National Aeronautics and
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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

STANDARD

NDE GUIDELINES AND REQUIREMENTS

FOR

FRACTURE CONTROL PROGRAMS

Prepared by:
Nondestructive Evaluation Branch
Engineering Physics Division
Materials and Processes Laboratory

MSFC-STD-1249

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GEORGE C. MARSHALL SPACE FLIGHT CENTER
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John M. Knadler, II — 9/11/85

Prepared By — Nondestructive Evaluation Branch — Date

R. J. Schwinghamer

Approved By — Director, Materials & Processes Lab. — Date

Stress Approval — Date

Ted T. Kuebling Jr. — 9/11/85

Materials Approval — Date

9.13.85

S&E Director Approval — Date

1.0 SCOPE

This standard provides guidelines for selection and prescription of NDE (Nondestructive Evaluation) techniques required to fulfill the demands of a Fracture Control Program. Also provided are the minimum crack-like flaw sizes deemed reliably (90% probability, 95% confidence) detectable via the traditional NDE techniques, Penetrant, Eddy Current, Magnetic Particle, Ultrasonics, and (manual) Radiography, when implemented as prescribed herein.

2.0 REFERENCED DOCUMENTS

The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposals shall apply.

2.1 Military Standards

MIL-STD-410, Nondestructive Testing Personnel Qualification and Certification

MIL-STD-2154, Inspection, Ultrasonic, Wrought Metals, Process For

MIL-STD-00453 (USAF), Inspection, Radiographic

2.2 Military Specifications

MIL-I-6866, Inspection, Penetrant Method Of

MIL-I-6868, Inspection Process, Magnetic Particle

2.3 Society Standards

ASTM-E426, Recommended Practice for Electromagnetic (Eddy Current) Testing of Seamless and Welded Tubular Products, Austenite

3.0 REQUIREMENTS

3.1 General

The Fracture Control Program concept dictates that fracture mechanics design assessments of aerospace structures and pressure vessels assume the potential existence of crack-like flaws in crucial, higher stressed zones of hardware. Mission fulfillment expectations are thus confirmed by fracture mechanics calculations of acceptable maximum size initial crack-like flaws (Critical Initial Flaw Size - CIFS) that would <u>not</u> grow to catastrophic-failure size within the number of cyclic exposures dictated for mission assurance.

NDE then is obligated to assure that the CIFS does not exist in the newly fabricated hardware. The CIFS may prove to be smaller than is reliably detectable by standard "normally," economically practiced NDE; causing special efforts in the form of special attention by the NDE operator/inspector, refinements in inspection material and equipment selection, and refinements in inspection technique/procedure. Occasionally, the CIFS still may be beyond the reliable detectability of implementable NDE, necessitating other considerations such as redesign or periodic reinspections for larger flaws.

3.1.1 Selection and implementation of NDE techniques are dependent upon numerous factors which vary with each application. The key factor influencing all NDE techniques is ACCESSIBILITY. Surface flaw detection is grossly impeded if the surface area of concern is not freely accessible. Likewise, internal/embedded flaw detection is seriously impeded by irregular geometries and other access limiting factors.

Scheduling of NDE often can be arranged such that flaw detection inspection is achieved utilizing the most economic technique at the point in the manufacturing sequence that affords reliable NDE implementation. This requires effective preplanning, which more often than not is not experienced on payloads programs.

Inspection of wrought stock for internal crack-like flaws can best be achieved by employing ultrasonics on stock pieces cut in rectangular cross-section, prior to further configuration machining. Surface flaw detection is generally more economically implemented via penetrant inspection; however, machined surfaces must be etched prior to penetrant application to remove smeared masking material. Fine finish surfaces can be near-finish machined, etched, penetrant inspected, and finally finish machined. Eddy Current inspection, owing to its penetrating electromagnetic principals, does not require etch removal of typically smeared material in order to detect surface crack-like flaws, and may be utilized on coated surfaces; however, more sophisticated equipment and procedural preparations are required. Magnetic Particle inspection likewise does not require etching of machined surfaces; however, its application is limited to magnetic materials and the generally applied technique lacks the reliability to detect smaller flaws. Radiography is the least sensitive technique for detection of crack-like flaws, even when the extensive criteria of the special released MIL-STD-00453 (USAF) are invoked. However, radiography generally is much easier than ultrasonics to apply in inspection for internal anomalies and for that reason more often is employed.

While its crack-like flaw detectability is poor, radiography does afford disclosure of internal abnormalities, such as inclusions, porosity/voids, which can accompany cracks.

3.1.2 In order to formulate levels of detectability for each of the fundamental NDE techniques, basic assumptions of effecting factors were established. They are as follows.

a. General

(1) NDE technique implementation capability equal to that generally evidenced by principal aerospace industries, wherein NDE inspection operations are conducted on a daily basis.

(2) Personnel engaged in NDE operations are trained and certified as required by MIL-STD-410.

(3) Environment in which NDE operations are performed is typical controlled humidity and temperature "shirt sleeve" environment found in indoor production and laboratory facilities.

b. Penetrant Inspection

(1) Unrestricted accessible surface without sharp-root recesses.

(2) Roll-formed surface, or machined surface which was effectively etched to remove smeared masking material.

(3) Surface not contaminated with paints, coatings, oils, etc., which would prevent surface wetting or restrict penetrant flow into cracks.

(4) Surface finish of 125 RMS or better quality (roughness, pattern), typical of aerospace hardware.

(5) Penetrant family employed certified as meeting the Group VI level sensitivity.

c. Eddy Current Inspection

(1) Surface inspected is flat or has consistent, regular geometry, and is readily accessible.

(2) Surface is bare metal or has a consistent thickness coating/plating not exceeding 0.003 inch thickness.

(3) Material inspected is in the nonmagnetic category.

(4) Surface finish of 125 RMS or better quality (roughness, pattern), typical of aerospace hardware.

(5) Current state-of-art equipment and appropriate probe adaptors utilized.

(6) Probe coil technique utilized.

d. Magnetic Particle Inspection

(1) Unrestricted accessible surface without sharp-root recesses.

(2) Surface not contaminated with paints, coatings, oils, etc., which would prevent surface wetting or restrict particulate/carrier flow around cracks.

(3) Surface finish of 125 RMS or better quality (roughness, pattern), typical of aerospace hardware.

(4) Material inspected is in magnetic category.

(5) Wet process, continuous method, fluorescent particle technique utilized.

e. Ultrasonic Inspection

(1) Longitudinal wave ultrasonics performed on rectangular formed stock via unobstructed bare flat surfaces, or on advanced machined stock via unobstructed bare surfaces at right-angles to critical flaw orientation.

(2) Shear wave ultrasonics performed on bare flat surface of parallel-face sheet/plate, with unobstructed access to flat surface.

(3) Interface surface finish to be 125 RMS or better quality.

(4) Current state-of-art equipment utilized.

f. Radiographic Inspection

(1) Material radiographed is of consistent thickness, and configured such that the film can be unobstructively placed in close contact with the back surface and the X-ray source unobstructively placed opposite the film.

(2) Critical crack-like flaw orientation is in the plane of X-radiation.

(3) Current state-of-art technique employing film and X-ray source utilized.

3.2 Technical

To achieve a more consistent level of performance, specific requirements governing the implementation of each NDE technique must be prescribed. These requirements utilize the standards and specifications generally recognized in industry and provide selected complementing options and criteria needed to assure refined consistency of NDE application. The NDE guidelines/requirements of Appendix A address both "Standard" and "Special" levels of NDE.

3.3 NDE Detectability Assumptions

Based on NDE technique implementation criteria set forth in Section 3.2, and fundamental assumptions set forth in Section 3.1.2, minimum size crack-like flaws deemed reliably (90% probability/95% confidence) detectable by NDE techniques have been identified. The compilation presented in Appendix B draws upon various studies and summations previously derived by industry and Government agencies, including guidelines documents derived by other NASA Centers.

Variations in conditions set forth in Section 3.1.2 may or may not have an influencing effect on flaw sizes assumed detectable, and can only be judged when all of the factors surrounding a specific application are collectively assessed.

4.0 QUALITY ASSURANCE

Quality Assurance shall verify that the technical requirements of Section 3.2 are effectively implemented in behalf of Fracture Control Programs, when such requirements are formally prescribed for hardware implementation.

Custodian:
NASA-George C. Marshall
Space Flight Center

Performing Activity:
George C. Marshall Space Flight
Center, EH13

Standard and Special
NDE Guidelines/Requirements

I. PT - Penetrant Inspection

Penetrant inspection shall be in accordance with MIL-I-6866, latest revision. A penetrant family certified as meeting the Group VI level sensitivity shall be utilized.

For special-level inspection, the ability of the detailed process and the operator to reliably detect the given size cracks must be demonstrated.

All personnel performing penetrant inspection must be properly certified per MIL-STD-410, latest revision.

Note - All machined or otherwise mechanically disturbed surfaces which are to be penetrant inspected must be adequately etched to assure removal of smeared, masking material prior to penetrant application.

II. ET - Eddy Current Inspection

Eddy current inspection shall be in accordance with the general requirements of ASTM-E426, latest revision. The probe coil technique shall be utilized. The reference standard shall have a simulated open-surface crack (EDM notch) of 0.080 ± 0.005 inches length, 0.010 ± 0.001 depth, and width not exceeding 0.007, and a corner crack having a radial pattern and radius of 0.030 ± 0.003, width not exceeding 0.007, for standard inspection.

For special-level inspection, the reference standard shall have a simulated open-surface crack of 0.040 ± 0.004 inches length, 0.010 ± 0.001 depth, and width not exceeding 0.007, and a corner crack having a radial pattern and radius of 0.020 ± 0.002, width not exceeding 0.007.

A Signal-to-Noise response of no less than 3:1 shall be demonstrated on the appropriate reference standard(s) utilized, for both standard and special inspections.

Appropriate probe designs and/or probe adaptors shall be utilized to assure reliable, repeatable inspections.

All personnel performing eddy current inspection must be properly certified per MIL-STD-410, latest revision.

Note: Etching of machined surfaces generally is not required prior to eddy current inspection.

III. MT - Magnetic Particle Inspection

Magnetic particle inspection shall be in accordance with MIL-I-6868, latest revision. The wet process, continuous method, with fluorescent particle, technique shall be utilized.

For special-level inspection, the ability of the detailed process and the operator to reliably detect the given size cracks must be demonstrated.

All personnel performing magnetic particle inspection must be properly certified per MIL-STD-410, latest revision.

IV. UT - Ultrasonic Inspection

Ultrasonic inspection shall be in accordance with MIL-STD-2154, latest revision (supersedes MIL-I-8950). Quality Class shall be as cited in the Table, with the exception that "Linear discontinuities," i.e., elongated stringer type indications, of any length are not acceptable.

All personnel performing ultrasonic inspection must be properly certified per MIL-STD-410, latest revision.

V. RT - Radiographic Inspection

Radiographic inspection shall be in accordance with MIL-STD-00453 (USAF), latest revision. Radiographic quality shall be Level 1 (equivalent to Level 2-1T). Special requirements of paragraphs 5.5 and 5.16 of the subject Standard should be noted.

For special-level inspection, the ability of the detailed process and the operator to reliably detect the given size cracks must be demonstrated.

All personnel performing radiographic inspection must be properly certified per MIL-STD-410, latest revision.

Initial Flaw Size (Minimum) Detectability Assumptions for Structures and Pressure Vessels

Area	NDE Method	Part Thickness	Crack Type	Aspect Ratio (a/2c)	Crack Depth	Crack Length
Open Surface	PT-STD	t<0.075	TC		t	0.200
			PTC	0.1		0.250
				0.2		0.200
				0.5	(0.075 max.)	0.175
		t≥0.075	TC		t	0.150
			PTC	0.1		0.250
				0.2		0.200
				0.5		0.150
	PT-SPCL	t<0.075	TC		t	0.100
			PTC	0.1		0.125
				0.2		0.100
				0.5		0.100
		t≥0.075	TC		t	0.075
			PTC	0.1		0.125
				0.2		0.100
				0.5		0.075
Surface Edges, and Around Drilled or Reamed Holes	PT-STD	t<0.075	TC		t	0.100
			CC		t	0.125
		t≥0.075	TC		t	0.100
			CC		0.075	0.100
	PT-SPCL	t<0.075	TC		t	0.075
			CC		t	0.075
		t≥0.075	TC		t	0.075
			CC		0.075	0.075
Open Surface	ET-STD	t≥0.020	TC		t	0.100
			PTC	0.1		0.100
				0.2		0.100
				0.5		0.100
	ET-SPCL	t≥0.020	TC		t	0.050
			PTC	0.1		0.075
				0.2		0.050
				0.5		0.050

Initial Flaw Size (Minimum) Detectability Assumptions
for Structures and Pressure Vessels

Area	NDE Method	Part Thickness	Crack Type	Aspect Ratio (a/2c)	Crack Depth	Crack Length
Surface Edges, and Around Drilled or Reamed Holes	ET-STD	t≥0.020	TC CC		t 0.020	0.050 0.050
	ET-SPCL	t≥0.020	TC CC		t 0.020	0.025 0.025
Open Surface	MT-STD	t≥0.070	TC PTC	 0.1 0.2 0.5	t	0.250 0.375 0.275 0.250
	MT-SPCL	t≥0.070	TC PTC	 0.1 0.2 0.5	t	0.150 0.225 0.175 0.150
Surface Edges, and Around Drilled or Reamed Holes	MT-STD	t≥0.070	TC CC		t 0.070	0.250 0.250
	MT-SPCL	t≥0.070	TC CC		t 0.070	0.150 0.150
Raw Stock, and Machined Product	UT-STD (L-Wave)	t≥0.300	Embedded or PTC, TC, CC	Class B Class A	0.200 dia. 0.130 dia.	(Equiv. Area) (Equiv. Area)
	UT-SPCL (L-Wave)	t≥0.200	Embedded or PTC, TC, CC	Class AA	0.080 dia.	(Equiv. Area)
	UT-STD (S-Wave)	t≥0.300	Embedded or PTC, TC, CC	Class B Class A	0.200 dia. 0.130 dia.	(Equiv. Area) (Equiv. Area)
	UT-SPCL (S-Wave)	t≥0.150	Embedded or PTC, TC, CC	Class AA	0.080 dia.	(Equiv. Area)
Raw Stock, and Machined Product	RT-STD	t≥0.050	Embedded PTC, TC, CC	Ellipse 1/2 Ellipse	0.7t 0.7t	t (0.150 min.) t (0.150 min.)
	RT-STD	t<0.050	Embedded	Ellipse	0.7t (0.025 min.)	0.150
			PTC, TC, CC	1/2 Ellipse	0.7t (0.025 min.)	0.150

Initial Flaw Size (Minimum) Detectability Assumptions
for Structures and Pressure Vessels

Area	NDE Method	Part Thickness	Crack Type	Aspect Ratio (a/2c)	Crack Depth	Crack Length
Raw Stock, and Machined Product	RT-SPCL	t≥0.050	Embedded PTC, TC, CC	Ellipse 1/2 Ellipse	0.6t 0.6t	t (0.100 min.) t (0.100 min.)
	RT-SPCL	t<0.050	Embedded	Ellipse	0.6t (0.025 min.)	0.100
			PTC, TC, CC	1/2 Ellipse	0.6t (0.025 min.)	0.100

Table Codes

I. NDE Methods:

PT - Penetrant

ET - Eddy Current

MT - Magnetic Particle

UT - Ultrasonics

RT - Radiographic

- STD - Standard Practices
- SPCL - Special Practices

II. Crack Types:

TC - Through Crack

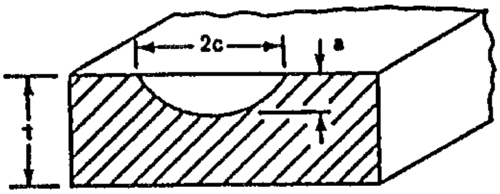
PTC - Part Through Crack

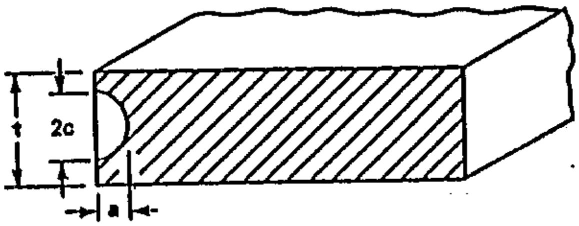
CC - Corner Crack

See Figures Attached.

INITIAL CRACK GEOMETRIES FOR PARTS WITHOUT HOLES

PART-THROUGH CRACKS





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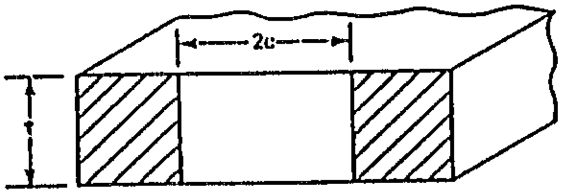

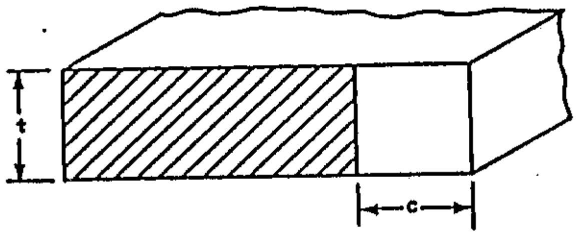

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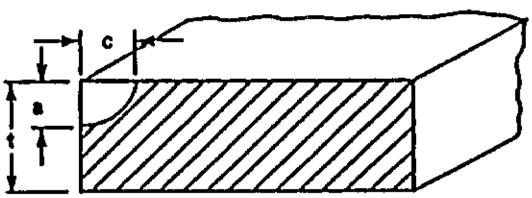
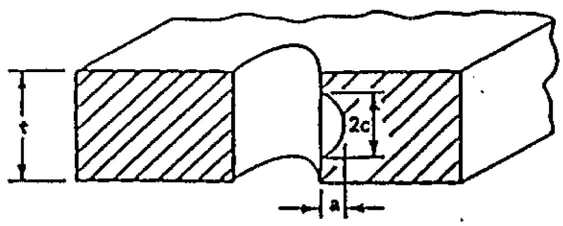


INITIAL CRACK GEOMETRIES FOR PARTS WITH HOLES

PART-THROUGH CRACK



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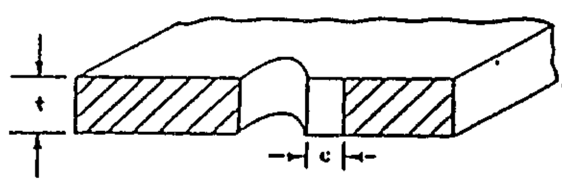

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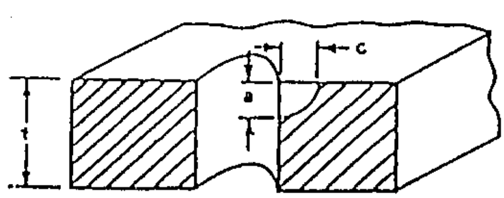
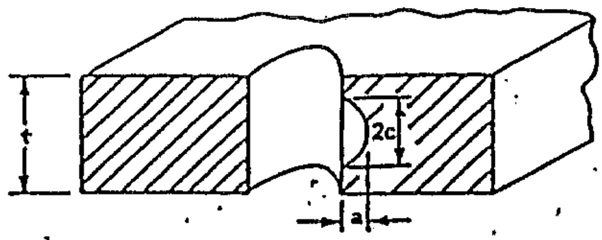


INITIAL CRACK GEOMETRIES FOR PARTS WITH HOLES

PART-THROUGH CRACK



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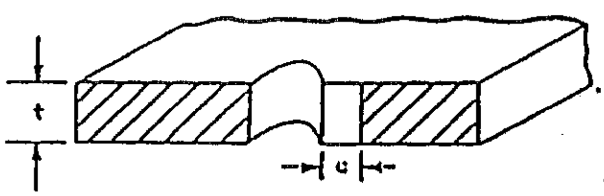

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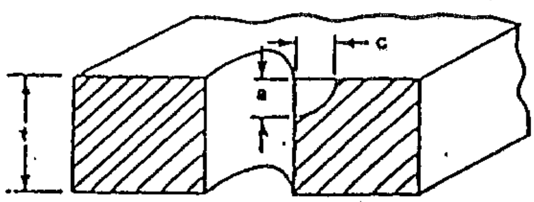

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14. SPECIAL INSTRUCTIONS: Multi-program document outlining NDE techniques and their application to flight & non-flight hardware

15. CONTRACTOR/SUBMITTING ORGANIZATION, ADDRESS AND PHONE NUMBER:
Craig Bryson
ED32
MSFC, AL 35812
(256) 544-2553

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VI. TO BE COMPLETED BY MSFC DOCUMENTATION REPOSITORY

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Tammy Wise	10-15-03	

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