHz.
      (2) The instruments that follow were used to help prepare the procedure.
         (a) Phasc; GE Inspection Technologies
         (b) Nortec; Olympus NDT
         (c) Elotest; Rohmann GmbH
   C. **Probes**
      (1) Use a flat, shielded probe that operates at a frequency range shown in Table 2. The frequency range is specified in Table 2 for the thickness of the external skin repair.
      (2) The probes in Table 301 were used to help prepare this procedure.

### Table 301: Probe Data

<table>
<thead>
<tr>
<th>PROBE NUMBER</th>
<th>DIAMETER (inches)</th>
<th>PROBE TYPE</th>
<th>FREQUENCY RANGE</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDP .35-1K</td>
<td>0.35</td>
<td>REFLECTION</td>
<td>1 kHz to 10kHz</td>
<td>Techna NDT</td>
</tr>
<tr>
<td>SPO-5327</td>
<td>0.31</td>
<td>REFLECTION</td>
<td>700 kHz to 80kHz</td>
<td>Olympus NDT</td>
</tr>
<tr>
<td>SPO-5328</td>
<td>0.44</td>
<td>REFLECTION</td>
<td>500 kHz to 60kHz</td>
<td>Olympus NDT</td>
</tr>
<tr>
<td>RS1005-2/TF</td>
<td>0.50</td>
<td>REFLECTION</td>
<td>1 kHz to 40kHz</td>
<td>Olympus NDT</td>
</tr>
<tr>
<td>SPO-5330</td>
<td>0.62</td>
<td>REFLECTION</td>
<td>100 kHz to 20kHz</td>
<td>Olympus NDT</td>
</tr>
</tbody>
</table>
CAUTION: IN SOME INSPECTION AREAS, DIFFERENT LAYER THICKNESSES CAN OCCUR IN FRONT OF THE PART TO BE EXAMINED. IT IS IMPORTANT THAT YOU USE THE CORRECT FREQUENCY AND REFERENCE STANDARD FOR THE THICKNESS OF LAYER THAT IS IN FRONT OF THE PART TO BE EXAMINED. FAILURE TO USE THE CORRECT FREQUENCY AND REFERENCE STANDARD WILL DECREASE THE SENSITIVITY OF THE INSPECTION AND CRACKS WILL NOT ALWAYS BE FOUND.

(3) Use a probe that can operate at the necessary inspection frequency. The necessary inspection frequency is specified in Table 302 and changes when the thickness of the layer in front of the part to be examined changes.

(4) Probes with small diameters are recommended for use on thin layers.

D. Reference Standards

NOTE: It is possible that you will have to use more than one reference standard if the part has more than one thickness.

(1) Use reference standards identified in Table 302 that has a thickness range that includes the thickness of the part. See Figure 301 for data about the reference standards.

E. Special Tools

(1) Use a nonconductive circle template as a probe guide when the part has flush head fasteners. Use a hole diameter in the template that will keep the edge of the probe adjacent to the fastener.

3. Preparation for Inspection

A. Get access to the inspection areas.

B. Identify the inspection locations, fastener types and thicknesses of the part.

C. Remove loose paint, dirt, and sealant from the surface of the inspection area.

4. Instrument Calibration

A. Do a check in the area to find:

(1) The thickness of the layer in front of the layer to be examined and

(2) The type of fasteners that are used.

B. Refer to Figure 301 and Table 302 with the data of Paragraph 4.A. to identify the necessary reference standard to use during the inspection.

NOTE: Two reference standards are necessary to do the inspection of some parts, for example lap splices, because of thickness changes. The thickness of the layer to be examined must be in the thickness range that is specified in Table 302 for the reference standard.

C. Identify the necessary inspection frequency for the instrument from Table 302.

D. Get a flat surface probe that can operate at the frequency identified in Paragraph 4.C.

NOTE: Use the smallest diameter probe possible that will give a smooth scan inspection around the fastener and the best separation of the notch signal from the edge effect signal.

E. Connect the probe to the instrument and set the frequency to the frequency specified in Table 302.

NOTE: Use the instrument instructions supplied by the manufacturer to make all adjustments to the instrument.

F. If the inspection area is painted, put a shim that is not conductive on top of the reference standard. The shim thickness must be within 0.003 inch (0.076 mm) of the thickness of the paint.
G. Set the horizontal gain equal to the vertical gain.

H. Put the probe on the reference standard at position 1 so that it is adjacent to the same type of fastener as in the part. See Figure 302.

   NOTE: If the part has different types of fasteners, calibrate the instrument before you examine around each different fastener type.

I. Balance the instrument.

J. Set the balance point in the lower center of the instrument screen display as shown in Figure 303.

K. Adjust the instrument for lift-off:

   1. Adjust the phase control so that the signal moves horizontally to the left when the probe is lifted off the part as shown in Figure 303.

L. Move the probe above the reference notch of the reference standard as shown by position 2 in Figure 302. Adjust the position of the probe above the notch to get a maximum notch signal.

   NOTE: Make sure the probe is adjacent to the same type of fastener on the reference standard that is used in the part.

M. Make sure the signal from the reference notch is 90 degrees from the lift-off line (see Figure 303). Adjust the frequency to get a 90 degree separation between the lift-off line and the notch signal.

   NOTE: If the signal from the reference notch is positioned to the left of vertical (90 degree phase), then increase the frequency. If the notch signal is positioned to the right of vertical, then decrease the frequency. The frequency must be in the range specified in Table 302.

N. Adjust the sensitivity of the instrument to get a signal from the reference standard notch that is 40 percent of full screen height (see Figure 303). The horizontal and vertical gain must be equal.

O. Balance the probe at position 3 (see Figure 302) and move the probe around each side of the fastener. Monitor the notch signal and the edge effect as the probe passes above the edge. A beveled edge gives a different signal than a square edge (see Figure 304).

   NOTE: Make sure the probe is adjacent to the same type of fastener on the reference standard that is used in the part.

P. If flush head fasteners are used, move the probe above the top of the fastener and compare this signal with the notch signal (see Figure 304).

Q. If the signal moves horizontally off of the instrument screen display when the probe moves around the fastener heads and the probe is not near the reference standard notches or edges, set the horizontal gain so that it is less than the vertical gain. If the horizontal gain must be set less than the vertical gain, do Paragraph 4.L. thru Paragraph 4.P. again. Monitor the position of the signals on the instrument screen display.

   NOTE: Make sure there is sufficient separation between the flush head fastener signal, edge margin signal, and notch signal to identify a crack. If the separation is too small, increase the horizontal gain (or decrease the vertical gain) and do Paragraph 4.L. thru Paragraph 4.P. again. The horizontal gain must not be more than the vertical gain.

5. Inspection Procedure

   A. Examine parts that are behind other layers for cracks as follows:

      1. Put the probe on the part surface so that it is adjacent to and above the fastener head for the fastener type to be examined.

      2. Balance the instrument.
(3) Slowly do a scan around the fastener and monitor the instrument screen display at the same time. During the scan:
   (a) For protruding-head fasteners, keep the probe adjacent to the fastener head during the scan.
   (b) For flush-head fasteners, use a circle template to keep the probe an equal distance from the flush-head fastener during the scan.
   (c) For fasteners near the edge, move the probe around to the edge of the part until the edge effect signal goes off the screen display.
   (d) Make a mark at the locations where you get a signal that is 20 percent or more of full screen height and looks almost the same as the notch signal from the reference standard.

(4) Frequently do a calibration test of the instrument as follows:
   (a) Put the probe on the reference standard to get the maximum signal from the notch. Make sure to put the probe adjacent to the fastener on the reference standard that is the same type as the inspection.
   (b) Compare the signal you got from the notch during calibration with the signal you get now.
   (c) If the signal from the notch in the reference standard has changed 10 percent or more from the signal you got during calibration, do the calibration and inspection again for all of the fasteners examined since the last calibration test.

6. Inspection Results

A. Signals that are 20 percent or more of full screen height and look almost the same as the notch signal from the reference standard are signs of a possible crack.

B. Compare the signals to the signals you got from the reference standard.

C. The types of conditions that can occur during the inspection are as follows:
   (1) A crack on the lower edge of the fastener hole near the edge of the part.
      (a) If a crack occurs on the lower edge of the fastener hole near the edge of the part, the signal will go up as the probe is moved above the crack but will not go down to the baseline because of the edge effect condition from the part. See Figure 6 for an example of a crack signal that is near an edge.

      NOTE: The separation of the crack signal from the edge effect signal will be more with the inspection on thin layers. As the thickness of the layer increases, the separation of the crack signal from the edge effect signal will decrease. Be careful when you examine near the edge of the part.

   (2) A subsurface edge effect signal from a repair cutout in the skin (below the repair material).
      (a) If an inspection is necessary for fasteners near a repair cutout, it is possible to get a subsurface edge effect signal from the edge of the cutout in the skin. This condition can occur if there is not a sufficient amount of edge margin.
      (b) Be careful when you examine fasteners that are near the edge of a cutout because a crack can occur near the edge. Monitor the location of the probe around each fastener because an edge effect condition will usually occur at the same location.

   (3) Space (gap) between layers.
      (a) This condition can cause the balance point to go up. The balance point signal will go up slowly during the scan as the space between the layers increases.

   (4) A thickness change of the layer below the inspection layer.
(a) If the thickness of the layer below the inspection layer changes, it can cause the balance point to change. Do a check of the balance point signal regularly and balance the instrument as necessary.

D. If you want to make sure of the results, do the rotary scanner fastener hole inspection procedure specified in 51-EQ-06 page 601.

### Table 302; Reference Standard Specifications

<table>
<thead>
<tr>
<th>THICKNESS RANGE OF THE LAYER IN FRONT OF THE LAYER TO BE EXAMINED</th>
<th>REFERENCE STANDARD</th>
<th>MINIMUM THICKNESS OF THE LAYER TO BE EXAMINED</th>
<th>INSPECTION FREQUENCY (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.040 AND LESS</td>
<td>ANDT1049</td>
<td>0.032</td>
<td>6.0 – 9.0</td>
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<tr>
<td>0.041 – 0.050</td>
<td>ANDT1050</td>
<td>0.036</td>
<td>5.0 – 7.0</td>
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<tr>
<td>0.051 – 0.056</td>
<td>ANDT1077</td>
<td>0.036</td>
<td>4.0 – 6.0</td>
</tr>
<tr>
<td>0.057 – 0.075</td>
<td>ANDT1051</td>
<td>0.036</td>
<td>2.0 – 4.0</td>
</tr>
<tr>
<td>0.076 – 0.090</td>
<td>ANDT1052</td>
<td>0.036</td>
<td>1.0 – 3.0</td>
</tr>
<tr>
<td>0.091 – 0.110</td>
<td>ANDT1053</td>
<td>0.050</td>
<td>0.9 – 2.0</td>
</tr>
<tr>
<td>0.111 – 0.125</td>
<td>ANDT1054</td>
<td>0.063</td>
<td>0.9 – 1.5</td>
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<tr>
<td>0.126 – 0.160</td>
<td>ANDT1055</td>
<td>0.071</td>
<td>0.8 – 1.0</td>
</tr>
<tr>
<td>0.161 – 0.200</td>
<td>ANDT1056</td>
<td>0.080</td>
<td>0.5 – 0.7</td>
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<td>0.201 – 0.220</td>
<td>ANDT1057</td>
<td>0.100</td>
<td>0.4 – 0.6</td>
</tr>
<tr>
<td>0.221 – 0.250</td>
<td>ANDT1015</td>
<td>0.100</td>
<td>0.3 – 0.5</td>
</tr>
</tbody>
</table>

ALL DIMENSIONS ARE IN INCHES

**NOTE:** Reference standards ANDT1049 thru ANDT1057 replace NDT1006 thru NDT1014. If you have reference standards NDT1006 thru NDT1009, it is not necessary to replace them with ANDT1049 thru ANDT1052 if they have Alodined rivets.
NOTES:

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)
- TOLERANCES (UNLESS SPECIFIED DIFFERENTLY):
  - INCHES: MILLIMETERS
    - X.XXX = ±0.005 X.X = ±0.1
    - X.XX = ±0.025 X.X = ±0.5
    - X.X = ±0.050 X = ±1
- MATERIAL: USE BARE OR CLAD 2024-T3 OR T4 OR 7075-T6
- SEE TABLE I FOR THE REFERENCE STANDARD SPECIFICATIONS AND DIMENSIONS IDENTIFIED IN THIS FIGURE AS LETTERS A THRU E, M, N AND P.
- BE CAREFUL WHEN YOU INSTALL THE RIVETS. THE BOTTOM PIECE CAN BECOME DAMAGED IF INSTALLED TOO TIGHT.

1. THE CHAMFER WIDTH IS 0.16 INCH FOR ANDT1049 THRU ANDT1052, ANDT1056 AND ANDT1077; 0.10 INCH FOR ANDT1053; 0.13 INCH FORANDT1054; 0.14 INCH FOR ANDT1055; 0.20 INCH FOR ANDT1057 AND ANDT1015
2. ETCH OR STAMP THE PART NUMBER ANDT1XXX AS SPECIFIED IN TABLE I. PUT A LETTER "A" IN FRONT OF THE REFERENCE STANDARD NUMBER TO SHOW THAT IT HAS ALODINED RIVETS. REFER TO FLAGNOTE 5.
3. REFERENCE NOTCH. SIX LOCATIONS. MAKE THE NOTCH LESS THAN 0.030 (0.76) WIDE. SEE TABLE I, DIMENSION M, FOR THE NOTCH LENGTH.
4. OR EQUIVALENT
5. THESE RIVETS MUST HAVE A CONVERSION COATED (ALODINED) FINISH. TO MAKE SURE THE FINISH IS ALDINE, REFER TO PART 1, 51-06-01. INSTALL THE RIVETS AS SPECIFIED IN PART 1, 51-01-04.
## Reference Standards ANDT1015, ANDT1049 thru ANDT1057 and ANDT1077 Figure 301 (Sheet 2 of 2)

### Reference Standard Specifications

**Table I**

<table>
<thead>
<tr>
<th>Reference Standard Number</th>
<th>Fastener Type A</th>
<th>Fastener Type B</th>
<th>Fastener Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANDT1049</td>
<td>BACB30FN5</td>
<td>BACR15CE5D</td>
<td>BACR15ET70</td>
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<tr>
<td>ANDT1050</td>
<td>BACB30FN5</td>
<td>BACR15CE5D</td>
<td>BACR15ET70</td>
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<tr>
<td>ANDT1077</td>
<td>BACB30FN5</td>
<td>BACR15CE5D</td>
<td>BACR15ET70</td>
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<td>BACR15CE6D</td>
<td>BACR15BB8D</td>
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<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
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<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
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<tr>
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<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
</tr>
<tr>
<td>ANDT1055</td>
<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
</tr>
<tr>
<td>ANDT1056</td>
<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
</tr>
<tr>
<td>ANDT1057</td>
<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
</tr>
<tr>
<td>ANDT1015</td>
<td>BACB30FN8</td>
<td>BACR15CE8D</td>
<td>BACR15BB8D</td>
</tr>
</tbody>
</table>

Note:
- Reference Standards ANDT1049 thru ANDT1057 replace NDT1006 thru NDT1014. If you have reference standards NDT1006 thru NDT1009, it is not necessary to replace them with ANDT1049 thru ANDT1052 if they have alodined rivets. Refer to FlagNote S.

### Reference Standards

- ANDT1015
- ANDT1049 thru ANDT1057
- ANDT1077 Figure 301 (Sheet 2 of 2)
NOTES:

- Probe positions 1 thru 3 are the probe positions during instrument calibration for all fastener types.
- The screen display in Fig. 3 is an example of the calibration signals at probe positions 1 and 2. The notch signal can look different with different probes and instruments.

Probe Positions on the Reference Standard During Instrument Calibration Figure 302
NOTES:

- This screen display is an example of the calibration signals when the probe is at probe positions 1 and 2 (as shown in Fig. 2). The notch signal can look different with different probes and instruments.
NOTES:

- The screen displays above are signals with the probe adjacent to the type "C" fastener (see Table 1 in Figure 1).
- The screen displays above show the separation between the notch signal and the edge effect signal with an increase in the thickness of the top layer.

1. Edge effect signal from the side of the fastener with no notch.
2. Start of the edge effect signal from the side of the fastener with the notch.
3. Notch signal with the edge effect signal.

Screen Display Examples
Figure 304
Screen Display Examples

Figure 305

NOTES:

- The screen displays above are signals with the probe adjacent to the type "C" fastener (see Table 1 in Figure 1).
- The screen displays above show the separation between the notch signal and the edge effect signal with a change to a smaller diameter probe.

1. Edge effect signal from the side of the fastener with no notch.
2. Start of the edge effect signal from the side of the fastener with the notch.
3. Notch signal with the edge effect signal.
Screen Display Examples
Figure 306

NOTES:

- All dimensions are in inches (millimeters are in parentheses)
- The screen displays above are signals with the probe adjacent to the type "C" fastener (see Table 1 in Figure 1).
- The screen displays above compare the notch signal at probe position 3 to a notch at the lower edge of the fastener hole near the edge of the part.

1. Edge effect signal from the side of the fastener with no notch.
2. Start of the edge effect signal from the side of the fastener with the notch.
3. Notch signal with the edge effect signal.
ALUMINUM PARTS SURFACE INSPECTION (METER DISPLAY)

1. Purpose
   A. Use this procedure to do an inspection for surface cracks in aluminum parts.
   B. This procedure uses an instrument with a meter display.

2. Equipment
   NOTE: Instrument/probe combinations used shall be capable of detecting the calibration notch in the reference standard to the sensitivity requirements of Paragraph 4.
   A. Instrument
      (1) Battery-operated multi-frequency instruments with audible or visual alarms are recommended. The following instruments were used in the development of this procedure:
         (a) ED 520, ED 530, Magnaflux Corporation
         (b) MIZ 10, MIZ 10A, MIZ 10B, Zetec, Inc.
         (c) Locator UH, Locator UHB; Hocking Instruments
   B. Probes
      (1) Shielded pencil probes are recommended. Probes must meet the configuration and dimensional callouts of Figure 401, and the performance guidelines of Figure 402 and Figure 403.
         (a) Shielded or non-shielded probes may be used, provided the calibration notch in the reference standard can be reliably detected.
            Non-shielded probes should be used carefully. Meter response interference can be expected from adjacent structure, radii or close edge margins due to the unrestricted magnetic field of these probes.
         (b) Probe coil arrangement shall be such that a single coil in the probe tip comes in contact with the test structure.
         (c) Normal probe operating frequency is between 50 kHz and 500 kHz. Other frequencies may be used, provided the calibration notch in the reference standard can be reliably detected.
         (d) Probes should not give interfering responses from normal handling, manipulation, or operating pressure variations on the sensing coil.
   C. Reference Standard
      (1) Use reference standards 126, 188A, 189, or NDT1048. See Figure 404 thru Figure 407 for data about the reference standards.
      (2) Other reference standards can be used if they are equivalent to those shown in Figure 404 thru Figure 407.
   D. Special Tools
      (1) Use a nonconductive circle template as shown in Figure 409 to help examine the area around flush head fasteners for cracks.
      (2) Use a nonconductive straightedge as shown in Figure 410 and Figure 411 to help examine near the edges of parts for cracks.
3. Preparation for Inspection
   A. Identify the location of the inspection areas.
   B. If needed, obtain a smooth inspection surface by lightly sanding away surface roughness and sharp edges of chipped paint.
      NOTE: It is not necessary to remove paint or other nonconductive coatings.
   C. Wipe surface clean.
   D. Locate inspection equipment a minimum of 10 feet (3 m) away from any items that generate large magnetic fields, such as large motors, generators, transformers or power lines.

4. Instrument Calibration
   A. Set the frequency, if applicable, between 50 and 500 kHz.
      NOTE: To examine scribe lines, set the frequency between 50 and 150 KHz, if possible
   B. Calibrate the instrument with the applicable reference standard. Paragraph 5.D. identifies the different types of structural configurations that can be examined. The reference standards to use for the different structural configurations to be examined are:
      (1) Large Areas, Near an Edge, On an Edge, Radius -- Use reference standard 126.
         NOTE: To examine an area where scribe lines have been removed and before more material is removed for an insurance blend, it is permitted to use a reference standard with a notch depth as small as 0.008 inch (0.20 mm). It is not permitted to use a notch depth that is less than 0.008 inch (0.20 mm). Before you blend scribe lines, make sure it is permitted in the repair instructions.
      (2) Flush Head Fasteners -- Use reference standard NDT1048.
      (3) Protruding Head Fasteners -- Use reference standard 188A.
   C. If the inspection area is painted, put a nonconductive shim, which is the same thickness as the paint, on top of the reference standard. The nonconductive shim must be ± 0.003 inch (0.80 cm) of the paint thickness.
   D. Put the probe on the surface crack reference standard at least 0.5 inch (0.13 cm) away from the edge of the block and artificial crack. Balance the instrument according to the manufacturer’s instructions.
   E. Adjust lift-off to obtain less than 5 percent of full scale needle movement when probe is slid from a 0.002- to 0.004-inch (0.005 to 0.010 cm) non-conductive shim to the bare surface of the reference standard.
      NOTE: One sheet of ordinary writing paper, approximately 0.003 inch (0.007 cm) thick, can be used for the nonconductive shim.
   F. Slide the probe across the reference standard notch and adjust the sensitivity control to obtain a 20 to 40 percent of full scale meter deflection when passing the probe across the notch. Refer to Figure 408, Detail A. The signal to noise ratio must be 3:1, or better.
      NOTE: Inspection scanning speed may be increased by using an instrument with an audible or visual alarm. Set the alarm to respond at 50 percent of the reference standard notch signal amplitude. Refer to Figure 408, Detail B.
   G. Check the balance and lift-off again. If adjustments are made, check sensitivity (Paragraph 4.F.) again.
H. Find the maximum inspection scanning speed by sliding the probe across the reference standard notch. Note when the meter response does not fall below 90 percent of the calibration response, or when the alarm set in Paragraph 4.F. NOTE fails to trigger.

5. Inspection Procedure
   A. Prepare for inspection. Refer to Paragraph 3.
   B. Perform instrument calibration. Refer to Paragraph 4.
   C. Put the probe on the inspection surface. Check the balance and lift-off. If necessary, adjust on the part. NOTE: Do not adjust sensitivity.
   D. Scan all inspection areas. If not otherwise identified, a scanning pattern shall be established such that surface cracks 0.15 inch (0.38 cm) or more in length are detected. A scan direction should be chosen so that the probe is scanned across the crack. Do not exceed the maximum inspection scanning speed (Paragraph 4.H.).

Commonly encountered structural configurations may require these scanning techniques:
   1. Large area -- A grid system should be used for scanning. The distance between scans depends on the size of the probe sensing diameter and the minimum length crack to be detected. The scans should overlap so that the probe will scan over the potential crack twice. NOTE: To examine an area where a scribe line was removed by blending, make small scans across the location where the scribe line was. Do not make the scan too large as this can cause false indications from the change in clad thickness caused by the blend operation.
   2. Flush-head fasteners -- Inspect using a hole template. Position template to detect a crack extending 0.10 inch (0.25 cm) beyond the fastener head. Instrument/probe combinations must meet the performance guidelines of Figure 409.
   3. Protruding-head fasteners -- Inspect using the fastener head or washer as probe positioner to detect a crack extending 0.10 inch (0.25 cm) beyond fastener head. Instrument/probe combinations shall meet performance guidelines of Figure 410.
   4. Radius -- As the probe is scanned in the radius, it should be adjusted so that it is held perpendicular to the surface of the radius. Select scan increments based on probe sensing diameter and minimum crack length to be detected. Where crack orientation is unknown, make scans parallel and across the radius. Refer to Figure 411.
   5. Edges -- A constant distance must be maintained between the probe and the edge of a part. The minimum probe-to-edge spacing depends on the sensing area of the probe coil. Inspect near an edge by putting a nonconductive straightedge a constant distance away from the edge of the part. Refer to Figure 412 for inspections near the edge of aluminum structure. Refer to Figure 413 for inspections on the edge of aluminum structure.

E. Periodically check the instrument/probe calibration responses. For balance and lift-off responses, refer to Paragraph 5.C. For sensitivity response, refer to Paragraph 4.F. If any response is found to be unsatisfactory, inspect again all areas that were inspected since last calibration check.

F. Note all locations where a rapid upscale meter deflection, similar to the response from reference standard notch is obtained.

NOTE: Probe held at an angle other than perpendicular may cause meter fluctuation. Probe should be held perpendicular to part surface throughout the inspection.
6. **Inspection Results**

A. A potential defect is indicated by a rapid upscale meter deflection. Compare the defect response to the reference standard notch response at the same scanning speed.

B. A rapid meter deflection that is greater than 50 percent of the reference standard notch response amplitude and similar to the reference standard notch response indicates the presence of a crack.

   (1) Determine the end points of the crack by scanning along the crack until a meter response is no longer received.

   (2) Estimate crack depth (for crack lengths greater than probe sensing diameter) by comparing the crack response amplitude to the reference notch response amplitude. Note crack depth as less than, equal to, or greater than reference notch depth or compare crack response to reference notch responses of different depths.

   **NOTE:** Approximate crack depth can be determined by high frequency surface eddy current measurements when the crack depth in aluminum is less than 0.1 inch (0.254 cm).

C. Questionable indications or a response less than 50 percent of the reference standard notch response amplitude may indicate a defect condition. The following may be used to help defect determination.

   (1) A nonconductive probe fixture may reduce meter response variations caused by the probe not being held perpendicular to the part.

   (2) Teflon tape put over the sensing coil may improve the ratio of the crack-to-noise responses. Calibrate again when tape is added or removed from the probe sensing area.

   (3) The crack sensing distance traveled by the eddy current probe when crossing a suspected crack should be equal to the sensing distance traveled when crossing the reference standard notch.

   (4) Nonconductive coatings greater than 0.006 inch (0.015 cm) thick may reduce the amplitude of the crack signal. Remove the coating in the suspect area and inspect again.

D. Verification of surface cracks may be performed by either or both of the methods listed. The crack verification methods are not as sensitive in the detection of surface cracks as eddy current for in-service conditions. Care should be taken when comparing any negative verification results to a positive crack response obtained using eddy currents.

   (1) Remove the surface finish, grease, etc., and examine the area at 10X to 25X magnification with adequate lighting. A crack visible by this method requires no further investigation.

   (2) Perform a high sensitivity fluorescent penetrant inspection. Refer to B/E Aerospace NDT Manual 51-EQ-09/901.

   **NOTE:** Penetrant results may be enhanced on areas with metal smear or on tight fatigue cracks by surface etching. Etching requires local engineering approval.
NOTES

- THE PROBE CONFIGURATIONS SHOWN CAN BE USED TO ACCESS MOST INSPECTION AREAS WHEN IT IS NECESSARY TO USE PENCIL PROBES. SHIELDED PENCIL PROBES ARE RECOMMENDED. WHEN A SPECIAL PROBE CONFIGURATION IS NECESSARY, SPECIFY THE PROBE DIMENSIONS AS SHOWN FOR PROBE 2:

  A - THE PROBE DROP, OR DIMENSION A
  B - THE PROBE HEIGHT, OR DIMENSION B
  C - THE PROBE HANDLE LENGTH, OR DIMENSION C.

  IF THE HANDLE MUST BE BENT, IT WILL BE NECESSARY TO KNOW DIMENSION C1 AND THE HANDLE ANGLE (ANGLE THETA - \( \theta \)). FOR MOST USES, THE PROBE LENGTH WILL BE 3-5 INCHES (76.0-127.0 MM).

- DIAMETER: 0.20 INCH (5.1 MM) MAXIMUM.

  A DIAMETER OF 0.12 INCH (3.0 MM) IS RECOMMENDED FOR AREAS WITH NOT MUCH ACCESS.

- \( \alpha \) - THE ANGLE (\( \alpha = \text{ALPHA} \)). DIFFERENT ANGLES ARE POSSIBLE.

Pencil Probe Configuration (Example)
Figure 401
NOTES

- TO DETERMINE PENCIL PROBE ANGULARITY PERFORMANCE:
  1) CALIBRATE PROBE/INSTRUMENT COMBINATION TO THE REQUIREMENTS OF PAR. 4
  2) TIP PROBE ON THE SURFACE OF THE REFERENCE STANDARD IN SEVERAL DIRECTIONS 20 DEGREES TO THE SURFACE. THE PROBE ANGULARITY SHOULD NOT CAUSE MORE THAN A 10 PERCENT FULL SCALE SIGNAL RESPONSE CHANGE
  3) SCAN PROBE ACROSS NOTCH WHEN HELD NORMAL TO THE SURFACE AND AGAIN WHEN HELD AT 20 DEGREES FROM NORMAL. NOTCH SENSITIVITY SHOULD NOT DECREASE MORE THAN 10 PERCENT

EXAMPLE: SIGNAL RESPONSE FROM A 0.015 TO 0.020 INCH (0.038 TO 0.051 CM) DEEP CALIBRATION NOTCH ON THE REFERENCE STANDARD IS 40 PERCENT OF FULL SCALE WHEN THE PROBE IS PERPENDICULAR TO THE SURFACE. AT A PROBE ANGLE OF 20 DEGREES TO THE SURFACE, THE NOTCH RESPONSE SHOULD NOT BE LESS THAN 28 PERCENT OF FULL SCALE (40% SIGNAL X 0.3 = 12% AND 40% X -12% = 28%)

Pencil Probe Angularity Performance
Figure 402
**NOTES**

- TO DETERMINE IF A SHIELDED PENCIL PROBE HAS ADEQUATE SHIELDING:
  1) CALIBRATE PROBE/INSTRUMENT COMBINATION TO THE REQUIREMENTS OF PAR. 4
  2) USING THE PROTRUING-HEAD FASTENER REFERENCE STANDARD, MOVE PROBE FROM POSITION 1 TO POSITION 2. THE MAGNETIC STEEL SHOULD NOT CAUSE MORE THAN A 10 PERCENT SIGNAL CHANGE

Pencil Probe Shielding
Figure 403
NOTES

- ALL DIMENSIONS ARE IN INCHES
  (CENTIMETERS ARE IN PARENTHESES)
- TOLERANCE ±0.050 (0.127 CM) ON ALL
  DIMENSIONS EXCEPT AS NOTED
- FABRICATE FROM ANY OF THE FOLLOWING:
  2024-T3 OR -T4
  7075-16 OR -T73
  7079-16
  7178-16
- SURFACE FINISH: 63 OR BETTER
- REFER TO SUPPLEMENTARY MANUAL 51-EQ-02 SERIES DOCUMENT
  2-120483-800 FOR MANUFACTURING AND ORDERING INFORMATION
- ETCH OR STEEL STAMP WITH THE NUMBER 126

Reference Standard 126 for Surface Inspection of Aluminum Parts
Figure 404

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT
51-EQ-04

51-EQ-04
Page 408
Mar 29/16
NONDESTRUCTIVE TEST (NDT) MANUAL

SECTION A-A

NOTES

- DRAWING IS NOT TO SCALE.
- ALL DIMENSIONS ARE IN INCHES (CENTIMETERS ARE IN PARENTHESES).
- MATERIAL: 2024-T3 OR T4, 7075-T6, 7079-T6, 7178-T6
- SURFACE FINISH: 60 OR BETTER.
- IF YOU HAVE REFERENCE STANDARD 187, YOU CAN USE IT FOR THE INSPECTION AROUND ALUMINUM FASTENERS.

Flush-Head Fastener Reference Standard
Figure 405

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT

51-EQ-04
Manual No.: 2-120483-800
Page 409
Mar 29/16
NOTES

- All dimensions are in inches (centimeters are in parentheses).
- Tolerance ±0.005 (0.127 cm) except as noted.
- Fabricate from any of the following:
  2024-T3, 6945-T6
  7075-T6
  7079-T6
  7178-T6
- Refer to supplement NDT manual 41-EDU-1, eriDoc document 2-120483-802, for manufacturing and ordering information.
- Surface finish: ☑/or better.

Protruding-Head Fastener Reference Standard
Figure 406
NOTES

- ALL DIMENSIONS ARE IN INCHES (CENTIMETERS ARE IN PARENTHESES)
- TOLERANCE ±0.050 (0.127 CM) EXCEPT AS NOTED
- FABRICATE FROM ANY OF THE FOLLOWING: 2024-T3 OR T4, 7075-T6, 7079-T6 OR 7178-T6 (ALL MEMBERS MUST BE OF THE SAME ALLOY AND HEAT TREAT)
- SURFACE FINISH: 03 OR BETTER
- FASTENER - ANY ALUMINUM OR TITANIUM FASTENER WITH A MAE DIAMETER LESS THAN 0.5 (1.27 CM)

* REFER TO SUPPLEMENT NTM MANUAL 51-EQ-02, ERTSG DOCUMENT S-120460-882, FOR MANUFACTURING AND ORDERING INFORMATION

NOTCH = 0.305 (0.012 CM) MAX WIDTH, 0.040 (0.010 CM) DEPTH
ETCH OR STEEL STAMP WITH 189

Reference Standard 189 – For Cracks at Edge of a Part
Figure 407
NOTE

20 TO 40 PERCENT NEEDLE DEVIATION FROM THE REFERENCE STANDARD NOTCH

SENSITIVITY ADJUSTMENT DETAIL A

| 40% |
| 20% |

METER RESPONSE

NOTES

3. ALARM RESPONSE SET POINT = 50 PERCENT OF NOTCH RESPONSE

REFERENCE STANDARD NOTCH RESPONSE (TYP)

ALARM ADJUSTMENT DETAIL B

Alarm Adjustment
Figure 408
Flush-Head Scanning Guidelines
Figure 409

NOTES

- TO CONFIRM PROBE/INSTRUMENT SENSITIVITY FOR 0.09-0.10 INCH (0.220-0.254 CM) NOTCH ON FLUSH-HEAD FASTENER REFERENCE STANDARD:

1) CALIBRATE TO THE REQUIREMENTS OF PAR. 4

2) USE THE HOLE TEMPLATE AS A SCANNING GUIDE AROUND THE FASTENER. SELECT TEMPLATE HOLE SIZE AND CENTER ON THE FASTENER SO THAT THE PROBE SENSING DIAMETER REACTS TO THE NOTCH WITH A METER RESPONSE EQUAL TO OR GREATER THAN THE RESPONSE FROM THE CALIBRATION NOTCH AS THE PROBE IS MOVED AROUND THE FASTENER

REBALANCING THE INSTRUMENT MAY BE REQUIRED. DO NOT CHANGE THE CALIBRATION SENSITIVITY
FASTENER SCANNING WITH FASTENER HEAD AS GUIDE

NOTES

- TO CONFIRM PROBE/INSTRUMENT SENSITIVITY FOR 0.09-0.10 INCH (0.228-0.254 CM) NOTCH ON PROTRUDING-HEAD FASTENER REFERENCE STANDARD:
  1) CALIBRATE TO THE REQUIREMENTS OF PAR. 4
  2) USE THE FASTENER HEAD OR WASHER AS A SCANNING GUIDE SO THAT THE PROBE SENSING DIAMETER REACTS TO THE NOTCH WITH A METER RESPONSE EQUAL TO OR GREATER THAN THE RESPONSE FROM THE CALIBRATION NOTCH AS THE PROBE IS MOVED AROUND THE FASTENER. REBALANCING THE INSTRUMENT MAY BE REQUIRED. DO NOT CHANGE THE CALIBRATION SENSITIVITY
Radius Inspection
Figure 411

NOTES

- Hold probe normal to radius
- Space between scans is dependent on the crack size which must be detected
NOTES

- Position a non-conductive straightedge a constant distance away from the structure.
- Minimum probe to edge spacing is dependent upon the sensing area of the probe coil.
- To determine minimum probe to edge spacing:
  1) Calibrate to the requirements of PAR. 4
  2) Place the non-conductive straightedge a constant distance away from the notched edge of a reference standard.
  3) Scan probe along the straightedge and note the meter response. The minimum probe to edge spacing is when the meter response falls below 90% of the calibration response, or when the alarm set in accordance to PAR 4.E. fails to trigger.

Rebalancing the instrument may be required. Do not change the calibration sensitivity.

Inspection Near an Edge
Figure 412
NOTES

- Position a non-conductive straightedge to maintain a constant distance on the edge of the member in question.

- Minimum structure width for crack detection is dependent upon the sensing area of the probe coil.

- To determine minimum structure width:
  1) Calibrate to the requirements of Par. 4. Use reference standard 126.
  2) Position the non-conductive straightedge to maintain a constant distance along a notched member of the reference standard.
  3) Scan the probe along the straightedge and note the meter response. The minimum structure width is when the meter response falls below 95% of the calibration response, or when the alarm set in accordance to Par. 4 fails to trigger.

  Rebalancing the instrument may be required. Do not change the calibration sensitivity.

Inspection on an Edge
Figure 413
ALUMINUM PARTS FASTENER HOLE INSPECTION
(IMPEDANCE PLANE DISPLAY)

1. Purpose
A. To identify requirements for eddy current inspection, using impedance plane analysis, of fastener holes in aluminum structure with fasteners removed.
B. It is recommended that the hole be more than 0.063 inch (1.54 mm) deep to use this procedure.

2. Equipment

**NOTE:** Refer to B/E Aerospace NDT Manual 51-EQ-02/201 for data about the equipment manufacturers.

A. Instrument

   (1) Any eddy current instrument with impedance plane signal display that will satisfy the performance requirements of this procedure is suitable for this inspection. The following instruments were used during the development of this procedure and found suitable:

        (a) EM 4300; Automation Industries, Inc.
        (b) Defectoscope 2.830; Foerster Instruments, Inc.
        (c) MIZ-10, MIZ-10A, MIZ-17; Zetec, Inc.
            **NOTE:** Auxiliary CRT monitor for impedance plane display required with MIZ-10 or MIZ-10A.
        (d) NDT-18, NDT-19; Nortec
            **NOTE:** Instruments for impedance plane analysis usually work on a dual coil or driver-pickup coil principle. These instruments need the two coil probes or one coil probes with balance coil adapter.

B. Probes

   (1) The probe/instrument combination used in this procedure should meet the liftoff and sensitivity requirements of Paragraph 4. See Figure 501 for typical fastener hole probe configuration.

        (a) Probes should be compatible with dual coil or driver-pickup coil impedance plane instrumentation. Probes may have dual coils or single coil with balance coil adapter.
        (b) Probe diameter should be adjustable to obtain a tight fit in the hole.
        (c) Probes should have an adjustable collar which controls the penetration depth in the hole. The collar is to be used as a guide as the probe is rotated inside the hole.
            **NOTE:** See Figure 502 for sample probe list.
        (d) Probes should not give interfering responses from normal handling pressures or manipulation or from normal operating pressure variations on the sensing coil.

C. Test Block

   (1) Test blocks should have suitable natural cracks or artificial slots to simulate cracks in each of the hole sizes being tested. A standard test block should meet the following requirements:

        (a) Block should be of aluminum alloy with approximately the same conductivity as the part to be inspected.
        (b) Block should contain a suitable range of hole diameters to permit calibration of instrument for diameter of each hole to be tested.
(c) The crack or slot in the block must give an eddy current instrument calibration comparable to that obtained from the recommended test block (see Figure 503).

D. Reference Standards

(1) Test blocks should have suitable natural cracks or artificial slots to simulate cracks in each of the hole sizes being tested. A standard test block should meet the following requirements:

(a) Use reference standard 186A, 186B, 186C, 186D, 186E or 186F. See Figure 503 for data about the reference standards.

(b) Other reference standards can be used if they are equivalent to those shown in Figure 503.

3. Preparation for Inspection

A. Identify the inspection location(s) and the size of the fastener holes to be examined.
B. Clean loose dirt, chipped paint, and sealant from inside and around fastener hole.
C. Remove buildup of paint, sealant, etc., from around outside of hole where probe collar will bear.

NOTE: If surface of hole is extremely rough, a cleanup ream may be necessary. A 1/64 (0.016) inch diameter oversize is usually satisfactory.

4. Instrument Calibration

A. Attach appropriate probe to instrument, and if necessary, balance coil adapter.
B. Turn instrument on and allow to warm up per manufacturer’s instructions.
C. For instruments with adjustable frequency select frequency appropriate for test probe, usually between 100 and 500 kHz.
D. Select appropriate test block and place probe in hole with sensing coil away from notch. Expand loose probe to obtain snug fit. Probe should fit snugly to reduce probe wobble, but not so tight as to cause excessive wear of probe.
E. Balance instrument according to the manufacturer’s instructions.
F. With probe balanced in calibration hole, adjust instrument/CRT controls to position “flying dot” in center of screen.
G. Adjust instrument for liftoff.

(1) With probe balanced in calibration hole, manipulate probe to cause the coil to be lifted from hole surface.

NOTE: Probe liftoff can be achieved by squeezing the end of the probe so the coil moves away from the hole surface, or by placing a piece of tape 0.002-0.003 inch (0.005-0.007 cm) thick on the inside surface of the hole and rotating the probe until the coil is on the tape.

(a) Single coil probe - Adjust phase rotation control so that when probe coil is lifted off from the hole surface, the flying dot deflects horizontally toward the left side of screen (see Figure 504).

(b) Dual coil probe - Adjust phase rotation control so that when the probe is rocked in the hole, the flying dot deflects horizontally both right and left (see Figure 505).

H. Adjust instrument sensitivity for hole edge crack inspection

(1) Use the probe collar to adjust depth of coil in hole to obtain maximum flying dot deflection from 0.030-inch (0.076 cm) edge slot (see Figure 503, Slot No. 3). Check instrument balance for flying dot at center of screen and liftoff lying horizontal toward left side of screen.
(2) Adjust instrument sensitivity to obtain approximately one-third full screen width flying dot deflection from the 0.030-inch (0.076 cm) test block notch.

(a) Single coil impedance plane signal for notch will appear approximately as indicated in Figure 504.

(b) Dual coil impedance plane signal for notch will appear approximately as indicated in Figure 505.

NOTE: Both sides of loop may not always appear exactly the same.

The rework and modification procedures are based on the reliable detection of cracks 0.030-inch (0.076 cm) or greater in depth (radially). The instrument and probe should detect the 0.030-inch (0.076 cm) notch reliably.

I. Adjust instrument sensitivity for hole centered crack inspection.

(1) Repeat Paragraph 4.H. except use the probe collar to adjust depth of coil in hole to obtain maximum flying dot deflection from slot located between ends of hole in test block (see Figure 503, Slot No. 1).

J. Adjust instrument sensitivity for hole faying surface crack inspection.

(1) Repeat Paragraph 4.H. except use the probe collar to adjust depth of coil in hole to obtain maximum flying dot deflection from slot located at faying surface of hole in test block (see Figure 503, Slot No. 2).

5. Inspection Procedure

A. Calibrate instrument per Paragraph 4. for specific area of fastener hole to be inspected, i.e., surface, faying surface or mid-hole.

B. Adjust probe to required depth and insert into hole.

NOTE: Use test block to establish probe to upper or faying surface edge distance for detection of 0.030-inch (0.076 cm) hole edge cracks.

C. Check liftoff and flying dot placement. If necessary adjust balance control to position flying dot at center of screen and liftoff deflection lying horizontal toward left of screen.

D. Slowly scan entire circumference of hole using probe collar to maintain a constant probe depth in hole. Note position of any response which has approximately the same direction as and a length which is 60 percent, or more, of the response obtained from the 0.030-inch (0.076 cm) notch in the test block.

NOTE: Significant distortion of fastener hole impedance plane response patterns can result from hole gouges, out-of-round, corrosion, sealant, etc. These conditions generally produce horizontal deflections of the impedance plane signal without the rapid signal change associated with a surface crack. Significant improvement in the response pattern may be obtained by a 1/64 (0.016) inch hole oversize ream (see Figure 506).

For instruments with signal horizontal deflection control, an improved signal presentation maybe obtained by employing reduced horizontal sensitivity. If adjustment is made to signal horizontal deflection, check test block notch response. Note indications which are approximately in the same direction and 60 percent or more of test block response.

E. Adjust probe collar and repeat Paragraph 5.A. thru Paragraph 5.D. at incremental depths of 0.050- inch (0.13 cm) to within 0.025-inch (0.064 cm) from bottom end of hole or mating layer interfaces.

F. Recheck calibration of instrument with aluminum test block periodically to ensure proper sensitivity.
6. Inspection Results

A. A positive crack response is characterized by a rapid deflection of the impedance plane signal over a short scan distance and in the same general direction as the test block notch response. Deflection occurs as the coil moves over the crack. The related probe movement is equivalent to an arc of approximately 40 degrees in a 0.025-inch fastener hole and 20 degrees in a 0.50-inch hole for a hole probe with a 0.1-inch (0.25 cm) diameter coil.

**NOTE:** Impedance plane signal of in-service crack indication may not appear exactly like the notch response of the test block. Crack signals may appear as a sharp peak within a rounded or conical shaped signal. A 1/64 (0.016) inch ream may improve response interpretation. Examples of hole crack impedance plane response before and after reaming 1/64 (0.016) inch oversize is given in Figure 6 for a single coil probe.

B. Note locations of any questionable indications, i.e., crack-like indications causing responses less than the one obtained from 0.030-inch (0.076 cm) notch in test block, or indications not conforming to a positive crack response. To help do the inspections at these locations, do a maximum 1/64-inch cleanup ream and do this test again, paying particular attention to areas where the indications were noted. Note the location and the response of all positive crack indications.

C. When hole is reamed to clean up or remove the cracks, do an eddy current test after each increase in hole diameter. It is recommended that a hole be oversized in increments of no more than 1/64 inch in diameter. This is done to make sure the piece stays within permitted oversizing limits. The permitted limits for hole oversizing are specified in the repair document applicable to the structure (i.e., service bulletin, repair drawing or structural repair manual).

**NOTE:** When reworking a cracked part, it is imperative that an "insurance cut" be made after the eddy current inspection shows that the crack is fully removed. If possible, the depth of the insurance cut should be equal to or greater than the depth of the minimum detectable crack to make sure of complete crack removal. Get local engineering approval before you do an insurance cut.

D. An acceptable fastener hole response lies near the liftoff line and can oscillate horizontally along this line up to the entire screen width.
Typical Eddy Current Fastener Hole Probe – Absolute Type
Figure 501
## Vendor Part Number for Typical Fastener Hole Probes

**Figure 502**

<table>
<thead>
<tr>
<th>HOLE DIA (INCHES)</th>
<th>ABSOLUTE BOLT HOLE PROBES</th>
<th>DIFFERENTIAL BOLT HOLE PROBES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NORTEC PART NO.</td>
<td>NDT PRODUCT ENG PART NO.</td>
</tr>
<tr>
<td>3/16 (0.188)</td>
<td>2917 BP-12</td>
<td>BPFG-12</td>
</tr>
<tr>
<td>7/32 (0.219)</td>
<td>2918 BP-14</td>
<td>BPFG-14</td>
</tr>
<tr>
<td>1/4 (0.250)</td>
<td>2919 BP-16</td>
<td>BPFG-16</td>
</tr>
<tr>
<td>5/16 (0.313)</td>
<td>2921 BP-20</td>
<td>BPFG-20</td>
</tr>
<tr>
<td>3/8 (0.375)</td>
<td>2923 BP-24</td>
<td>BPFG-24</td>
</tr>
<tr>
<td>7/16 (0.438)</td>
<td>2925 BP-28</td>
<td>BPFG-28</td>
</tr>
<tr>
<td>1/2 (0.500)</td>
<td>2926 BP-32</td>
<td>BPFG-32</td>
</tr>
<tr>
<td>9/16 (0.563)</td>
<td>2927 BP-36</td>
<td>BPFG-36</td>
</tr>
<tr>
<td>5/8 (0.625)</td>
<td>2928 BP-40</td>
<td>BPFG-40</td>
</tr>
<tr>
<td>11/16 (0.688)</td>
<td>2929 BP-44</td>
<td>BPFG-44</td>
</tr>
<tr>
<td>3/4 (0.750)</td>
<td>2930 BP-48</td>
<td>BPFG-48</td>
</tr>
</tbody>
</table>

**NOTES**

When using absolute bolt hole probes with instruments requiring two coils, use two similar absolute probes or a single absolute probe with balance coil adapter.

**EFFECTIVITY**

**EDDY CURRENT**

ALL AIRCRAFT

Manual No.: 2-120483-800

Page 506

Mar 29/16
**NOTES**

- All dimensions are in inches
- Tolerance on all dimensions ±0.005 inch except as noted
- Material: 2014, 2024-T3 or -T4, 7075, 7079, 7178 aluminum alloy
- Refer to supplement NDT manual 51-EQ-02, enter document 2-D-204303, for manufacturing and ordering information
- Finish ream hole and do not deburr
- Electric discharge machine per given dimensions
- Hole diameter is standard
  - 0.1875
  - 0.2500
  - 0.3125
  - 0.3750
  - 0.4375
  - 0.5000
- Tolerance ±0.005
- Tolerance ±0.000 on all holes

---

<table>
<thead>
<tr>
<th>SLOT NUMBER</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.005</td>
<td>0.060</td>
<td>0.038</td>
</tr>
<tr>
<td>2</td>
<td>0.005</td>
<td>0.030</td>
<td>0.038</td>
</tr>
<tr>
<td>3</td>
<td>0.005</td>
<td>0.030</td>
<td>0.038</td>
</tr>
</tbody>
</table>

Tolerance maximum ±0.005 ±0.003

---

Aluminum Part Fastener Hole Test Block
Figure 503
General Single Coil Impedance Plane Response from 0.030 –Inch Notch
Figure 504
General Dual Coil Impedance Plane Response from 0.030 – Inch Notch
Figure 505
NONDESTRUCTIVE TEST (NDT) MANUAL

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT

51-EQ-05

Manual No.: 2-120483-800
Page 510
Mar 29/16

Impedance Plane Crack Response Improvement
Figure 506

EXAMPLE A

EXAMPLE B

NOTES
- SCREEN OMITTED FOR CLARITY
- SINGLE COIL PROBE RESPONSE
- UNACCEPTABLE RESPONSE PATTERNS
- ACCEPTABLE RESPONSE PATTERNS OBTAINED AFTER 1/64 (0.016) INCH CLEAN-UP REAM
ALUMINUM PART FASTENER HOLE INSPECTION
(ROTARY SCANNER)

1. Purpose
   A. To do an eddy current inspection of open fastener holes in aluminum parts with the use of a rotary scanner. The minimum material thickness that can be examined during this procedure is 0.020 inch (0.50 mm).

2. Equipment
   NOTE: Refer to B/E Aerospace NDT Manual 51-EQ-02/201 for data about the equipment manufacturers.
   A. All eddy current instruments with a rotary scanner that can satisfy the calibration instructions of this procedure can be used.
      (1) Instrument
         (a) An eddy current instrument that can operate in the dynamic mode (time related display) with a rotary scanner is necessary. The instrument must be able to operate between 300 kHz and 500 kHz. These instruments were used to prepare this procedure:
            1) AV100SE - Hocking, Ltd
            2) Defectoscoop D2.831 – Forster
            3) Elotest Bl – Rohman
            4) NDT-19 – Nortec
            5) Phasc 1.1 - Hocking, Ltd.
         (b) Rotary Scanner
            1) To do this procedure, a rotary scanner is necessary. The rotary scanner is used to turn automatically the probe connected to it. The rate at which the probe is turned is a function of the eddy current instrument. The rate of probe movement through a fastener hole is controlled by the operator.
   B. Probes
      (1) See Figure 601 and Figure 602 for examples of probe configurations for use with the rotary scanner. Probes that can be expanded for a close fit in the fastener hole are recommended. To do this procedure, the instrument and probe must be able to get the necessary lift-off and sensitivity results. Fastener hole probes must have these properties:
         (a) Probes must be able to operate at a frequency range between 100 kHz and 500 kHz.
         (b) The probes must have a differential-bridge coil or a differential reflection coil.
         (c) The probes must be able to operate with a minimum 5:1 signal-to-noise ratio on the reference standard and a minimum 3:1 signal-to-noise ratio on the part to be examined. Refer to Paragraph 4.K.
            NOTE: To get a better signal-to-noise ratio, you can add 0.003 inch (0.076 mm) thick tape to cover the probe coil area. Make sure that the tape is not conductive.
         (d) The probe diameter to use is determined by the diameter of the fastener hole to be examined.
            1) If you use a probe that cannot be expanded, make sure the difference between the hole diameter and the probe outer diameter is not more than 0.010 inch (0.25 mm).
2) Probes that can be expanded must be set so that there is a light interference fit when the probe is put into the fastener hole.

NOTE: If the probe fit is too tight, the probe will wear quickly.

3) This probes were used to prepare this procedure:
   i. 0.125 inch (3.18 mm), Part Number BPD-8, NDT Engineering Corp.
   ii. 0.187 inch (4.75 mm), Part Number BPD-12, NDT Engineering Corp.
   iii. 0.187 inch (4.75 mm) to 0.25 inch (6.35 mm) adjustable probe; Part Number BXEM-12/16, NDT Engineering Corp.

C. Reference Standards
   (1) Fastener hole reference standards must have EDM notches. See Figure 603 for the correct notch size. A reference standard for each hole size to be examined is necessary unless expandable probes are used. Reference standards can be different than those specified in Figure 603 if the hole sizes, EDM notch locations, and EDM notch sizes agree with the conditions specified in Figure 603.

3. Preparation for Inspection
   A. Identify the inspection location(s) and the size of the fastener holes to be examined.
   B. Clean loose dirt and sealant from inside the fastener hole.
   C. Visually look into all holes to be eddy current examined for surface conditions that can cause rejectable noise signals during the inspection. Borescopes, endoscopes or other optical aids can be used to help the visual inspection. Look for these conditions:
      (1) Burrs
      (2) Galling
      (3) Corrosion
      (4) Out-of-round holes

   NOTE: If a cleanup ream is necessary to remove one or more of these conditions, a 125 RHR or better surface finish is necessary. Get local engineering approval to do a cleanup ream.

4. Instrument Calibration
   A. Connect the rotary scanner to the instrument.
   B. Make sure the instrument is on and let it warm up. Refer to the manufacturer's instruction manual.
   C. Get the applicable reference standard and probe.
   D. Connect the probe to the rotary scanner.
   E. Set the instrument's frequency between 100 and 500 kHz.
   F. If possible, set the speed above 1000 RPM. Rotary scanner speeds less than 1000 RPM are not recommended because it is easy to miss a small defect at the lower speeds.
   G. Set the instrument in the impedance plane mode (X/Y). Make sure the rotary scanner is on and put the probe into the reference standard hole. Make sure the probe coil is away from the EDM notch.
   H. Balance the instrument. Refer to the instrument's instruction manual. Use the instrument's vertical position control to put the signal at approximately the center of the screen.

   NOTE: If your instrument does not have a balance function, ignore this step and go to Paragraph 4.I.
I. Put the probe on the surface of the reference standard. With the phase control, turn the signal to the horizontal position. See Figure 604.

J. Change the instrument display to the timebase mode. To do this, turn the sweep function on. Refer to the instrument's instruction manual.

K. If the instrument filters are set automatically when the rotary scanner is connected, go to Paragraph 4.L. If the instrument filters are not set automatically when the rotary scanner is connected, it will be necessary to set the filters manually. Use the steps that follow to adjust the filters:

1. High Pass Filters (HP) - Increase the filter to maximum or until the reference notch signal is decreased by 50%. This will decrease low frequency noise signals.

2. Low Pass Filters (LH) - Decrease to the lowest adjustment possible that does not cause the signal height to decrease.

3. Band Pass (BP) - If available, it is an alternative to the high pass and low pass filters. Adjust to get the best signal-to-noise ratio. A minimum signal to noise ratio of 5:1 is necessary.

NOTE: If the speed of the rotary scanner is changed, the filters will need to be adjusted. The maximum high pass filter adjustment must not be higher than the low pass filter adjustment.

L. Put the probe in the hole of the reference standard. Calibrate the probe on the 0.030 inch (0.76 mm) length notch unless told to calibrate on the 0.020 inch (0.51 mm) length notch by Maintenance Document.

M. Adjust the instrument gain (vertical) to get a 40 to 60 percent full screen height signal from the 0.020-inch or the 0.030-inch reference notch. See Figure 605. A minimum signal-to-noise ratio of 5:1 is necessary. See Figure 606. Adjust the instrument gain and filter controls to get the necessary signal-to-noise ratio. Refer to Paragraph 4.K. for information on how to adjust the filters. Refer to the note in Paragraph 2.B.(3) for more information on how to decrease the signal-to-noise ratio.

NOTE: The reference standard has the usual 0.030-inch (0.76 mm) notch but also includes a 0.020-inch (0.51 mm) notch. If your instrument can satisfactorily find the 0.020-inch (0.51 mm) notch, an instrument calibration with this notch permits a more sensitive evaluation.

N. Find the maximum speed that the probe can be put into a fastener hole. To do this, follow these steps:

1. Move the probe through the reference standard used to set the screen calibration. Refer to Paragraph 4.L.

2. Monitor the response level of the reference standard notch.

3. Increase the speed the probe is moved through the reference standard until the signal drops to 90% of the calibration level. This is the maximum speed that the probe can be moved through a fastener hole.

NOTE: The use of an audible or visual alarm is recommended. Set the alarm to operate at 50 percent of the reference standard notch signal.

O. The location of a crack or notch signal on the timebase line is directly related to the location of the crack or notch in the fastener hole. See Figure 607.

5. Inspection Procedure

A. Prepare for inspection. Refer to Paragraph 3.

B. Do the instrument calibration. Refer to Paragraph 4.

NOTE: If the equipment or the instrument controls are changed after an instrument calibration, you must calibrate again.
C. Examine all necessary fastener holes. To do this, make sure the rotary scanner unit is on and move the probe smoothly through the length of each fastener hole. Do not do a scan faster than the scan rate found in Paragraph 4.N. Do an instrument calibration check regularly and after all fastener holes have been examined. If the sensitivity has decreased since the last calibration, all fastener holes examined since the last calibration must be examined again.

NOTE: An approved light oil or grease put on the probe coil area will decrease probe wear.

D. Do Paragraph 5.A. thru Paragraph 5.C. for each size fastener hole to be examined.

E. Make a record of all fastener hole locations where a crack signal occurs. Also make a record of those fastener holes where it is necessary to do a cleanup ream before a satisfactory inspection can be made. Refer to Paragraph 3.

F. Do a minimum 0.016-inch (0.41 mm) cleanup ream on those fastener holes recorded in Paragraph 5.E. where a cleanup ream is necessary.

NOTE: Get local engineering approval to do a cleanup ream.

G. Make an inspection again of all fastener holes where a ream was necessary.

6. Inspection Results

A. Fastener holes with no crack signals are acceptable. An eddy current crack signal will look almost the same as the reference standard notch signal. Noise signals have a wider shape than crack signals and can make it hard to see crack signals. If the signal-to-noise ratio between the reference standard notch signal and the inspection surface noise level is less than 3:1, refer to Paragraph 3.C.

B. Fastener holes with crack signals that are 100% or more of the reference standard notch signal must be rejected.

C. To remove a crack, oversize the hole a minimum 0.016 inch (0.40 mm) and do an eddy current inspection again. If the crack was removed by the first oversize ream, go to Paragraph 6.D. If the crack was not removed after the first oversize ream, continue to oversize and do an eddy current inspection of the hole until the crack is completely removed.

NOTE: Get local engineering approval for all holes that need to be oversized.

Monitor and make a record of the depth of the position of the crack. When you examine the hole again, look carefully at this location. New indications that occur at other locations can be caused when the hole is oversized and can be ignored.

If a larger probe is necessary to examine an oversize hole, you must calibrate again before you do the examination.

D. When a crack has been removed and cannot be found by the eddy current inspection, it is necessary to do one more ream as an "insurance cut". If the 0.020-inch (0.51 mm) reference standard notch was used for the instrument calibration, a 0.047-inch (1.19 mm) oversize ream is recommended. If the 0.030-inch (0.8 mm) reference standard notch was used for the instrument calibration, a 0.063-inch (1.59 mm) oversize ream is recommended. This "insurance cut" is done to make sure that a crack too small to find by the eddy current inspection is fully removed.

NOTE: Get local engineering approval before you do an insurance cut.

E. A fastener hole with an eddy current signal that looks almost the same as a crack signal and is between 50% and 100% of the reference standard notch signal must be examined some more. Examine by:

(1) Do a visual inspection of the fastener hole. Look for surface conditions that can cause an eddy current crack signal. Refer to Paragraph 3.C. If a surface condition is seen at the same depth and in the same position of the eddy current signal, the fastener hole can be accepted. If no surface
conditions are seen that could be the cause of the eddy current signal, reject the hole and go to Paragraph 6.C.

**NOTE:** Get local engineering approval to accept the hole with the surface condition that caused the eddy current indication.

---

**Example of an Expandable Fastener Hole Probe**

**Figure 601**

---

**NOTES**

- All dimensions are in inches (millimeters are in parentheses).
- The usual probe configuration is shown. Different probe manufacturers make probes that are symmetrically different or have different end connector fittings.
- Probes must have a differential-bridge coil or a differential-reflection coil.
- The probe head diameter must fit the inspection hole. Usual probe head diameters are: 0.187 (4.75), 0.250 (6.35), 0.312 (7.92), 0.375 (9.53), 0.437 (11.1), 0.500 (12.7).
- The probe is adjustable for the diameter range specified on the probe body. The usual not engineering probes that will fit an inspection of hole diameters from 0.188-0.875 (4.75-22.2) are:
  - BXU-22/16 0.187-0.250 (4.75-6.35)
  - BXU-20/20 0.250-0.312 (6.35-7.92)
  - BXU-24/28 0.312-0.375 (7.92-9.53)
  - BXU-28/32 0.375-0.437 (9.53-11.1)
  - BXU-32/40 0.437-0.500 (11.1-12.7)
  - BXU-40/48 0.500-0.625 (12.7-15.8)
  - BXU-48/56 0.625-0.750 (15.8-19.1)
  - BXU-56/64 0.750-0.875 (19.1-22.2)

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**EDDY CURRENT**

51-EQ-06

Manual No.: 2-120483-800
Example of a Fastener Hole Probe – Non Adjustable
Figure 602

NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)
- THE USUAL PROBE CONFIGURATION IS SHOWN. DIFFERENT PROBE MANUFACTURERS MAKE PROBES THAT ARE SYMMETRICAL DIFFERENT OR HAVE DIFFERENT END CONNECTOR FITTINGS
- USE PROBES SO THAT THE DIFFERENCE BETWEEN THE HOLE DIAMETER AND THE PROBE OUTER DIAMETER IS NOT GREATER THAN 0.010 (0.25)

PROBES MUST HAVE A DIFFERENTIAL-BRIDGE COIL OR A DIFFERENTIAL-REFLECTION COIL

THE PROBE HEAD DIAMETER MUST FIT THE INSPECTION HOLE. DIFFERENT PROBE SIZES ARE AVAILABLE IN 0.05 (0.79) INCREMENTS
NOTES

- All dimensions are in inches (millimeters are in parentheses).
- Tolerance on all dimensions ±0.05 (0.27) unless specified differently.
- Material: all aluminum alloys that have a conductivity between 28 and 35% IACS (International Annealed Copper Standard) such as 2024-T3 or -T6, 7075-T6, 7079-T6.
- Reference standards made at specified in supplement/NTManual 6-12EQ-02. Entred document 2-10248303, are acceptable.

- Finish the ream hole to 63 Ra. Do not deburr.
- Electrical discharge machine (EDM) notch. Refer to the given dimensions.

> When probes that are not adjustable are used, the hole diameter must equal the fastener hole to be examined.

REFERENCE STANDARD HOLE DIAMETERS FOR ADJUSTABLE PROBES:

<table>
<thead>
<tr>
<th>Reference Standard</th>
<th>Hole Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND11056</td>
<td>0.118 (4.70)</td>
</tr>
<tr>
<td>ND11057</td>
<td>0.250 (6.35)</td>
</tr>
<tr>
<td>ND11058</td>
<td>0.313 (7.94)</td>
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<tr>
<td>ND11059</td>
<td>0.375 (9.55)</td>
</tr>
<tr>
<td>ND11060</td>
<td>0.438 (11.17)</td>
</tr>
<tr>
<td>ND11061</td>
<td>0.508 (12.92)</td>
</tr>
<tr>
<td>ND11062</td>
<td>X.XXX (X.XXX)</td>
</tr>
</tbody>
</table>

TOLERANCE ON ALL HOLES: ±0.005 (0.13)

- Other hole diameters can also be used if necessary. Use reference standard number ND11064 and make sure to identify the hole diameter as specified in flag note 5.

- Identify the hole diameter and the reference standard part number on the reference standard. (The location for their identification mark is optional.)

- If the hole diameter is from 1.750 (44.45) to 2.250 (57.10), race the outer diameter 3.0 (76).
NOTE

- With the rotary scanner on, and the probe against the side of the reference standard, use the phase control to turn the lift-off signal to the horizontal position.

Phase Adjustment
Figure 604
NOTES

1. THE HORIZONTAL POSITION OF THE SIGNAL ALONG THE TIMEBASE LINE IS RELATED TO THE LOCATION OF THE NOTCH OR CRACK IN THE FASTENER HOLE. SEE FIGURE 7

2. WHEN THE SCREEN IS DIVIDED INTO EIGHT PIECES, EACH PIECE EQUALS 12.5% OF FULL SCREEN HEIGHT

Instrument Calibration
Figure 605
Use of Signal Filter to get 5:1 Signal-to-Noise Ratio

Figure 606

NOTE

When the screen is divided into eight pieces, each piece equals 12.5% of full screen height.
NOTE

△ THE SIGNAL LOCATION ON THE TIME BASE LINE WILL BE DIFFERENT WITH DIFFERENT INSTRUMENTS. USE A REFERENCE STANDARD NOTCH TO COMPARE THE SIGNAL LOCATION ON THE TIME BASE LINE TO THE CRACK LOCATION IN THE TEST PIECE.

Crack Location
Figure 607
SURFACE CRACK INSPECTION OF FAYING SURFACE

1. Purpose
   A. Use this procedure to do an inspection for subsurface cracks that:
      (1) Are adjacent to fastener holes.
      (2) Are near the external surface of the first layer of aluminum fuselage structures.
      (3) Start at the internal (faying) surface.
   B. This procedure can be used to find:
      (1) Cracks that start at fastener holes and move out in a radial direction.
      (2) Cracks that start away from the fastener hole and are alongside the hole (eyebrow cracks).

2. Equipment
   A. General
      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.
      (2) Refer to B/E Aerospace NDT Manual 51-EQ-02/201 for data about the equipment manufacturers.
   B. Instrument
      (1) Use an impedance plane instrument that operates in a frequency range of 10 to 50 kHz.
      (2) The instruments specified below were used to help prepare this procedure.
         (a) NDT-19 Staveley Instruments
         (b) MIZ 22; Zetec Inc. Reference Standards
   C. Probes
      (1) Use a probe that can operate in a frequency range of 10 to 50 kHz.
      (2) If you make an order for a probe, make sure to give the instrument or connector type.
      (3) The probes identified below were used to prepare this procedure.
         (a) MT-30/50K; NDT Engineering Corp.
         (b) P/50-100K/A/0.0/3; Staveley Instruments
         (c) LP903-50B/2-12K; NDT Engineering Corp.
         (d) SPO-6464; Staveley Instruments
         (e) SPC4TF-105; EC/NDT Company
         (f) LS905-50B; NDT Engineering Corp.
   D. Reference Standard
      (1) Use reference standard ANDT4126. See Figure 701 for data about the reference standard.

3. Preparation for Inspection
   A. Identify the location of the inspection areas.
   B. Get access to the inspection areas.
C. Remove loose paint, dirt, and sealant from the surfaces of the inspection area.
D. Make the inspection surfaces smooth if they are rough.

4. Instrument Calibration
   A. Set the frequency between 10 and 50 kHz.
   B. If the inspection area is painted, put a nonconductive shim on top of the reference standard. The thickness of the nonconductive shim must be within ± 0.003 inch (0.08 mm) of the paint thickness.
   C. Put the probe on reference standard ANDT4126 at position 1 on the side of the reference standard opposite the fastener heads (see Figure 702).
   D. Balance the instrument.
   E. Adjust the instrument phase to get a lift-off signal that moves horizontally to the left as shown in Figure 702.
   F. Adjust the horizontal gain or vertical to horizontal gain ratio to get a lift-off signal of less than 20% of full screen width when the probe is lifted off the reference standard 0.003 inch (0.08 mm) (one sheet of paper is approximately 0.003 inch, 0.08 mm).
   G. Move the balance point to the position shown in Figure 702.
   H. Move the probe above the reference standard notch at probe position 2 as shown in Figure 702.
      NOTE: This notch is used to calibrate the equipment to do an inspection for cracks along the side of the fastener hole.
   I. Adjust the instrument gain to get signal amplitude of 80 percent of full screen height as shown in Figure 702.
   J. It will be necessary to use a different frequency between 10 and 30 kHz and do Paragraph 4.F. thru Paragraph 4.I. again if:
      (1) The signal to noise ratio is less than 3:1 or,
      (2) The notch signal is not vertical to the lift-off line.
   K. Move the probe above the reference standard notch at probe position 3 as shown in Figure 702. This notch causes a radial crack signal to occur on the screen display. Monitor the signal as you move the probe above the notch. The radial crack signal must occur in the shaded area shown in Figure 702.

5. Inspection Procedure
   A. Put the probe on the inspection surface adjacent to a fastener.
      NOTE: After the instrument is calibrated from the tail side of a fastener, the inspection can be done from the head or the tail side of a fastener. Refer to the document that specified to use this procedure to identify the correct inspection surface.
   B. Balance the instrument.
   C. Do a scan of the inspection area as follows:
      (1) Use a scan pattern that will permit you to find subsurface cracks that are 0.25 inch (6.4 mm) or more in length. Figure 703 shows a possible scan pattern.
         (a) Use the end of the fastener as a probe guide and do the scan completely around the fastener.
         (b) Make a second scan completely around the fastener with the probe moved a distance of 0.25 inch (6.4 mm) from the fastener.
      (2) Keep the probe vertical to the part surface to decrease the balance point movement.
(3) Frequently do a check of the instrument/probe calibration during the inspection as follows:
   (a) Put the probe on the reference standard to get a signal from the notch.
   (b) Compare the signal you got from the notch during calibration with the signal you get now.
   (c) If the signal has changed 10% or more, do the calibration and inspection again on all areas examined since the last calibration check.

(4) Monitor all areas for fast upscale signals that are almost the same as the signals you got from the reference standard notches.

6. Inspection Results
   A. Indications of possible cracks are as follows:
      (1) Signals more than 40 percent of the display.
      (2) Fast upscale signals that occur when the probe is moved a small angular distance (signals such as those you got during calibration).

   B. Some cracks follow a circumferential path around the fastener and do not always end at the fastener hole. These type of cracks cause a fast upscale signal that will keep the same signal amplitude as the probe is moved around the fastener head for the length of the crack.

   C. To find the length, or the ends, of a crack, do a scan across the length of the crack until a signal does not occur.

   D. You can do more examination to make sure a crack signal is the result of a crack as follows:
      (1) For crack that starts at fastener holes, use the high frequency inspection procedure detailed in B/E Aerospace NDT Manual 51-EQ-03/301 for the Manual Probe, and B/E Aerospace NDT Manual 51-EQ-04/401 for the Rotating Probe.
NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)
- TOLERANCES (UNLESS SPECIFIED DIFFERENTLY)

<table>
<thead>
<tr>
<th>INCHES</th>
<th>MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>X.XX = ±0.025</td>
<td>X.X = ±0.040</td>
</tr>
<tr>
<td>X.XX = ±0.040</td>
<td>X.X = ±0.10</td>
</tr>
</tbody>
</table>

ANGULAR: ±1.0 DEGREE

- SURFACE ROUGHNESS = 125 RA OR BETTER

ETCH OR STEEL STAMP THE REFERENCE STANDARD NUMBER ANDT4126 AT APPROXIMATELY THIS LOCATION. PUT A LETTER "A" IN FRONT OF THE REFERENCE STANDARD NUMBER TO SHOW THAT IT HAS ALUMINUM RIVETS.

EDF NOTCH: PUT THE NOTCH ADJACENT TO THE HOLE EDGE WITHIN ±0.005 (±0.10). NOTCH DIMENSIONS AND TOLERANCES:

- DEPTH: 0.040 (1.04)
- WIDTH: 0.025 (0.75) MAXIMUM
- LENGTH: 0.250 (6.4)

THIS NOTCH STARTS AT THE HOLE CENTERLINE AND IS TANGENT TO THE HOLE.

FASTENERS: NAS1345-6 OR EQUIVALENT (4 LOCATIONS). THESE RIVETS MUST HAVE CONVERSION COATED (ALUMINUM) FINISH.

Reference Standard ANDT4126
Figure 701
Instrument Calibration
Figure 702

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT 51-EQ-07

Manual No.: 2-120483-800
NONDESTRUCTIVE TEST (NDT) MANUAL

PROBE POSITIONS FOR A POSSIBLE SCAN PATTERN

MOVE THE PROBES AROUND THE FASTENERS AT TWO RADIAL DISTANCES TO MAKE A SCAN.

OPPOSITE SIDE OF THE FASTENER HEADS

A-A

TYPICAL CRACK SIGNAL

LIFT-OFF SIGNAL

IMPEDANCE PLANE DISPLAY

BALANCE POINT

80%

40% (REJECT LEVEL)

20%

Inspection Scan Pattern and Defect Indications

Figure 703

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT

51-EQ-07

Manual No.: 2-120483-800

Page 706
Mar 29/16
DETECTION OF CRACKS AT EDGE OF CUTOUTS

1. **Purpose**
   A. Detection of surface cracks at edges of cutouts.
   B. Procedures describe applies to aluminum structures (Minimum Thickness of 0.040 inch).

2. **Remarks/Description**
   A. This inspection method is designed to detect cracks which emanate from the edges of single or multiple layer cutouts or travel from fastener holes to the edge of a cutout.

3. **General Safety and Precautions**
   A. Prior to the start of testing operations, survey the general area for possible hazards such as loose or protruding equipment and structure, electric cords, presence of flammable or toxic fluids and/or fumes. If AC power is supplied to the equipment, ensure that it is well grounded. Firmly secure all equipment when not in use or when in used above ground level.
   B. If testing involves the entry of personnel into confined areas or into areas where normal breathing may be affected, the use of auxiliary breathing apparatus, ventilation apparatus, observers, and other safety measures must be employed.

   **WARNING**: Take necessary precautionary measures to ensure the health and safety of all personnel and to prevent damage to equipment and structures.

4. **Access**
   A. When performing this inspection procedure around door jamb comer cutouts, remove door jamb scuff plates if existing.

5. **Preparation and Cleaning**
   A. Remove all dirt, grease, loose paint, and sealant from the external surface of the cutout edges. If sealant is encountered it may be advisable to remove it with a nonmetallic scraper in lieu of chemical compounds to prevent paint removal and entrapment of chemicals between the structural layers.
   B. Thoroughly clean the inspection area with approved cleaning solvent, or equivalent. For information regarding the safe use of this solvent see the General Safety and Precautions section of this manual.

6. **Equipment/Materials**
   A. Eddy Current Flaw Detector
      (1) Impedance Plane Display* or Meter Display (incorporating a flaw gate alarm function)
      * = Preferred Equipment
      (2) Frequency Range = 100 kHz to 500 kHz.
   B. Eddy Current Probe
      (1) ¼ Inch Diameter, open hole probe
      (2) Frequency Range = 100 kHz to 200 kHz
      (3) Absolute Coil
      (4) Shielded
   C. Modified hole probe collar – See Figure 801 and Figure 807.
   D. Probe lead(s) and adapter(s) if required.
E. Eddy Current Reference Standard.
   (1) Stackable standard construction to simulate the structure to be inspected and subject defect(s). See Figure 802 for typical example and Figure 808 for fabrication instructions.
   (2) Utilize the same material type (aluminum, titanium, etc.) as that being inspected.

   NOTE: The equipment/material listed above were used to develop this procedure. See B/E Aerospace NDT Manual 51-EQ-02/201 for supplier/vendor information.

   Equipment/material substitution producing results equivalent to those defined by this document may also be used. See B/E Aerospace NDT Manual 51-EQ-01/101 for equipment/material information.

7. Equipment Adjustment
   A. Connect the probe to the instrument and set operating frequency at 100 - 200 kHz.
   B. Stack the reference standard plates as shown in Figure 803 according to the configuration of the structure to be inspected. Refer to the specific document if applicable.
   C. Center the probe on the edge of the reference standard plate representing the layer to be inspected and null/balance the instrument per the manufacturer’s instructions. See Figure 804.

   NOTE: For meter instruments, the needle should deflect no more than 10% of full scale when the probe is moved on and off a 0.003 inch thick piece of paper on the standard.

   D. Scan the eddy current probe across the simulated defect in the reference standard as shown in Figure 4. Calibrate as follows:
      (1) For impedance plane instruments, adjust the controls to obtain a display from the simulated defect similar to that shown in Figure 805.
      (2) For meter instruments, adjust the controls to obtain a needle deflection from the simulated defect of 80% of full scale. Check lift-off adjustment at this calibration setting. Set flaw gate and alarm to activate at half the calibration deflection.

8. Procedure
   A. Place probe on the cutout edge, centered on the layer represented during calibration, and renull/balance the instrument.
   B. Scan the inspection area, identified by the applicable specific document, while observing the instrument display for crack indications. See Figures 805 and 806.
   C. Utilizing the information supplied in this specific document, repeat the Equipment Adjustment and Procedure steps above for all layers to be inspected.

9. Indication Evaluation
   A. Unless specified otherwise by the individual procedure, the following general criteria may be considered applicable:
      (1) For impedance plane display instruments, an optimized indication which exhibits the same relative phase angle and amplitude equal to, or greater than 50% of that from the simulated defect is considered a crack.
      (2) For meter display instruments, an optimized indication is considered a crack if the needle deflection is equal to, or greater than 50% of that from the simulated defect. When evaluating suspect indications, always use the same scan rate as that used during calibration.
10. **Acceptance and Repair Standards**
   
   A. Unless otherwise specified by the applicable maintenance document, cracks are not allowed.
FOLLOW INSTRUCTIONS AS DETAILED
FIGURE 7 TO MODIFY THE COLLAR

Eddy Current Open Hole Probe
with Modified Collar
Figure 801

FOLLOW FABRICATION INSTRUCTIONS AS DETAILED
IN FIGURE 8, USE THE DATA SUPPLIED IN THE APPLICABLE
SPECIFIC FIGURE TO DETERMINE PROPER MATERIAL AND
THICKNESS TO USE FOR FINAL PLATE CONFIGURATION.

*CLAMP ASSEMBLY

SIMULATED DEFECT
CREATED BY PLATE
EDGE INTERFACE

* "C" CLAMP MAY BE USED IN LIEU OF CLAMP ASSEMBLY

Stackable Reference Standard
Figure 802
Reference Standard Material Stack-up
Figure 803
Calibration
Figure 804
Impedance Plane Display
Figure 805

Inspection of Cutout Edge (Typical)
Figure 806

EFFECTIVITY
ALL AIRCRAFT

EDDY CURRENT

51-EQ-08
Manual No.: 2-120483-800
Page 807
Mar 29/16
Modification of High Frequency Eddy Current Fastener Hole Probe Collar
Figure 807
NOTES:

1. Fabricate -3 and -5 from any aluminum angle
   A. Align back-to-back for drilling 0.188/0.195 hole 2 places
   B. Install hardware (No. 10 screw, washer and wing nut) 2 Places
2. Fabricate -7 Plates from 7075-T6, or 2024-T4 AL., (Clad optional)
   A. Make 2 plates for each thickness to be inspected and 1 additional plate for each adjacent thickness in inspection area stack-up
   B. Plate edges must be straight and smooth (RA = 64 or less)
   C. Identify each plate thickness by ink stamp or vibropeen (Do not metal stamp)
3. Dimensions in inches
4. Scale = None

Stackable Reference Standard for Edge Inspection
Assembly
Figure 808 (Sheet 1 of 2)
**Stackable Reference Standard for Edge Inspection**

**Assembly**

Figure 808 (Sheet 2 of 2)

* "C* clamp may be used in lieu of clamp assembly*
1. **Introduction**
   A. This data is general. It is not about all situations of specific installations. Use this data to help you write minimum requirements.
   B. B/E Aerospace will not test penetrate materials for the customers, or act as an intermediary between vendors and customers.
   C. Industry standard specifications AMS 2647 and ASTM E1417 are acceptable alternatives to this procedure.

2. **General**
   A. Penetrant examination uses the property of a liquid to go into a defect that is open at the surface of the part. The liquid is applied to the surface and permitted to soak in. Unwanted liquid is removed from the surface, but some liquid stays in the defect. A developer is applied to pull the liquid out of the defect so it can be seen. Fluorescent penetrants are examined under ultraviolet light.
   B. Penetrants are usually used on nonferrous metals, but they can be used on all metals, ceramics, glass and plastics. With some special alloys or plastics, precautions must be used to prevent damage to the part.
   C. A penetrant inspection system is a group of penetrant materials used together to do the inspection. These systems are put into groups by penetrant type, removal method, developer type, and sensitivity level. The details of the systems are shown in Table 901.

   **Table 901: Penetrant Classifications per QPL-AMS-2644**

<table>
<thead>
<tr>
<th>Penetrant Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fluorescent Dye</td>
</tr>
<tr>
<td>2</td>
<td>Visible Dye (not for flight hardware)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Penetrant Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Water washable</td>
</tr>
<tr>
<td>B</td>
<td>Post emulsifiable, liphophilic</td>
</tr>
<tr>
<td>C</td>
<td>Solvent removable</td>
</tr>
<tr>
<td>D</td>
<td>Post emulsifiable, hydrophilic</td>
</tr>
<tr>
<td>E</td>
<td>Water washable, water base (Ref. ASTM D2513)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensitivity Level(^{(1)})</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>Ultra low (not applicable to flight hardware)</td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Ultra-high</td>
</tr>
</tbody>
</table>
### Developer Form

<table>
<thead>
<tr>
<th>Developer Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Dry Powder</td>
</tr>
<tr>
<td>b</td>
<td>Water Soluble</td>
</tr>
<tr>
<td>c</td>
<td>Water Suspendible</td>
</tr>
<tr>
<td>d</td>
<td>Nonaqueous Wet Type 1</td>
</tr>
<tr>
<td>e</td>
<td>Nonaqueous Wet Type 2</td>
</tr>
<tr>
<td>f</td>
<td>Special Application</td>
</tr>
<tr>
<td>g</td>
<td>No Developer</td>
</tr>
</tbody>
</table>

### Remover Class

<table>
<thead>
<tr>
<th>Remover Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Halogenated</td>
</tr>
<tr>
<td>2</td>
<td>Non Halogenated</td>
</tr>
<tr>
<td>3</td>
<td>Special Application</td>
</tr>
</tbody>
</table>

(1) The sensitivity level classifications are for Type 1 penetrant systems only.

---

D. The latest revision of the Qualified Product List to AMS2644 gives a full list of all approved penetrant materials. Other materials can be used if they become approved to be added to that list.

E. In each penetrant inspection system, use the materials from only one manufacturer at a time. Do not use materials of one manufacturer with those from a different manufacturer unless tests make you sure the results will be satisfactory.

F. If the overhaul instructions do not give the sensitivity level for penetrant inspection, use the data in Table 2 as a guide. This gives minimum sensitivity levels. Higher sensitivity levels can be used unless specified by overhaul instructions.

### Table 902: Selection of Penetrant Sensitivity Level

<table>
<thead>
<tr>
<th>Type</th>
<th>OPL-AMS-2644 Sensitivity Level</th>
<th>Used For</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Castings, other than precision or titanium, and parts made from such castings.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>All Materials and product forms not shown under another sensitivity level.</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>Portable Method C inspection of areas of possible damage and local areas of repair on flight hardware.</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>As specified by overhaul instructions.</td>
</tr>
<tr>
<td>2</td>
<td>N/A</td>
<td>Inspection of ground handling or support equipment, tools and tooling.</td>
</tr>
</tbody>
</table>
G. Selection of penetrants for metallic parts.
   (1) Unless specified differently, use the sensitivity levels in Table 902.
   (2) Examine aluminum-lithium alloys with Method B or Method D penetrants only.
   (3) Method C penetrants can be used to examine local areas.
   (4) On parts which will contain liquid oxygen, and which cannot be fully cleaned after the examination, use Method E penetrants.

H. Selection of penetrants for nonmetallic or composite
   (1) Make sure that the inspection materials will not damage the surface. The inspection materials must not cause cracks, crazing, pits, etching, or discoloration.
   (2) Phenolic and equivalent plastics can be safely examined with all Type 1 penetrants.
   (3) Nonmetallic materials can be examined with Type 1 Method E penetrants.
   (4) Teflon and equivalent plastics can be examined with Type 1, Method E penetrants. For these penetrants, QPL-25135 approval is not necessary.
   (5) Developer is not necessary when you penetrant examine plastics. If you use the developer with Method E penetrants, use only dry powder developer.

I. Do not use visible penetrants. If visible penetrants are used before fluorescent penetrants, mixtures of visible penetrants with fluorescent penetrants will prevent fluorescence and you will not see the defects. Also, visible penetrants can become hard, and when they get into thin cracks, the penetrant cannot be removed with the usual cleaning procedures.

3. Materials
   A. Chemical Etch
      (1) Sodium hydroxide flakes or pellets, technical grade
      (2) Nitric acid (20% solution of 40-42° Baume, technical grade acid)
      (3) Nitric-fluoride etch solutions for titanium (BAC5753 Method II A)
      (4) Hydrochloric acid, concentrated
      (5) Hydrofluoric acid, concentrated
      (6) Hydrofluoric acid, 70%
      (7) Ammonium bifluoride
   B. Penetrants – Refer to the QPL of AMS 2644 for a full list of approved products. Other materials can be used if they become approved to add to that list.
   C. Aliphatic naphtha – TT-N-95.
   D. Thinner – TT-T-291 Grade 1

4. Equipment
   A. Set up the penetrant inspection equipment to keep to a minimum possible contamination of the penetrant materials by water, dust, or dirt. Include a good flow of air when you will use solvents, removers, developers which are not water-based, or if you spray the penetrants.
   B. For black light inspections
1. Use bulbs to send out light in the 320-400 nanometer range, to give a minimum of 1000 microwatts per square centimeter at 15 inches (38 cm) from the bulb of filter face.

2. Do tests of the black light intensity as follows:
   (a) Weekly, if the intensity is more than 1500 microwatts per square centimeter at the 15 inch (38 cm) minimum distance.
   (b) Daily if the intensity is 1000-1500 microwatts per square centimeter at the 15 inch (38 cm) minimum distance.

3. Black light intensity at the part surface – See Table 903.

Table 903: Type 1 Inspection Light Requirements

<table>
<thead>
<tr>
<th>Ambient White Light(^{(1)})</th>
<th>Inspection Conditions</th>
<th>Minimum Black Light (\mu W/cm^2)(^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 Foot Candles (\leq 20\text{ Lux})</td>
<td>Darkened Inspection Area with Developer</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Darkened Inspection area without Developer</td>
<td>3000</td>
</tr>
<tr>
<td>(&gt; 2) Foot Candles (&gt; 20\text{ Lux})(^{(2)})</td>
<td>Subdued Lighting, use Developer</td>
<td>5000</td>
</tr>
</tbody>
</table>

\((1)\) Light intensity at the inspection surface.
\((2)\) If possible, decrease ambient light to less than 2 Foot Candles (20 Lux). Do not do black light inspections with white light levels greater than 10 Foot Candles (100 Lux).

5. **Sequence of Operations**

A. Penetrant examine parts after heat treatment, welding, final machining operations, or other procedures that could cause defects or make them come to the surface.

B. Penetrant examine parts before surface treatments that will smear metal, close surface openings or get into the defects of any contamination which cannot be removed or which will cause a problem with the penetrant. Some of these operations are:
   1. Application of conversion coatings such as anodize, chemical treatment, chromate treatment, and passivation.
   2. Peening
   3. Impregnation, plating, painting, and application of solid film lubricant.
   4. Abrasive cleaning, blasting, sanding, buffing, burnishing, honing, and grinding. For machine-ground bushings, penetrant examine after machining but before final grinding.

C. If the surface has a conversion coating (anodize, chemical treatment, chromate treatment or passivation), coating removal before you penetrant examine is not necessary unless there is a high penetrant background.

D. If the surface has smeared metal, chemical etch per Paragraph 6 to remove a minimum of 0.0002 inch from the surface. The etch is not necessary before a penetrant check of a operation that forms or straightens a part after the operation that smeared the metal.
E. Do not penetrant examine shot-peened surfaces unless the overhaul instructions are different.

F. Remove impregnations, plating, paint, or solid film lubricant before you penetrant examine.

6. Chemical Etch
   A. Use this procedure to chemically remove smeared metal when necessary.
   B. When necessary and to prevent changes to important dimensions, give holes with small tolerances the protection of mask or plugs before the etch. Remove this protection after the etch and before the penetrant examination.
   C. For aluminum Alloy
      (1) Solutions
         CAUTION: THESE CHEMICALS ARE VERY CORROSIVE AND POISONOUS. DO NOT BREATHE THE VAPORS OR THE MISTS. DO NOT GET THE CHEMICALS IN THE EYES, ON THE SKIN, OR ON CLOTHING. DON NOT LET THE CHEMICALS TOUCH MATERIALS THAT CAN BURN. WHEN YOU MIX THESE CHEMICALS WITH WATER, ALWAYS ADD THE CHEMICAL TO THE WATER, DO NOT ADD WATER TO THE CONCENTRATED CHEMICAL, BECAUSE THE WATER WILL BOIL AT AN EXPLOSIVE RATE AS YOU ADD IT.
         (a) Method 1 (Sodium Hydroxide etch) – Make a solution of 10 grams sodium hydroxide in 90 mL tap water.
         (b) Method 2 (Flicks etch) – add 10 mL concentrated hydrofluoric acid and 15 mL concentrated hydrochloric acid to 90 mL tap water. Mix fully.
      (2) Carefully clean the surfaces to remove all grease, oil, dirt and other contamination.
      (3) Apply the solution with swabs to the surfaces for 2-5 minutes. Be careful not to let the solution get into faying surfaces. This etch solution will make black smut.
      (4) Rinse with a good flow of water.
      (5) Remove the black smut with the 20% nitric acid solution applied with swabs.
      (6) Rinse with a good flow of water. This step is very important, because etchant that stays on the surface can cause intergranular corrosion.
      (7) Dry fully with a hot air dryer. The surface must be completely dry before you apply the penetrant.
      (8) If the amount of etch is not sufficient, do Paragraph 6.C.(3) thru Paragraph 6.C.(7) again.
      (9) Let the surface cool to below 100°F (38°C) before you apply the penetrant.

7. Surface Preparation
   A. The parts to be examined must be clean, dry, and free of grease, oil, grinding compounds, rust, scale, acids, or alkalis, fluxes, burrs, feather edges, smeared metal, paint (primer, enamel), layout dye, or any other material which could hide defects and result in irrelevant indications of which will interfere with the examination procedure.
   B. If parts, plating’s, or coatings were removed or chemically etched, the parts must be rinsed and dried before the penetrant examination. Make sure that chemicals do not go into faying surfaces. If you gave holes the protection of masks or plugs before the etch, remove this protection before the penetrant examination.
   C. Carefully wash with water and dry the parts that were treated with acids or alkalis. Chemicals and moisture that could be caught in the defects must be removed. Chemicals in the defects could react with the penetrant and prevent good indications of defects. Ultrasonic cleaning can help.
D. The surface must be fully dry before you apply the penetrant. If you think there is moisture in defects, heat the surfaces to 225°F (107°C) maximum until the moisture is gone or the surface is dry. Let the surface cool to 100°F (38°C) or less before you apply the penetrant.

E. Removal of anti-friction bearings and disassembly of parts is recommended before penetrant inspection. If bearings are not removed, or parts are not disassembled, they must be completely masked to prevent contamination by penetrant fluid.

8. Application of Penetrant

A. Before you start, make sure the penetrant and part temperature is 40-120°F (4-49°C).

B. Under black light, apply a layer of penetrant on all of the surfaces to be examined. You can apply the penetrant with a spray, swabs, a flow of liquid, or you can put the part in the penetrant.

C. Do not let the penetrant collect in holes, recesses, or pockets. Put the part in a rack or turn or move it as necessary to let the penetrant drain equally from all surfaces.

D. Let the penetrant soak in for these minimum times (which include drain times):
   (1) Oil-base, water-washable penetrants – 10 minutes
   (2) Post-emulsifiable penetrants – 20 minutes
   (3) Solvent-removable penetrants – 20 minutes
   (4) Water-base, water-washable penetrants – 10 minutes

E. These penetration times are applicable for penetrant or part temperatures 20-120°F (15-49°C). For penetrant or part temperatures 40-60°F (4-15°C) multiply these times by 2.

9. Removal of Unwanted Penetrant

A. After the applicable soak and drain time, remove the penetrant from the surfaces by water spray, emulsifier-water spray, or solvent, as applicable. Do this under black light of 100 microwatts per square centimeter minimum at the work surface, and visible light is no stronger than 10 foot candles. Remove the penetrant until the background fluorescence is gone. This will let the remaining penetrant be only in the defects. Be careful not to remove too much penetrant, or you will not be able to find the defects.

B. Remove the unwanted penetrant before it dries too much, or it will not be easy to remove it from the surfaces. If the penetrant does get too dry, completely clean the parts and apply the penetrant again per Paragraph 7 and Paragraph 8 above.

C. Water washable penetrant
   (1) Rinse with a water spray, with 50-100°F (10-38°C) water at 40 psi maximum pressure.

D. Post emulsifiable penetrant with lipophilic emulsifier
   **CAUTION:** EMULSIFICATION TIME STARTS WHEN THE EMULSIFIER OR REMOVER IS APPLIED TO THE PART. THEREFORE, THE PART MUST BE COMPLETELY COVERED AS QUICKLY AS POSSIBLE.
   (1) Put the part in the emulsifier.
   (2) Let the part drain for 5 minutes maximum.
   (3) Rinse with a water spray, with 50-100°F (10-38°C) water at 40 psi maximum pressure.

E. Post emulsifiable penetrant with hydrophilic remover. Use one of these procedures:
   **CAUTION:** EMULSIFICATION TIME STARTS WHEN THE EMULSIFIER OR REMOVER IS APPLIED TO THE PART. THEREFORE, THE PART MUST BE COMPLETELY COVERED AS QUICKLY AS POSSIBLE.
(1) Put the part in the remover.
   (a) Rinse with a water spray to remove unwanted penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
   (b) Use a water spray, with metered hydrophilic remover no stronger than 5 percent (0.25 percent is recommended) to remove the remaining penetrant.
   (c) Rinse with a water spray to remove the remaining penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.

(2) Spray on the remover
   (a) Rinse with a water spray to remove unwanted penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
   (b) Use a water spray, with metered hydrophilic remover no stronger than 5 percent (0.25 percent is recommended) to remove the remaining penetrant.
   (c) Rinse with a water spray to remove the remaining penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.

F. If parts are on an automatic line, do not let the line stop with emulsifier on the part surface. If the emulsification time is longer than the limit, clean and dry the parts and start over again. Parts on an automatic line can be rinsed without black light if the procedure is controlled to be sure the rinse is sufficient to remove the penetrant.

G. If a water rinse could cause corrosion because the water could make puddles or be slow to dry, use this Method C procedure:
   (1) Wipe the area with a clean, dry, lint-free cloth. Turn the cloth to use a clean surface for each wipe. Wipe until most of the penetrant is removed.
   (2) Wipe the area with a clean, lint-free cloth lightly moist with a cleaner approved by the QPL to AMS 2644. Turn the cloth to use a clean surface for each wipe. Wipe until the penetrant is removed.
      (a) When the penetrant is removed, immediately apply a very thin layer of non-aqueous wet developer.

10. Drying
    A. Part surfaces must be fully dry before you apply dry developer or developer which is not water based. Water based developers must be applied while the surface is wet, and then the surfaces must be fully dried.
    B. Dry parts with warm air up to 105°F (71°C). The recommended temperature is 120°F (49°C). If a drier is not available, let the parts dry in air or use a fan. Do not dry parts longer than 30 minutes. Too high a temperature or too long a time will decrease the sensitivity of the penetrant.
    C. For plastic parts, dry the surfaces with clean, lint-free cheesecloth or equivalent wipers or with a good flow of air up to 105°F (38°C).

11. Application of Developer
    A. Developer must be used for all parts unless the overhaul instructions are different.
    B. Development time for wet developers is measured from the time the developer is completely dry to the time you examine the surface. For dry developers, development time is measured from the time you apply the developer to the time you examine the surface. For all developers, use a minimum of 10 minutes development time. More development time could be necessary for some types of defects or to help you find out how important the indications are.
C. Dry Developers
   (1) Sift, dust, or spray the developer on the parts or put the parts in the developer to make sure you apply the developer to all surfaces.
   (2) Do not shake or spray too much, or the developer could rub off some of the penetrant that shows indication of defects.

D. Wet Developers – Aqueous (water) Suspendible and Aqueous (water) Soluble
   (1) Immediately after you remove the unwanted penetrant, spray the developer on the surfaces or put the parts in the developer. Do not apply this developer with a brush. Make sure you apply the developer as a continuous, fully-mixed suspension or solution that wets all of the surfaces to be examined.
   (2) Do not let the developer collect in puddles. Use low air pressure or suction, or move the parts, to remove unwanted developer.
   (3) Immediately after you apply the developer to all of the surfaces, dry the surface with warm air per Paragraph 10.

E. Wet developers – Nonaqueous (not water-based)
   (1) Shake the developer container to fully mix it before you apply it.
   (2) For best results and best sensitivity, a thin smooth layer of the developer is necessary. To get a thin layer, spray the developer with a very fine nozzle and constant movement of the spray. Two or three thin coats are better than one thick coat.

12. Inspection of the Part
A. Examine the parts in a booth with the black light per Paragraph 4.
B. Before you examine under black light and each time your eyes are open to visible light, let your eyes adjust to the darkness for at least 3 minutes. Special scales are available from penetrant manufacturers to help you know if your eyes are sufficiently adapted to the darkness.
C. Do not use corrective lenses or spectacles which are photo-chrome, photo-gray, or equivalently sensitive to light. Under black light, when there is no white light, this type of eyewear can decrease visual sensitivity.
D. Do not look directly at the source of the black light, or your eyeballs will fluoresce and temporarily decrease visual sensitivity. Correctly filtered black light is not dangerous to the eyes, but if the filter is defective, it could let dangerous short-wave ultraviolet light through from the bulb. Replace defective or cracked filters immediately.
E. Examine the surfaces as carefully as your eyes will permit. This is the practical limit of penetrant inspection. If this is not sufficiently satisfactory, the overhaul instructions will give other inspection procedures to make sure the part is serviceable.
F. When you examine castings which were in service, reject parts only if they have signs of cracks or corrosion caused by the period of service, unless the overhaul or service bulletin instructions are different. Do not reject the parts if there are only indications of porosity.
G. Reject parts that have surface defects which are more than permitted limits. If the limits are not specified, reject parts that have shrinkage cracks or porosity, cold shuts, fatigue cracks, forming cracks, grinding and heat-treat cracks, seams, laps, and bursts.
H. If permitted by the overhaul instructions, repair the defects and penetrant examine the part again to see if it became serviceable.
13. Cleaning of Part after Penetrant Inspection
   A. Clean the accepted parts in 4 hours or less after you applied the developer.
   B. Penetrant material remaining on the part could cause corrosion or can be a problem for subsequent machining and inspection. Remove the remaining developer as follows:
      (1) Dry powder developer – Blow with an air hose. If necessary, alkaline or solvent clean.
      (2) Wet developer – Use a brush or wipe with a dry cloth. Rinse or spray with water. If necessary, alkaline or solvent clean.
   C. After you clean the parts, examine them under black light to make sure all of the penetrant and developer is gone.