Process Specification for Ultrasonic Inspection of Wrought Metals

Engineering Directorate

Structural Engineering Division

January 2020

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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REVISIONS		
VERSION	**CHANGES**	**DATE**
Baseline	Original version	7/26/99
A	Reviewed document per QMS requirements. Updated division name, organization codes, and document numbers.	12/19/02
8	Replaced references to MIL-STD-2154 with AMS-STD-2154. (MIL-STD-2154 was canceled on November 15, 2004.)	1/14/05
C	Added NASA-STD-5009 and NASA-STD-5019	9/25/06
D	Revised 4.0 References, Training and Certification of Personnel	02/16/10
E	Deleted reference to SOP-009.86 from paragraph 4.0. Revised paragraph 9.0 for uniformity across all NOE PRCs.	6/29/11
F	Deleted thickness limitation from paragraph 2.0. Added requirement for fracture critical parts to paragraph 3.1a. Deleted AMS-STD-2154 and NASA-STD-5003 from paragraph 4.0. Replaced AMS-STD-2154 with ASTM E2375 in paragraphs 5.0 and 6.1. Deleted NASA-STD-5003 from paragraph 7.0.	6/02/14
G	Added noise definition, alarm definition. Updated Table 1 for Standard Ultrasonic Inspection requirements.	01/07/2020

1.0 SCOPE

This process specification establishes the minimum requirements for ultrasonic inspection of wrought metals and wrought metal components.

2.0 APPLICABILITY

This specification is applicable to in-process, final, and in-service ultrasonic inspections to detect discontinuities in wrought metals and components made from wrought. This specification is not applicable to non-metals, composites, welds, and castings. In case of conflict with NASA-STD-5009 and this document, NASA-STD-5009 supersedes unless a variance is authorized by appropriate engineering authority. Ultrasonic inspections performed as "Engineering Evaluation" to meet intent of this specification may not meet all requirements of this specification.

3.0 USAGE

This specification shall be invoked by including an inspection note on the applicable engineering drawing or by reference in a Process Specification, Task Performance Sheet, Discrepancy Report/Material Review Record or other appropriate work authorizing document. The engineering drawing or referencing document shall specify the applicable ultrasonic acceptance class. When there are different acceptance classes for different areas on a component, the drawing shall be zoned with the acceptance class identified for each zone. If the number of components to be inspected and the amount of coverage of each component are not specified, all components shall be examined and shall receive 100 percent ultrasonic coverage.

The common ultrasonic inspection note for flight hardware and critical ground equipment is given below.

PERFORM CLASS A ULTRASONIC INSPECTION PER JSC PRC-6504.

The Standard ultrasonic inspection note for flight hardware and critical ground equipment is given below.

PERFORM CLASS A STANDARD ULTRASONIC INSPECTION PER JSC **PRC-6504.**

3.1 CLASSES

Except for Special ultrasonic testing, the ultrasonic acceptance class shall be specified in the inspection note or referencing document on the basis of the following:

a. Single discontinuities - Alarm level for parts requiring other than Standard ultrasonic testing is given as follows. Any single discontinuity producing an indication greater than the response from a reference flat-bottom hole or

equivalent notch at the estimated discontinuity depth of the size given in Table 1 is not acceptable. For parts requiring Standard ultrasonic testing, alarm level is given as follows. Any single discontinuity producing an indication greater than or equal to 50% of the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given in Table 1 is not acceptable.

b. Multiple discontinuities - Alarm levels for multiple discontinuities is given as follows. Multiple discontinuities producing indications greater than the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given in Table 1 are not acceptable if the centers of any two of these discontinuities are less than 1 inch apart. Not applicable to Class C.

c. Linear discontinuities - Alarm levels for linear discontinuities is given as follows. Any discontinuity longer than the length given in Table 1 with an indication greater than the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given in Table 1 is not acceptable. Not applicable to Class C. For flight hardware, linear discontinuities are not acceptable regardless of length.

d. Loss of back reflection - Alarm levels for loss of back wall reflection amplitude is given as follows. Loss of back reflection greater than the percent given in Table 1, when compared to a non-defective material in a similar part, is not acceptable when this loss of back reflection is accompanied by an increase in noise signal (at least double the normal background noise signal) between the front and back surface. The loss of back reflection is applicable only to the straight beam tests.

e. Noise - Noise that exceeds the level given in Table 1 is not acceptable, except for reforging stock.

f. Titanium - For Class AAA inspection of titanium, the minimum linear discontinuity length shall be 1/8-inch and the minimum response shall be same as that from 2/64-inch diameter flat bottom hole. For Class AA inspection of titanium, the minimum linear discontinuity length shall be 1/4 inch and the minimum response shall be same as that from 2/64-inch diameter flat bottom hole. UT should be performed on titanium whenever possible to prevent costly manufacturing re-works and issues.

Note: The ultrasonic acceptance class for flight hardware shall be at least Class A.

Table 1. Ultrasonic Acceptance Classes

Class	Alarm Level for Single Discontinuity Response (Diameter, inch)	Alarm Level for Multiple Discontinuity Response (Diameter, inch)	Alarm Level for Linear Discontinuity (Length - Response)	Alarm level for Loss of Back Reflection	Noise Level*	Standard Ultrasonic Testing Alarm Level
AAA	1/64 or 25% of 3/64	10% of 3/64	1/8 inch long and 10% of 3/64	50%	10% of 3/64	N/A
AA	3/64	2/64	1/2 inch - 2/64	50%	Alarm Level	N/A
A	5/64**	3/64	1 inch - 3/64	50%	Alarm Level	50% Signal response from 5/64" FBH or equivalent reflector in the reference standard
B	8/64	5/64	1 inch - 5/64	50%	Alarm Level	N/A
C	8/64	Not Applicable	Not Applicable	50%	Alarm Level	N/A

*-Noise is measured as maximum of peak amplitude in the neighborhood of the reference reflector for reference standard and corresponding inspection zone in the part.
**- Note that for this alarm level is replaced by 50% lower alarm level for Standard ultrasonic testing as given in last column. All other columns in class A are applicable to Standard ultrasonic testing.

3.2 INSPECTION SEQUENCE

The stage in the manufacturing process where ultrasonic inspection is performed should be specified on the engineering drawing or in the referencing document.

3.3 DISCONTINUITY ORIENTATION

Unless otherwise specified on the engineering drawing or in the referencing document, ultrasonic inspections shall be performed to detect discontinuities in all orientations. The responsible designer may limit the inspection to detection of discontinuities with specific orientations by indicating the relevant orientations on the engineering drawing. The designer and fracture mechanics analyst should determine the adequacy of inspections that are limited to specific discontinuity orientations.

3.4 SPECIAL NDE OF FRACTURE CRITICAL COMPONENTS

When implementation of fracture control requirements necessitates Special Nondestructive Evaluation (NOE) of a fracture critical component, the requirement for Special NDE shall appear in the inspection note as shown below.

PERFORM SPECIAL ULTRASONIC TESTING PER NASA-STD-5009 AND QUALIFICATION DOCUMENT No. XXXXXXX.

When Special NDE is required, the specific inspection procedure and inspector shall be qualified in accordance with Section 7.0.

4.0 REFERENCES

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. All documents listed are assumed to be the current revisions unless a specific revision is listed. In the case of conflict between this specification and the technical requirements cited in other referenced documents, the requirements of this document take precedence except for NASA-STD-5009 and NASA-STD-5019.

ASTM E2375	*Standard Practice for Ultrasonic Evaluation of Wrought Products*
ASTM B 594	*Standard Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products*
ASTM E114	*Standard Practice for Ultrasonic Pulse-echo Straight Beam Examination by Contact Method*
ASTM E214	*Standard Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves*

ASTM E213	*Standard Practice for Ultrasonic Examination of Metal Pipes and Tubing*
ASTM E587	*Standard Practice for Ultrasonic Angle Beam Examination by Contact Method*
ASTM E127	*Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks*
ASTM E428	*Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing*
ASTM E317	*Standard Practice for Evaluating Performance Characteristics of Pulse-echo Examination Instruments and Systems without the Use of Electronic Measurement Instruments*
ASTM E2192	*Standard Guide for Planer Flaw Height Sizing by Ultrasonics*
ASTM E1065	*Standard Guide for Evaluating Characteristics of Ultrasonic Search Units*
ASTM E1316	*Standard Terminology for Nondestructive Examinations*
NAS 410	*NAS Certification & Qualification of Nondestructive Test Personnel*
NASA-STD-5009	*Nondestructive Evaluation Requirements for Fracture Critical Metallic Components*
NASA-STD-5019	*Fracture Control Requirements for Spaceflight Hardware*
SNT-TC-1A	*Personnel Qualification and Certification in Nondestructive Testing*
SOP-007.1 JSC 8500	*Preparation and Revision of Process Specifications (PRC's)* *Engineering Drawing System Requirements*

5.0 MATERIAL REQUIREMENTS

Couplant and test block materials shall be in accordance with ASTM E2375.

6.0 PROCESS REQUIREMENTS

6.1 GENERAL

Ultrasonic inspections shall be performed in accordance with ASTM E2375 except as modified by this specification.

6.2 WRITTEN PROCEDURES

A detailed written procedure shall be prepared for each part to be inspected. The procedure shall meet the requirements of this specification and shall ensure the consistency and reproducibility of the inspection at the required sensitivity level. General procedures covering a variety of different parts may be used provided they meet the requirements of this procedure and clearly apply to the parts to be inspected. When general procedures are used, a written part specific technique shall be prepared. At a minimum, the part specific procedure or the general procedure and part specific technique shall cover all of the information required by ASTM E2375.

For work performed at JSC facilities, written procedures should consist of Detailed Process Instructions (DPIs) selected for use from the DPI-6504-XX series of work instructions.

6.3 SCAN PLAN

Unless otherwise specified on the engineering drawing or in the referencing document, scan plans shall be designed to detect discontinuities in all orientations. The scan plan shall specify the surfaces from which inspections are to be performed, the ultrasonic beam paths, the scan paths, and the scanning index.

6.4 FRACTURE CRITICAL COMPONENTS

Ultrasonic inspections of fracture critical components shall be performed in accordance with the process requirements in NASA-STD-5009. The requirements NASA-STD-5009 not otherwise covered in this specification are included in the following:

a. Surface finishes shall be 125 RMS or better.

b. Inspections shall be performed with the ultrasonic beam direction as close to perpendicular to the relevant discontinuity orientation as possible.

c. The inspection surfaces shall not be coated.

d. The component shall not be loaded in compression.

When Special NDE is specified by the engineering drawing or referencing document,

the inspection procedure and inspector shall be qualified in accordance with Section

7.0. SPECIAL NDE QUALIFICATION

Use of Special NDE in accordance with NASA-STD-5009, SSP 30558 or NASA- STD-5019 requires formal demonstration of the capability to detect flaws at least as small as the initial crack size for the specific component to a 90/95 detection reliability. Each procedure, procedure application, and operator must demonstrate the required capability. Requests for Special NDE qualification shall be directed to the JSC Materials and Processes Branch (ES4).

8.0 DEVIATIONS AND WAIVERS

Any deviations or waivers regarding the use of this process specification shall be requested in writing. This request shall be directed to the JSC Materials and Processes Branch {ES4) with the appropriate justification and rationale. A written response will be provided upon such a request.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

Personnel performing acceptance inspections of Class I, II, IIIW and GSE hardware shall be qualified and certified, at a minimum, to Level 2 in accordance with NAS 410. Personnel performing acceptance inspections requiring Special NOE shall also be qualified and certified for Special NDE in accordance with NASA-STD-5009.

Personnel performing acceptance inspections of Class Ill, STE/D, mockup, and facility hardware shall be qualified and certified in accordance with either NAS 410 or SNT-TC-1A. Personnel making accept/reject decisions shall, at a minimum, be certified to Level 2. Level 3 personnel making accept/reject decisions shall have successfully completed a hands-on practical examination equivalent to the examination required for Level 2. Level 1 personnel may perform acceptance inspections under the direct supervision of a Level 2 but shall not make accept/reject decisions.

10.0 DEFINITIONS

90/95	The point where the 95% lower confidence bound on the Probability of Detection (POD) vs. flaw size curve crosses 90% POD or 90% POD with 95% lower confidence bound.
Alarm Level	Signal response level in comparison to the reference discontinuity signal response. Indications with response equal to or higher than the alarm level are rejected. Also known as decision threshold.
Final Inspection	The final inspection performed for the acceptance of the component.

Discontinuity	An intentional or unintentional interruption in the physical structure or configuration of a material or component that may be detectable by nondestructive testing; a flaw. Discontinuities are not necessarily rejectable.
Flaw Detection Capability	It is an estimate of flaw detection reliability. It can be estimated by the Probability of Detection (POD) analysis of experimental flaw detection data. It implies 90% POD with minimum 95% confidence.
Fracture Critical Component	Classification which assumes that fracture or failure of the component resulting from the occurrence of a crack will result in a catastrophic hazard. Fracture critical components will be identified as such on the engineering drawing.
Indication	Evidence of a discontinuity that requires interpretation to determine its significance.
In-Process	Inspections that occur during manufacturing before a component is in final form.
In-Service	Inspections performed on components that are in use or storage.
Noise	Noise is same as signal response in area where it is known or assumed that no flaws exist. It is taken as maximum value of peak amplitude from multiple (40) measurements.
Special NDE	A fracture control term denoting nondestructive inspection process (that specifies personnel, procedures, and equipment) with a demonstrated capability to reliably (90/95) detect a specified flaw size that is smaller than those normally detected by the Standard NDE procedures.
Special Materials	A fracture control term denoting nondestructive inspection process with specified personnel, procedures, and equipment with a demonstrated capability to reliably (90/95) detect the specified flaw size that is smaller than those normally detected by the Standard NOE procedures.
Wrought Metals	Wrought metals include forging stock, forgings, rolled billet or plate, extruded or rolled bars, and extruded or rolled shapes.