Process Specification for Ultrasonic Inspection of Welds

Engineering Directorate

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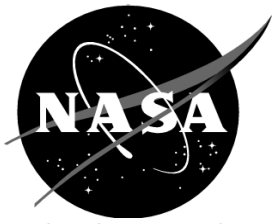

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REVISIONS		
VERSION	**CHANGES**	**DATE**
Baseline	Original version	
A	Added SNT-TC-1A and deleted SOP-009.86 from paragraph 4.0. Revised paragraph 9.0 for uniformity across all NDE PRCs.	06/29/2011
B	Reviewed document per QMS requirement. Updated document signatures. Added noise definition.	05/13/2020

1.0 SCOPE

This process specification establishes the minimum requirements for ultrasonic inspection of welds other than friction stir, fillet, and spot welds by the straight and/or angle beam pulse-echo technique.

2.0 APPLICABLITY

This specification is applicable to in-process, final, and in-service ultrasonic inspections to detect discontinuities in welds and the heat-affected zone. The inspection is intended to detect and evaluate discrete ultrasonic reflectors such as cracks and voids.

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 document. The engineering drawing or referencing document shall specify the applicable ultrasonic inspection reference standard and sensitivity class. When there are different sensitivity classes for different areas on a component, the drawing shall be zoned with the sensitivity 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 standard ultrasonic inspection note for flight hardware and critical ground equipment is given below.

PERFORM ULTRASONIC INSPECTION PER JSC PRC-6510, CLASS A

3.1 SPECIAL NDE OF FRACTURE CRITICAL COMPONENTS

When implementation of fracture control requirements necessitates Special Nondestructive Evaluation (NDE) of a fracture critical component, the requirement for Special NDE shall appear in the inspection note as shown below. When Special NDE is required, the specific inspection procedure and inspector shall be qualified in accordance with Section 7.

PERFORM ULTRASONIC INSPECTION PER JSC PRC-6510. SPECIAL NDE QUALIFICATION REQUIRED.

3.2 SENSITIVITY CLASS

Ultrasonic sensitivity is determined by the size of the reference reflector used for instrument standardization. The reference reflector shall be either a round flat bottom hole (FBH) or a narrow, semicircular surface notch machined normal to the part surface or at the angle of expected discontinuities. Both types of reflector may be used in a given ultrasonic examination. The Class A reflector is used to establish sensitivity for Standard NDE inspections defined in NASA-STD- 5009. Dimensions of the reference reflectors are given in Table 1.

Table 1. Reference Reflector Dimensions by Sensitivity Class

Class	Reflector Type	Diameter, Inches	Length, Inches	Depth, Inches
AA	FBH	0.047 +/-0.004		
AA	Surface Notch		0.061 +/-0.005	0.028 +/-0.003
A	FBH	0.078 +/-0.004		
A	Surface Notch		0.105 +/-0.005	0.050 +/-0.005

The “calibration reflector” used during instrument calibration may or may not be the same as the reference reflector. A side drilled hole, surface slot, surface groove, or other reflector can be used as a calibration reflector provided that an amplitude (dB) transfer is performed with respect to the applicable reference reflector at the same metal path. For phased array transducer techniques where the beam angle is swept, the transfer comparison between the reference reflector and the calibration reflector shall be performed at the center of the sweep angle (+/-5 degrees). For angle beam examination where a flat bottom hole is used as the reference reflector and a side drilled hole is used as the calibration reflector, the transfer shall be achieved with metal paths at 1/4 vee and 3/4 vee (per ASTM E 2375, Appendix A). If surface notch reflectors are used as reference reflectors, then long surface notches or slots may be used as calibration reflectors upon establishing the transfer at ½ vee and 1 vee paths. Calibration reflector size and tolerances shall meet the requirements of ASTM E 164.

3.3 CALIBRATION STANDARDS

Ultrasonic calibration standards are chosen based on similarity of expected flaws in the part to be inspected with the calibration reflectors. Appropriate calibration standards are developed and used based upon similarity with the part material, thickness, geometry, surface roughness, and the expected flaw size, location, orientation, and proximity to other flaws if multiple flaws are expected. Calibration standards shall have calibration reflectors located at several locations relative to the cross-sectional geometry of the weld, such that the ultrasonic technique can be demonstrated to provide flaw detection coverage in the entire weld bead and heat affected zone (minimum ¼ inch beyond the weld bead). At least one of the calibration reflectors shall be located at a depth of one half of the base metal thickness. All aluminum reference standards shall conform to the dimensional and finish requirements as defined by the most recent revision of ASTM E 127. All non-aluminum metal reference standards shall conform to the dimensional and finish requirements as defined by the most recent revision of ASTM E 428. A report on the dimensional inspection of the reflectors shall be maintained with each reference standard.

3.4 CALIBRATION STANDARDS AND BEAM ALIGNMENT

During calibration of a pulse-echo contact technique, the ultrasonic transducer contact location on the reference standard shall have the rotational and translational degrees of freedom needed to establish alignment of the ultrasonic beam centerline with the reflector such that the reflected signal can be maximized. In addition, there shall be adequate scanning space for the transducer about the maximum signal location such that the movement of the transducer along every possible degree of freedom away from the optimal position drops the signal amplitude below 50% of the maximum signal.

If a flat bottom hole is used as a calibration reflector for pulse-echo contact technique, the beam shall be normal to the reflector surface. If a side drilled hole reflector is used during the pulse-echo calibration, then the ultrasonic transducer shall be capable of being positioned such that the ultrasonic beam is normal to the side drilled hole axis such that the received signal is maximized. If a surface notch reflector is used during a pulse-echo calibration, then the ultrasonic transducer shall be capable of being positioned such that the ultrasonic beam can point towards and is normal to the corner formed by the surface notch maximizing the received signal.

3.5 ACCEPTANCE CRITERIA

Any indication equal to or exceeding 50% of the amplitude response from the applicable reference reflector shall be rejected regardless of length. All linear indications greater than 0.25 inches in length shall be rejected regardless of the amplitude response.

Neighboring rejectable indications shall be grouped if the nominal distance between any two adjacent indications is less than or equal to 0.5 inches. The combined length of the adjacent indications and the spacing in between shall be reported as the total length of the rejected area.

All components or details exhibiting discontinuities exceeding the acceptance criteria shall be rejected. If the type of anomaly causing the rejectable indication cannot be determined based on the results of the ultrasonic inspection, the inspector shall review the results of any supplemental visual or radiographic inspections to aid in determining the cause of the indication.

At a minimum, flight hardware shall be inspected using a Class A sensitivity. Other sensitivities are acceptable if approved by the customer. If a sensitivity class is not specified, Class A sensitivity shall be used.

Noise shall not exceed 25% of the amplitude response from applicable reference reflector. Noise is measured as maximum of peak amplitude in the neighborhood of the reference reflector where there is no flaw and corresponding inspection zone signal indicates that there is no flaw in the part.

3.6 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.

3.7 DISCONTIUITY ORIENTATION

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

of the entire weld bead and heat affected zone (a minimum of ¼ inch beyond the weld bead). Planer discontinuities may be normal, parallel or at angle to the part surface at weld location. Ultrasonic angle beam (shearwave) inspection is assumed for detecting flaws that are normal or at an angle to the surface and not accessible by zero degree longitudinal wave due to the presence of the weld crown or part geometry.

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 revision unless a specific revision is listed. In case of conflict between this specification and the technical requirements cited in other referenced documents, the requirements of this document shall take precedence.

ASME 2541	*Use of Manual Phased Array Ultrasonic Examination Section V*
ASME 2557	*Use of Manual Phased Array S-scan Ultrasonic Examination per Article 4*
ASME 2558	*Use of Manual Phased Array E-scan Ultrasonic Examination per Article 4 Section V*
ASTM E 127	*Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks*
ASTM E 164	*Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks.*
ASTM E 317	*Standard Practice for Evaluating Performance Characteristics of Pulse-Echo Examination Instruments and Systems Without the Use of Electronic Measurement Instruments*
ASTM E 428	*Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing*
ASTM E 587	*Standard Practice for Ultrasonic Angle Beam Examination by Contact Method*
ASTM E 1316	*Standard Terminology for Nondestructive Examinations*

ASTM E 1961	*Standard Practice for Mechanized Ultrasonic Testing of Girth Welds Using Zonal Discrimination with Focused Search Units*
ASTM E 2192	*Standard Guide for Planer Flaw Height Sizing by Ultrasonics*
ASTM E 2375	*Standard Practice for Ultrasonic Evaluation of Wrought Products*
ASTM E 2491	*Standard Guide for Evaluating Performance of Phased-Array Ultrasonic Examination Instruments and Systems*
NAS 410	*NAS Certification & Qualification of Nondestructive Test Personnel*
NASA-STD-5009	*Nondestructive Evaluation Requirements for Fracture Control Programs*
NASA-STD-5019	*Fracture Control Requirements For Spaceflight Hardware*
SNT-TC-1A	*Personnel Qualification and Certification in Nondestructive Testing*
SSP 30558	*Fracture Control Requirements for Space Station*

The following references were used to develop this process specification:

JSC 8500	*Engineering Drawing System Requirements*
SOP-007.1	*Preparation and Revision of Process Specifications (PRC's)*

5.0 MATERIAL REQUIREMENTS

Couplant and calibration standard materials shall be in accordance with ASTM E 164.

6.0 PROCESS REQUIREMENTS

6.1 GENERAL

Conventional ultrasonic techniques shall be performed in accordance with ASTM E 164 except as modified by this specification. ASTM E 1961 may be used for mechanized ultrasonic testing of girth welds. The requirements of ASTM E 587 apply for angle beam examination except as modified by this specification.

Phased array ultrasonic techniques shall be performed in accordance with ASTM E 164, ASTM E 2491, ASME 2557, ASME 2558 and ASME 2541 except as modified by this specification.

6.2 INSPECTION SURFACES

Inspection surfaces shall be free of weld flash, weld spatter, loose debris, paint, corrosion or other contact inhibiting materials. A 125 µin RMS or better, surface finish should be maintained so as not to degrade the ability to perform post weld inspection.

Depending on the required sensitivity class, weld reinforcement may have to be machined flush on one or both sides of the weld. For Special NDE, the weld reinforcement that is accessible shall be machined to provide a roughness not to exceed 125 µin RMS.

6.3 INSTRUMENT CALIBRATION

Inspection equipment shall be calibrated before and after each inspection (or series of inspections) or when changing power supplies, operator, or any other component of the inspection system. In all cases, the period between calibrations shall not exceed eight hours. If the sensitivity setting varies by more than 2 dB from the previous setting, all inspections performed since the previous calibration shall be repeated. The transducer shall be taken out of service when sensitivity and/or resolution requirements are not met.

Ultrasonic inspection instruments should receive an annual general calibration in accordance with ASTM E 317 to verify that the instrument still meets the manufacturer’s specifications.

6.4 SIGNAL TO NOISE RATIO

The transducer and technique shall provide a signal-to-noise ratio of 4:1 or better on the applicable reference reflector.

6.5 EVALUATION OF INDICATIONS

Indications should be evaluated and sized using any of the standard flaw sizing methods in ASTM E 2192.

6.6 MARKING OF PARTS

All rejected components or details shall be clearly marked indicating ultrasonic rejection. The location of rejected indications shall also be clearly marked on the part as accurately as possible. The locations of rejected indications should be numbered to match the tabulated record included in the inspection report.

6.7 WRITTEN PROCEDURES

A written procedure shall be prepared for each part to be inspected. The procedure shall meet the requirements of this specification and shall ensure consistency and reproducibility of the inspection at the required sensitivity class. General procedures covering a variety of different parts may be used, provided they meet the requirements of this specification 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 general procedure and part specific technique shall cover all of the information required by ASTM E 164 and shall include the details necessary for satisfactory calibration and inspection.

Procedures and technique sheets shall be approved by the cognizant NDE engineer for each standard shape and part number in accordance with the applicable specification.

For work performed at JSC facilities, the general written procedures should consist of Detailed Process Instructions (DPIs) selected for use from the DPI- 6510-XX series of work instructions.

6.8 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 number and the orientation of the scans shall be selected to guarantee the detection of flaws exceeding the applicable sensitivity class throughout the volume of the weld and HAZ. 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. Scans shall provide overlap of 50% of beam width. The scan plan shall be included in the inspection report.

6.9 FRACTURE CRITICAL COMPONENTS

The process requirements for fracture critical components not otherwise covered in this specification are:

a. Parent metal surface finishes shall be 125 µin RMS or better. Weld reinforcement shall be machined flush with a minimum surface finish of 125 µin RMS where accessible.

b. Inspections shall be performed with the ultrasonic beam as close to perpendicular to the relevant discontinuity reflector surface as possible. In addition, a longitudinal (0 degree) scan is also needed.

c. The inspection surfaces shall not be coated.

d. The weld 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.

7.0 SPECIAL NDE QUALIFICATION

Use of Special NDE in accordance with NASA-STD-5009 requires formal demonstration of the capability to detect flaws at least as small as the initial crack size for the specific component with a 90/95 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 NDE shall also be qualified and certified for Special NDE in accordance with NASA-STD-5009.

Personnel performing acceptance inspections of Class III, STE/D, mockup, and facility hardware shall be qualified and certified in accordance with either NAS410 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.

Formal qualification and certification is not required for personnel performing engineering evaluation inspections.

10.0 INSPECTION REPORTS

Inspection results shall be documented in an inspection report containing all of the data necessary to verify compliance with the requirements of this specification. At a minimum, the inspection report shall include the following:

a. Effectivity and weld code
b. Part Number
c. Part Serial Number(s)
d. Material identification including alloy designation and thickness
e. Process Control Number
f. Date of the inspection
g. Results of inspection
h. Identification of inspection equipment used including the inspection instrument, transducers, calibration standards, and reference standards
i. Scan plan
j. Instrument setup parameters
k. A recording of the calibration signal response
l. Inspector name and signature

Rejected indications shall be recorded in a numbered table together with their equivalent response and locations. The location of rejected indications shall be noted on a sketch of the part and identified for cross-reference to the tabulated information.

Raw phased array data files, setup files, calibration data files, and digital reports shall be stored on a secure database and identified by the test description and inspection report control number.

11.0 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% confidence.
Conventional Contact Technique	Ultrasonic inspection technique using a single element contact transducer.
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.
Final Inspection	The final inspection performed for the acceptance of the component.
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.
Heat Affected Zone (HAZ)	An area of base material adjacent to a weld which had its microstructure and associated properties altered by the welding process.
Indication	Evidence of a discontinuity that requires interpretation to determine its significance.
In-Process	Inspections which occur during manufacturing before a component is in final form.
In-Service	Inspections performed on components that are in use or storage.
Noise	Penetrant indication with a length to width ratio of 3:1 or greater.
Phased Array	Ultrasonic inspection technique using a phased array Technique contact transducer.
Special NDE	A fracture control term denoting nondestructive inspection personnel, procedures, and equipment with a demonstrated capability to reliably (90/95) detect flaws smaller than those normally detected by Standard NDE procedures.