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NONDESTRUCTIVE EVALUATION REQUIREMENTS FOR FRACTURE-CRITICAL METALLIC COMPONENTS

MEASUREMENT SYSTEM IDENTIFICATION:
METRIC (INCH-POUND)

DOCUMENT HISTORY LOG

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Interim		09-11-2006	Interim Release
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FOREWORD

This standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

NASA-STD-5009 supersedes NASA-STD-(I)-5009, Interim Nondestructive Evaluation Requirements for Fracture Critical Metallic Components, and MSFC-STD-1249, Standard NDE Guidelines and Requirements for Fracture Control Programs.

This standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities.

This standard establishes the nondestructive evaluation (NDE) requirements for any NASA system or component, flight or ground, where fracture control is a requirement. This standard specifically defines requirements for nondestructive evaluation in support of NASA-STD-5019, Fracture Control Requirements for Spaceflight Hardware.

Requests for information, corrections, or additions to this standard should be submitted via "Feedback" in the NASA Technical Standards System at http://standards.nasa.gov.

Original Signed By

April 7, 2008

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1. SCOPE

1.1 Purpose

The purpose of this standard is to establish the nondestructive evaluation (NDE) requirements for any NASA system or component, flight or ground, where fracture control is a requirement. This standard defines the primary requirements for NDE in support of NASA-STD-5019, Fracture Control Requirements for Spaceflight Hardware. NDE applied in-process for purposes of process control is not addressed in this document.

It is the policy of NASA to produce aerospace flight systems with a high degree of reliability and safety. This is accomplished through good design, manufacturing, test, and operational practices including the judicious choice of materials, detailed analysis, appropriate factors of safety, rigorous testing and control of hardware, and reliable inspection. NASA fracture control requirements stipulate that all aerospace flight systems be subjected to fracture control procedures to preclude catastrophic failure. Those procedures frequently rely on NDE to ensure that significant crack-like flaws are not present in critical areas.

a. NDE processes shall meet the requirements in this standard to screen hardware reliably for the presence of crack-like flaws.

b. Nothing in this document shall be construed as requiring duplication of effort dictated by other contract provisions.

c. Conversely, provisions stated herein shall not be interpreted to preclude compliance with requirements invoked by other provisions.

1.2 Applicability

This standard is applicable to the fracture control of metal components, e.g. aluminum, steel, titanium, and nickel alloys for any NASA system or component, flight or ground, where fracture control is a requirement.

Conditional notes on applicability are presented in section 4.2.3.

a. The requirements described herein shall apply to fracture-critical hardware developed for NASA by NASA Centers, international partners, contractors, and outside organizations.

This standard may be cited in contract, program, and other Agency documents as a technical requirement. Mandatory requirements are indicated by the word "shall"; explanatory or guidance text is indicated in italics.

b. Tailoring for application to a specific program or project shall be formally documented as part of program or project requirements and approved by the Technical Authority.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text.

The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority.

The applicable documents are accessible via the NASA Technical Standards System at http://standards.nasa.gov or directly from the Standards Developing Organizations or other document distributors.

2.2 Government Documents

NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware
NPR 7120.5	NASA Program and Project Management Processes and Requirements

(Copies of the above documents are available from any NASA installation library or document repository.)

2.3 Non-Government Documents

NAS 410	NAS Certification and Qualification of Nondestructive Test Personnel

(Copies of the above document are available from the Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005.)

ASTM-E-1417	Standard Practice for Liquid Penetrant Testing
ASTM-E-1444	Standard Practice for Magnetic Particle Testing

ASTM-E-1742	Standard Practice for Radiographic Examination
ASTM-E-2375	Standard Practice for Ultrasonic Examination of Wrought Products

(Copies of the above documents are available from the American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, PA 19428.)

SAE-ARP-4402	Eddy Current Inspection of Open Fastener Holes in Aluminum Aircraft Structure
SAE-AS-4787	Eddy Current Inspection of Circular Holes in Nonferrous Metallic Aircraft Engine Hardware
SAE-AMS-2647	Fluorescent Penetrant Inspection, Aircraft and Engine Component Maintenance

(Copies of the above documents are available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096.)

2.4 Order of Precedence

This document establishes NDE requirements and guidance where fracture control is a requirement, but does not supersede nor waive established Agency requirements found in other documentation. Conflicts between this standard and other requirements documents shall be resolved by the responsible technical authority.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms

ASTM	American Society for Testing and Materials
EDM	Electrical Discharge Machining
MRB	Material Review Board
MSFC	Marshall Space Flight Center
NAS	National Aerospace Standard
NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NDT	Nondestructive Testing
NSTS	National Space Transportation System
NTIAC	Nondestructive Testing Information Analysis Center
POD	Probability of Detection
QQI	Quantitative Quality Indicator
RFCB	Responsible Fracture Control Board

SAE	Society of Automotive Engineers
SSP	Space Station Program

3.2 Definitions

Applicable Documents: Documents cited in the body of the standard that contain provisions or other pertinent requirements directly related and necessary to the performance of the activities specified by the standard.

Calibration: A measurement procedure using reference standards or artifacts (for example: EDM slots or saw cuts) to assure that the NDE measurement system output is reproduced prior to initiating an NDE procedure.

Capability Demonstration Specimens: A set of specimens made from material similar to the material of the hardware to be inspected with known flaws used to estimate the capability of flaw detection, i.e., Probability of Detection (POD) or other methods of capability assessment, of an NDE system.

Cracks or Crack-Like Flaws: Flaws which are assumed to behave like cracks and may be initiated during material production, fabrication, or testing, or are developed during the service life of the part.

Fracture Control: The rigorous application of those branches of design engineering, quality assurance, manufacturing, and operations dealing with the analysis and prevention of crack propagation leading to catastrophic failure.

Fracture-Critical Hardware, Component, or Part: Classification that assumes that cracks in the hardware, component, or part could lead to a catastrophic failure, an event that results in loss of life, serious personal injury, loss of the manned flight system, or national asset.

Hardware Developer: The organization, NASA or prime contractor, responsible for the design, development, and manufacturing of hardware that is subject to fracture control.

Initial Crack Size: The crack size that is assumed to exist at the beginning of part damage tolerance analysis, as determined by NDE or proof testing.

Minimum Detectable Crack Size: The size of the smallest statistically based crack-like flaw that can be readily detected by Standard NDE methods and that is assumed to exist in a part for the purpose of performing a damage tolerance safe-life analysis of the part, component, or assembly.

NDE Plan: A plan that describes the process for establishment, implementation, and control of NDE of aerospace flight hardware during design, manufacturing, and its operational life.

NDE Reference Standards: Measurement aids or flawed specimens with known artifacts used to calibrate, establish process control, or estimate the flaw detection capability of the NDE system.

Nondestructive Evaluation (NDE), Nondestructive Inspection, Nondestructive Testing (NDT): Inspection techniques which do not cause physical, mechanical, or chemical changes to the part being inspected or otherwise impair its adequacy for operational service. These inspection techniques are applied to materials and structures to verify required integrity and to detect flaws.

Probability of Detection (POD): The statistical estimate of the proportion of all flaws of a given size that will be detected in a particular NDE inspection.

Reference Document: A document that is useful as background information for the reader to help in understanding the subject matter but does not constitute technical requirements of the standard.

Responsible Fracture Control Board (RFCB): The designated board at the NASA Center or sponsoring institution responsible for fracture control methodology that can interpret fracture control requirements. Designation may be in the form of specific duties assigned within an existing function.

Responsible NASA Center: The NASA Center where an organization or program office institutes a fracture-control program.

Responsible NDE Engineering: The NDE engineering organization of the hardware developer or the sustaining engineering organization responsible for the engineering aspect of fracture-critical NDE during manufacturing or operations and maintenance.

Special NDE: Nondestructive inspections of fracture-critical hardware that are capable of detecting cracks or crack-like flaws smaller than those assumed detectable by Standard NDE or do not conform to the requirements for Standard NDE as set forth in this document. Special NDE methods are not limited to fluorescent penetrant, radiography, ultrasonic, eddy current, and magnetic particle.

Standard NDE: NDE methods of metallic materials for which a statistically based flaw detection capability has been established. Standard NDE methods addressed by this document are limited to fluorescent penetrant, radiography, ultrasonic, eddy current, and magnetic particle.

Sustaining Engineering: The organization, NASA or prime contractor, responsible for operation and maintenance of hardware that is subject to fracture control.

4. NDE REQUIREMENTS

The requirements set forth in this standard are the minimum NDE requirements for fracture-critical hardware. The application of Standard and Special NDE per the requirements of this standard does not exempt fracture-critical hardware from routine NDE performed during manufacturing. The fracture control NDE procedures cited herein may exceed the requirements for NDE procedures that are routinely performed for purposes such as configuration control and process control. NASA-STD-5019 provides the definition of fracture-critical hardware for all spaceflight systems.

NASA-STD-5019 requires that all fracture-critical parts shall be subjected to NDE and/or proof testing to screen for internal and external cracks.

4.1 NDE Procedures, Standards, and Methods

NDE procedures, standards, methods, and acceptance criteria shall be defined, validated, documented, approved, implemented, and updated during all phases of life-cycle such as manufacturing, operation, and maintenance of each fracture-critical part.

a. All NDE inspections shall be conducted by certified NDE inspectors (see section 4.5.1).

b. The fracture-critical NDE inspection procedure shall be clearly defined for each type of part.

c. Effective and reliable NDE methods shall be selected for all part or component life cycles, including but not limited to manufacturing, maintenance, and operations.

d. All identified part areas shall be inspectable.

4.1.1 Cracks

All detected cracks or crack-like flaws, regardless of size, shall be cause for rejection (see section 4.4.2.1 and section 4.4.2.2).

4.1.2 Material Review Board (MRB)

The acceptance of cracks of any size in a fracture-critical part shall require an MRB action and the approval of the responsible fracture control board (RFCB) and Technical Authority.

4.1.3 Detailed NDE Requirements

The NDE methods applied shall comply with the Standard NDE requirements of section 4.2 or the Special NDE requirements of section 4.3.

4.1.4 NDE Drawing Callouts

NDE inspection requirements for all fracture-critical parts shall be clearly identified in all drawings.

a. The drawings shall clearly identify each inspection requirement by zone when different zones require different NDE inspection requirements and acceptance criteria.

b. The drawings shall be updated when NDE inspection requirements are updated.

4.1.5 NDE Process and Configuration Control

A written procedure for each fracture-critical part shall be developed that complies with the relevant specification for the NDE method selected.

a. Configuration control by revision or date shall be maintained current for the following:

(1) Personnel Qualification
(2) Personnel Certification
(3) NDE Specification
(4) NDE Standards
(5) NDE Part-Specific Procedures

b. All NDE process changes require approval by the responsible NDE organization and Technical Authority.

4.1.6 Capability Demonstration Specimens

a. NDE capability demonstration specimens shall be used for determining the detection capability for all Special NDE applications and may be used to validate the capabilities of Standard NDE procedures.

b. Specimens shall be representative of the material to be inspected and the critical inspection area for the applicable hardware, and of the flaw size, type, location, and orientation.

The list of parameters may vary by NDE method. Specimens may be borrowed from NASA or other Government departments when available.

c. If appropriate demonstration specimens are not available, specimens shall be built or procured that meet both specimen requirements and fracture control requirements.

d. Specimens used shall be documented as a part of the NDE procedures and personnel skill qualifications.

4.1.7 Supporting Data and Record Retention

All certification records, NDE reports, and associated paperwork shall be retained per NPR 7120.5, NASA Program and Project Management Processes and Requirements.

4.1.8 Organizational Guidelines and Documentation Requirement

It is recommended that a document be developed that meets the intent of the responsibilities and authorities described in Appendix A.

4.2 Standard NDE

Standard NDE shall consist of formal nondestructive inspections of fracture-critical hardware using the NDE methods cited in table 1 or 2.

The minimum detectable crack sizes shown in tables 1 and 2 are assumed in the damage tolerance fracture analyses and are applicable only for metals. The crack geometries for the cracks in table 1 or 2 are shown in figure 1.

4.2.1 Standard NDE Methods

Standard NDE methods shall be limited to eddy current, fluorescent penetrant, magnetic particle, radiography, and ultrasonics.

4.2.2 Standard NDE Crack Sizes

4.2.2.1 Nondestructive inspections of fracture-critical hardware shall detect the initial crack sizes used in the damage tolerance fracture analyses with a capability of 90/95 (90 percent probability of detection at a 95 percent confidence level).

The minimum detectable crack sizes for the Standard NDE methods shown in table 1 and 2 are based principally on an NDE capability study that was conducted on flat, fatigue-cracked 2219-T87 aluminum panels early in the Space Shuttle program, and meet the 90/95 capability requirement. Although many other similar capability studies and tests have been conducted since, none have universal application, neither individually nor in combination. Conducting an ideal NDE capability demonstration where all of the variables are tested is obviously unmanageable and impractical.

In order to make the broadest use of NDE flaw detectability data in table 1 or 2, good engineering judgment needs to be applied. For example, a flat panel is representative of a component with a large diameter curvature. It is also reasonable to use the table 1 or 2 data values for most aerospace structural alloys such as titanium or stainless steel.

4.2.2.2 *Regardless of the level of capability required of an inspection, the application of NDE generally requires that the surfaces inspected be clean, smooth, and accessible. The component's features, such as sharp radii, fillets, recesses, surface finish, cleanliness, material selection, and other conditions can influence the capability of the applied Standard NDE method;*

a. When this occurs, the method shall be evaluated to ensure that the Standard NDE detection capability is not reduced (see section 4.2.3).

b. The conditions and their evaluation shall be documented in the NDE Summary Report.

4.2.3 Table 1 (or 2) —Minimum Detectable Flaw Sizes Conditional Notes

Since the table 1 (or 2) crack sizes were derived from a limited set of specimens of simple geometry, applying the crack sizes to complex geometries, other materials, material forms, material processes, and nonstandard NDE applications should be done with caution. Where the real inspection conditions deviate significantly from the concept of flat fatigue-cracked panel inspections, the transferability or similarity of the application of the table 1 or table 2 crack sizes to real inspection situations should be evaluated and verified by documented evidence, such as experimental data or other available test data documentation, for example, a demonstration using penetrant, where capillary action is compared using penetrant on a curved part and then a flat part. Similarity can be established by other studies, data, or by supportable rationale. Similarity considerations should meet the intent of MIL-HDBK-1823, Nondestructive Evaluation System Reliability Assessment.

If similarity cannot be established, additional tests may be required including Standard or Special NDE demonstration tests (see section 4.3). The values listed in tables 1 and 2 may not apply to thick-section components; threaded parts; weldments; compressively loaded structures; double wall radiography; and other unique material, structural, or inspection applications.

4.2.4 Demonstration of Standard NDE Capability

a. NDE procedure calibration on simulated or real crack-like flaws shall demonstrate detection of the minimum detectable crack size.

b. Implementation of Standard NDE methods in accordance with the following requirements shall not require a formal demonstration of crack detection capability.

4.2.4.1 Eddy Current

Eddy-current inspections shall be in accordance with SAE-ARP-4402, Eddy Current Inspection of Open Fastener Holes in Aluminum Aircraft Structure; SAE-AS-4787, Eddy Current Inspection of Circular Holes in Nonferrous Metallic Aircraft Engine Hardware; or NASA fracture control and NASA NDE Engineering-approved contractor internal specifications.

Eddy-current inspection can only be applied to nonmagnetic, nonferromagnetic, and conductive metals.

4.2.4.1.1 The influence of coatings and lift-off variations on the reliability of an eddy-current Standard NDE inspection process shall be evaluated and taken into account in the application.

4.2.4.2 Fluorescent Penetrant

Fluorescent Penetrant inspection shall be in accordance with ASTM-E-1417, Standard Practice for Liquid Penetrant Testing; SAE-AMS-2647, Fluorescent Penetrant Inspection, Aircraft and Engine Component Maintenance; or NASA fracture control and NASA NDE Engineering-approved contractor internal specifications.

4.2.4.2.1 Penetrant System

The penetrant system used shall be a fluorescent penetrant of Level 4 sensitivity.

4.2.4.2.2 Mechanically Disturbed Surfaces

Mechanically disturbed surfaces shall be etched prior to the penetrant inspection and at an appropriate time in the manufacturing flow.

The final penetrant inspection can be performed prior to metal finishing operations such as buffing or sanding that do not by themselves produce flaws.

4.2.4.2.2.1 Etching Procedure

a. An etching procedure shall be developed, approved, and controlled to prevent part damage.

b. The etching procedure shall specify the minimum amount of material to be removed to ensure that smeared metal does not mask cracks.

c. If etching is not feasible:

(1) It shall be demonstrated, or
(2) Documented justification shall be provided that proves the required flaw size can be reliably detected.

4.2.4.2.2.2 The etching process shall not exceed engineering drawing tolerances for part dimensions and finishes.

When very close tolerances are required, critical surfaces should be machined near final dimensions, etched and inspected, and finish machined.

4.2.4.3 Magnetic Particle

Magnetic Particle inspections shall be in accordance with ASTM-E-1444, Standard Practice for Magnetic Particle Testing, or NASA fracture control and NASA NDE Engineering-approved contractor internal specifications.

4.2.4.3.1 The Magnetic Particle inspection shall be the wet, fluorescent, continuous, or multi-mag method.

4.2.4.3.2 A Quantitative Quality Indicator (QQI) shall be used to validate the local field intensities. Hall probes are acceptable provided they are verified with a QQI. Pie gages are not acceptable for measuring field intensities.

4.2.4.4 Radiography

Radiographic inspections shall be in accordance with ASTM-E-1742, Standard Practice for Radiographic Examination, or NASA fracture control and NASA NDE Engineering-approved contractor internal specifications with the following additional requirements:

4.2.4.4.1 The minimum radiographic inspection sensitivity level shall be 2-1T.

4.2.4.4.2 Film density shall be 2.5 to 4.0.

4.2.4.4.3 The center axis of the radiation beam shall be within +/-5 degrees of the assumed crack plane orientation.

4.2.4.5 Ultrasonics

Ultrasonic inspections for wrought products shall be in accordance with ASTM-E-2375, Standard Practice for Ultrasonic Examination of Wrought Products, and NASA fracture control and NASA NDE Engineering-approved contractor internal specifications.

4.2.5 Inability to Meet Standard NDE Inspection Process Requirements

If the requirements of section 4.2 cannot be met, or smaller cracks or crack-like flaws than those shown in table 1 or table 2 have to be detected, then the inspection processes shall be considered Special NDE; and the Special NDE requirements of section 4.3 apply.

4.2.6 Standard NDE Classification Justification

a. The justification to classify an NDE procedure as a Standard NDE procedure shall be documented and then approved by NDE engineering and Technical Authority.

b. The justification shall be based upon evaluation of the NDE procedure as applied to the hardware.

c. Justification shall include evaluating the similarity of the NDE procedure on the hardware with other NDE procedures on similar or identical hardware that have documented flaw detectability equal to or better than the Standard NDE minimum detectable crack size from table 1 or table 2.

4.2.7 Standard NDE Deviations

All deviations from Standard NDE shall be approved by the responsible NDE engineering organization, the RFCB, and Technical Authority.

4.3 Special NDE

4.3.1 General

Special NDE consists of nondestructive inspections that must be capable of detecting crack-like flaws smaller than those detectable by Standard NDE (table 1 or table 2) or those that do not conform to the requirements for Standard NDE given in section 4.2, Standard NDE.

Special NDE methods are not limited to fluorescent penetrant, radiography, ultrasonic, eddy current, and magnetic particle methods.

4.3.2 Special NDE Crack Sizes

The Special NDE crack size can be any demonstrated size.

However, Special NDE inspections shall require the approval of the RFCB and Technical Authority.

In those cases where the damage tolerance analysis requires smaller flaw sizes than those given in table 1 or 2 for Standard NDE or the Standard NDE methods given in table 1 or 2 are not applicable, then a Special NDE inspection is required.

4.3.3 Demonstration of Special NDE Capability

A 90/95 percent flaw detection capability shall be demonstrated before a Special NDE inspection can be implemented.

The demonstration of the Special NDE inspection at a given crack size qualifies the Special NDE for implementation for the detection of cracks at the demonstrated size and larger.

a. The flaw detection capability of the Special NDE inspection method shall be demonstrated by testing with flawed specimens.

b. A sufficient number of flaws shall be included in the test demonstration to meet the 90/95 percent reliability requirement.

c. The tests shall be designed on the basis of either the Point Estimate Method (section 4.3.5), the Probability of Detection Method (section 4.3.6), or other approved method.

d. Special NDE Capability demonstration planning shall be approved by NDE engineering.

4.3.4 NDE Capability Demonstration Specimens

The most accepted method of demonstrating Special NDE capability is with fatigue-cracked specimens. The preparation and control of demonstration specimens and how to administer demonstration tests should meet the intent of MIL-HDBK-1823. In special cases, other flaws or crack types that are more representative of the application may be used for the demonstration with the approval of the RFCB and Technical Authority.

a. Special NDE demonstration specimen selection shall be justified and approved based on the similarity between the test hardware and the demonstration specimen.

b. The justification shall be documented in the NDE summary report.

4.3.5 Point Estimate Method

The Point Estimate Method approach assumes that the capability of flaw detection increases with the size of flaws in the neighborhood of the test flaw size. Since only a small number of flaws are required by this method, the minimum detectable flaw size may not be a determinant.

The above assumption shall be demonstrated or verified by documented evidence before the Point Estimate Method can be implemented.

Qualification by this method demonstrates that the procedure and the individual operator are capable of detecting flaws of the test size and larger. Use of the Point Estimate Method should be in accordance with the recommended practice found in Materials Evaluation, Vol. 40, No. 9, pp 922-932, 1982 (see section 5.1, Reference Documents).

4.3.6 POD Method

This method requires a large range of flaw sizes that span the initial crack size. The large number of flaws required by this method usually allows a minimum detectable flaw size to be determined. Qualification by this method demonstrates that the procedure, either manual or automated, and the individual operator are capable of detecting the minimum detectable flaw size and larger. Use of the POD method should meet the intent of MIL-HDBK-1823.

4.4 NDE Documentation

4.4.1 NDE Plan

An NDE plan shall be developed which addresses the following as a minimum:

a. Applicable specifications and standards.

b. Calibration artifact traceability.

c. Inspector training, qualification, and certification.

d. Method selection, application, and process control.

e. Acceptance criteria.

f. Application of requirements during manufacturing, maintenance, and operations.

g. NDE applied to fracture-critical hardware.

h. Standard NDE selection, application, and control.

i. Special NDE selection, application, and configuration control.

4.4.2 NDE Summary Report

An NDE Summary Report shall be developed and include, but not limited to, the following:

a. Identification of the fracture-critical part number.

b. Critical zones inspected.

c. NDE methods applied and procedures used.

d. Classification and justification of Standard NDE or Special NDE inspections.

e. Acceptance criteria.

f. Inspectors' names and inspection dates.

g. Evaluation of special conditions that affect Standard NDE.

4.4.2.1 The report shall provide inspection results including flaw descriptions, locations, sizes, and other non-conformances and problems encountered.

4.4.2.2 The report shall identify any cracks or crack-like flaws regardless of their size or disposition.

4.4.3 Supporting Data and Record Retention

a. The documents supporting the NDE Summary Report shall be kept for the life of the program.

b. Responsible NDE engineering shall acquire and retain all records during a change to a different contractor including, but not limited to, the following:

(1) Controlling NDE specifications and standards.
(2) Part-specific NDE procedures.
(3) Special NDE 90/95 percent capability demonstration data.
(4) Supporting data used to justify Standard NDE.
(5) Standard and Special NDE inspector qualification and certification documents.
(6) Standard and Special NDE process changes and approval documents.
(7) The hardware acceptance, inspection, and summary reports.
(8) Other supporting data including inspector identifications, inspection dates, detailed and zoned drawings, acceptance criteria, and NDE problem reports and resolutions.
(9) NDE reports.

4.4.3.1 These documents shall be available for review and approval by the Technical Authority, RFCB, and others.

4.5 Personnel Qualification and Certification

4.5.1 Standard NDE Qualification and Certification

Personnel performing standard nondestructive inspections of fracture-critical hardware shall be, at a minimum, certified Level II in accordance with NAS 410, NAS Certification and Qualification of Nondestructive Test Personnel.

4.5.2 Special NDE Qualification and Certification

a. Personnel performing Special NDE shall be qualified and certified for each Special NDE procedure and, as a minimum, be qualified to NAS 410 Level II.

Successful demonstration of 90/95 POD on the NDE capability demonstration specimens qualifies the specific written procedure and inspector performing the inspection for detecting the demonstrated flaw size and larger.

b. If there is a failure to demonstrate capability, then proof of improved inspector skills shall be required prior to a retest.

c. The following shall be observed:

(1) Qualification for Special NDE shall be specific to the procedure and the inspector.
(2) Special NDE inspection shall not be transferable to another procedure or inspector.

(3) The period of Special NDE certification shall be 3 years, with demonstration of skills required during the certification period.

Table 1—Minimum Detectable Crack Sizes for Fracture Analysis Based on Standard NDE Methods (See "Conditional Notes," section 4.2.3 for applicability.)

U. S. CUSTOMARY UNITS (inches)

Crack Location	Part Thickness, t	Crack Type	Crack Dimension, a*	Crack Dimension, c*
Eddy Current NDE				
Open Surface	**t ≤ 0.050** **t > 0.050**	**Through** **PTC**[1]	**t** **0.020** **0.050**	**0.050** **0.100** **0.050**
Edge or Hole	**t ≤ 0.075** **t > 0.075**	**Through** **Corner**	**t** **0.075**	**0.100** **0.075**
Penetrant NDE				
Open Surface	**t ≤ 0.050** **0.050<t <0.075** **t > 0.075**	**Through** **Through** **PTC**	**t** **t** **0.025** **0.075**	**0.100** **0.150 - t** **0.125** **0.075**
Edge or Hole	**t ≤ 0.100** **t > 0.100**	**Through** **Corner**	**t** **0.100**	**0.150** **0.150**
Magnetic Particle NDE				
Open Surface	**t ≤ 0.075** **t > 0.075**	**Through** **PTC**	**t** **0.038** **0.075**	**0.125** **0.188** **0.125**
Edge or Hole	**t ≤ 0.075** **t > 0.075**	**Through** **Corner**	**t** **0.075**	**0.250** **0.250**
Radiographic NDE				
Open Surface	**t ≤0.107** **t > 0.107**	**PTC** **PTC** **Embedded**	**0.7t** **0.7t** **2a=0.7t**	**0.075** **0.7t** **0.7t**
Ultrasonic NDE **Comparable to a Class A Quality Level (ASTM-E-2375)**				
Open Surface	**t ≥ 0.100**	**PTC** **Embedded****	**0.030** **0.065** **0.017** **0.039**	**0.150** **0.065** **0.087** **0.039**

[1] **PTC - Partly through crack (Surface Crack)**

* See figure 1 for definitions of "a" and "c" for different geometries.

** Equivalent area is acceptable, ASTM-E-2375 Class A.

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Table 2—Minimum Detectable Crack Sizes for Fracture Analysis Based on Standard NDE Methods (Metric Version) (See "Conditional Notes," section 4.2.3 for applicability.)

<u>Système International (SI) Units (millimeters)</u>

Crack Location	Part Thickness, t	Crack Type	Crack Dimension, a*	Crack Dimension, c*
<u>Eddy Current NDE</u>				
Open Surface	**t ≤ 1.27** **t > 1.27**	**Through** **PTC[1]**	**t** **0.51** **1.27**	**1.27** **2.54** **1.27**
Edge or Hole	**t ≤ 1.91** **t > 1.91**	**Through** **Corner**	**t** **1.91**	**2.54** **1.91**
<u>Penetrant NDE</u>				
Open Surface	**t ≤ 1.27** **1.27<t <1.91** **t > 1.91**	**Through** **Through** **PTC**	**t** **t** **0.64** **1.91**	**2.54** **3.81 – t** **3.18** **1.91**
Edge or Hole	**t ≤ 2.54** **t > 2.54**	**Through** **Corner**	**t** **2.54**	**3.81** **3.81**
<u>Magnetic Particle NDE</u>				
Open Surface	**t ≤ 1.91** **t > 1.91**	**Through** **PTC**	**t** **0.97** **1.91**	**3.18** **4.78** **3.18**
Edge or Hole	**t ≤ 1.91** **t > 1.91**	**Through** **Corner**	**t** **1.91**	**6.35** **6.35**
<u>Radiographic NDE</u>				
Open Surface	**t ≤2.72** **t > 2.72**	**PTC** **PTC** **Embedded**	**0.7t** **0.7t** **2a=0.7t**	**1.91** **0.7t** **0.7t**
<u>Ultrasonic NDE</u> **Comparable to a Class A Quality Level (ASTM-E-2375)**				
Open Surface	**t ≥ 2.54**	**PTC** **Embedded****	**0.76** **1.65** **0.43** **0.99**	**3.81** **1.65** **2.21** **0.99**

[1] PTC – Partly through crack (Surface Crack)

* See figure 1 for definitions of "a" and "c" for different geometries.

** Equivalent area is acceptable, ASTM-E-2375 Class A.

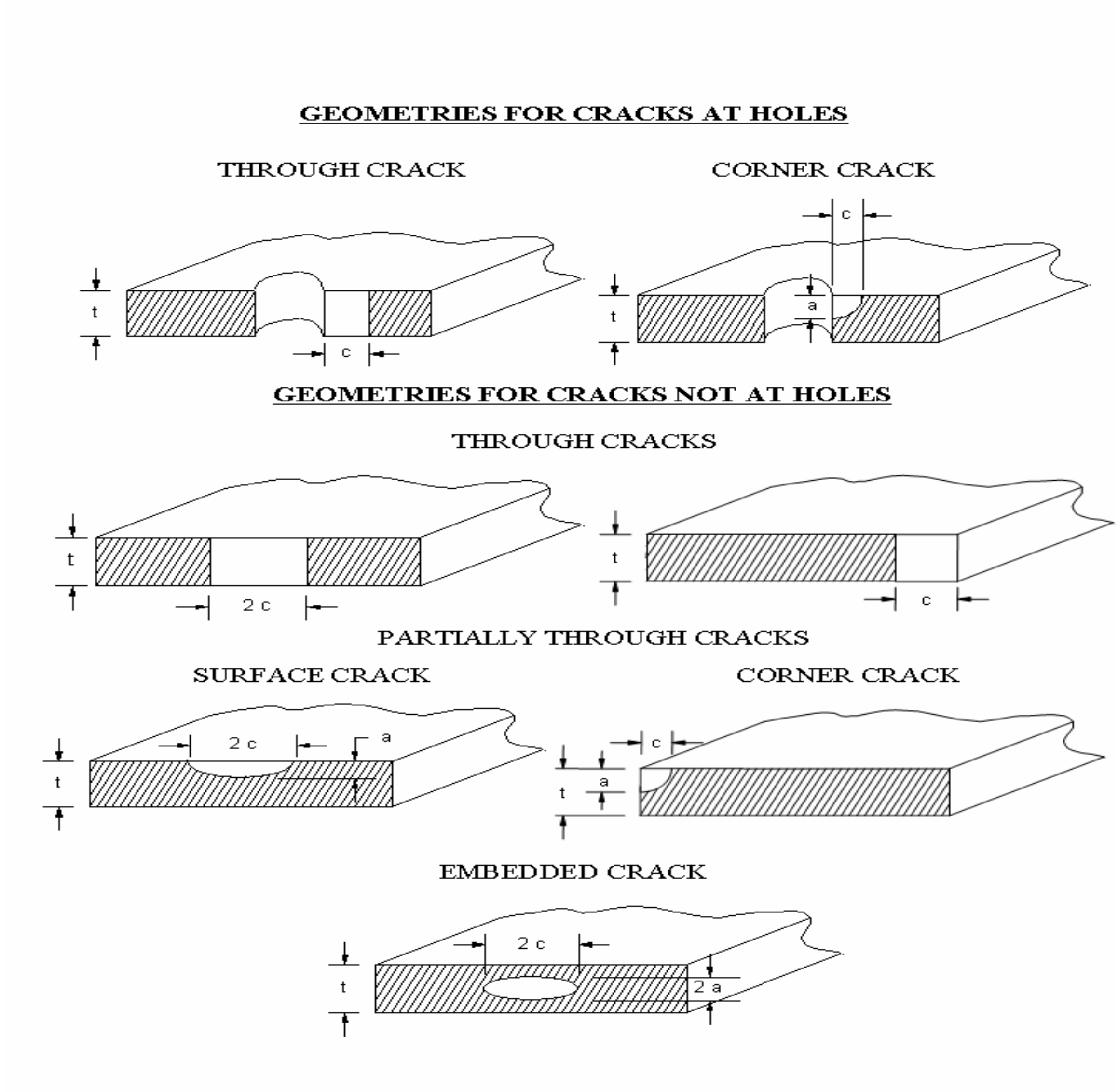

Figure 1—Assumed Flaw Geometries

5. GUIDANCE

5.1 Reference Documents

The reference documents that follow are recommended for further guidance.

5.1.1 Government Documents

MIL-HDBK-1823	Nondestructive Evaluation System Reliability Assessment

(Copies of the above document are available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.)

NASA-STD-5003	Fracture Control Requirements for Payloads Using the Space Shuttle
SSP 30558	Fracture Control Requirements for Space Station
SSP 52005	Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures
NSTS 1700.7B	ISS Addendum, Safety Policy and Requirements for Payloads Using the International Space Station, Change No. 3, February 1, 2002

(Copies of the above documents are available from any NASA Installation library or document repository.)

5.1.2 Non-Government Documents

NTIAC-DB-97-02	Nondestructive Evaluation (NDE) Capabilities Data Book
NTIAC-TA-00-01	Probability of Detection (POD) for Nondestructive Evaluation (NDE)

(Copies of the above documents are available from Advanced Materials, Manufacturing, and Testing Information Analysis Center, 201 Mill Street, Rome, NY 13440, Phone (315) 339-7117, Fax (315) 339-7117.)

Materials Evaluation, Volume 40, No. 9, 1982	Recommended Practice for a Demonstration of Nondestructive Evaluation (NDE) Reliability On Aircraft Production Parts," Ward Rummel.

APPENDIX A

EXAMPLE OF AN NDE ORGANIZATION

The following is an example of an NDE Organization with clearly defined roles, responsibilities, and implementation. This is not a requirement and could be used as an organizational model.

A.1 Implementation and Responsibilities

A.1.1 Oversight Responsibility

The responsible NASA Center shall provide an NDE oversight function and approval of the hardware developer's NDE Plan and program for the inspection of fracture-critical hardware. The NASA oversight function shall establish periodic reviews of the hardware developer's NDE program. The NDE oversight function shall be responsible for establishing the personnel certification system for Special NDE procedures when NASA conducts the certification tests. NDE standards and procedures for fracture-critical hardware shall be approved by the responsible NASA Center. In general, all plans, data, documentation, reference standards, and reliability demonstration specimens generated under contract from NASA to its contractors, subcontractors, and suppliers in fulfillment of these requirements during hardware development, manufacturing, operations, and maintenance shall be subject to examination, evaluation, and inspection by and delivery to the NDE oversight function or designated representatives of the responsible NASA Center.

A.1.2 Responsibility of Hardware-Specific NDE Requirements

The hardware developer, in concurrence with the RFCB and Technical Authority, shall establish and provide hardware-specific NDE requirements to its in-house NDE inspection organizations, suppliers, subcontractors, and vendors to accomplish the NDE during manufacturing. The hardware developer, in concurrence with the RFCB and Technical Authority, shall provide the hardware-specific NDE requirements for operations and maintenance to the responsible NASA Center or its designated sustaining engineering organization. The sustaining engineering organization, in concurrence with the RFCB and Technical Authority, shall be responsible for maintaining, changing, and establishing new hardware-specific fracture control requirements. The hardware developer or sustaining engineering organization shall perform a drawing review process that identifies fracture-critical parts, identifies all areas of the parts requiring NDE and identifies the appropriate type of NDE during manufacturing, maintenance, and operations. The review process shall include NDE engineering. NDE engineering shall ensure that the identified areas are inspectable and that efficient and reliable NDE methods are selected.

A.1.3 Responsibility of NDE Standards, Procedures, and Reference Standards During Hardware Development and Manufacturing

The hardware developer's responsible NDE engineering shall be responsible for establishing and approving NDE method standards, NDE procedures, and NDE reference standards and for ensuring that all NDE processes are implemented through approved written NDE procedures. The NDE procedures shall be performed by the hardware developer's NDE inspection organization or by an approved external NDE organization, provided that the NDE procedures approved by responsible NDE engineering are used by personnel certified for fracture-critical NDE. NDE engineering shall be responsible for administering Special NDE certification tests and approving certification of the NDE personnel.

A.1.4 Responsibility of NDE Standards, Procedures, and Reference Standards for Operations and Maintenance NDE

During hardware development, the hardware developer shall be responsible for establishing, approving, and providing operations and maintenance NDE requirements, method standards, NDE procedures, and NDE reference standards to the sustaining engineering organization designated by the responsible NASA Center. During operations and maintenance, the sustaining engineering organization, in concurrence with the RFCB and Technical Authority, shall be responsible for maintaining or changing existing NDE requirements, standards, and procedures as well as establishing and maintaining new hardware-specific NDE requirements, standards, and procedures. NDE procedures may be performed by an in-house NDE inspection organization or by an external NDE inspection organization provided that the NDE procedures approved by NDE engineering are used by the personnel certified for fracture-critical NDE. Responsible NDE engineering shall be responsible for administering Special NDE certification tests and approving certification of the NDE personnel.

A.1.5 NDE Drawing Callouts

The hardware developer's responsible NDE engineering shall review the zoned drawings, the NDE inspection methods, procedures, and acceptance criteria. Where there are different inspection requirements for different areas of a component, the drawing shall indicate separate inspection requirements for each zone.

A.1.6 NDE Process and Configuration Control

A written NDE procedure that complies with the relevant specification for the NDE method selected for the part is required for NDE inspection of each fracture-critical part. Configuration control by revision or date shall be maintained for the personnel qualifications and certifications and for the NDE specifications, standards, and part-specific procedures. Certifications shall remain current with revisions. NDE engineering shall approve NDE process changes. The RFCB and Technical Authority shall have final approval for NDE process changes that affect the reliability of fracture-critical NDE.

A.1.7 Capability Demonstration Specimens

NDE engineering shall be responsible for designing, approving, and providing Special NDE capability demonstration specimens. If possible, NDE engineering shall borrow the specimens from NASA or other government departments. If appropriate demonstration specimens are not available, the hardware developer or the sustaining engineering organization shall build or procure the demonstration specimens in concurrence with the RFCB and Technical Authority. Capability artifacts used in NDE procedure application shall be traceable to those used in the capability demonstration of the NDE procedure.

A.1.8 Responsibilities of NDE Inspection Organization

The NDE inspection organization shall be responsible for training, qualification, and facilitating NDE certification of its inspection personnel. NDE inspection shall be responsible for maintaining and operating NDE equipment and facilities used in the NDE inspection of fracture-critical hardware. NDE inspection shall be responsible for retention of certification records, NDE reports, and associated paperwork through the life of the program.