Process Specification for Radiographic Inspection

Engineering Directorate

Structural Engineering Division

January 2020

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

Process Specification for Radiographic Inspection

Revised and Reviewed by:	Signature on File	01/07/2020
	Ajay Koshti Materials and Processes Branch/ES4	Date
Revised and Reviewed by:	Signature on File	01/07/2020
	David Stanley Materials and Processes Branch/ES4	Date
Revised and Reviewed by:	Signature on File	01/07/2020
	Norman Ruffino Materials and Processes Branch/ES4	Date
Revised and Reviewed by:	Signature on File	01/07/2020
	Ovidio Oliveras Materials and Processes Branch/ES4	Date
Revised and Reviewed by:	Signature on File	01/07/2020
	Miles Skow Materials and Processes Branch/ES4	Date
Approved by:	Signature on File	01/17/2020
	Brian Mayeaux Materials and Processes Branch/ES4	Date

REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version	07/26/99
A	Reviewed document per QMS requirements. Updated division name, organization codes, and document numbers.	12/19/02
B	Deleted SNT-TC-1A and MSFC-STD-1249. Added NASA-STD-5009 and NASA-STD-5019. Added definition of discontinuity and indication.	02/14/07
C	Modified written procedures, special NDE qualification, and review of radiographic data	02/19/10
D	Deleted reference to SOP-009.86 from paragraph 4.0. Revised paragraph 9.0 for uniformity across all NDE PRCs.	06/29/2011
E	Updated signatures of document. Updated all sections to replace ES4 with ES18. Updated all sections to replace NAS 1514with AWS D17.1. Updated all sections, changed *"film density"* and *"radiographic density" to "optical* density" throughout. Updated section 2.0 - to add *"Engineering Evaluation".* Updated section 3.0 -to add "*work authorizing";* change NAS 1514 to "A*WS D17.1* Class *A".* Added Figure 2 Inspection Note for Standard radiographic inspections of welds. Updated section 3.1 - to add *"the size and weight of the component".* Added how Flight Hardware shall be handled and stored; radiographic inspection of welds may be performed before and after proof test. Updated section 4.0 - added *"except for NASA-STD- 5009";* removed NAS 1514. Revised para. 6.1, 6.2, 6.3, 6.5 and 6.6. Requirements updated to meet or exceed NASA-STD-50098. Updated all sections - changed *"minimum density range to 2.5".* Updated section 5.0 - removed *"non-film recording media"* Updated section 6.5 - to add *"1T penetrometer sensitivity";* add *"D/3 when detecting* flaws *smaller than 0.010" in diameter".* Updated section 6.6 - removed section *"d".* Updated section 11.0 - added *"Optical Density"*	01/07/2020

1.0 SCOPE

This process specification establishes the minimum requirements for film radiographic inspection of metallic and nonmetallic materials, components, and assemblies.

2.0 APPLICABILITY

This specification is applicable to in-process, final, and in-service radiographic inspections to detect cracks, porosity, voids, inclusions, improper assembly, density variations, corrosion, and other discontinuities in metallic welds, castings, additively manufactured materials and wrought materials.

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 criteria by which components are judged acceptable. An example of acceptance criteria for welded components are contained in AWS D17.1. When there are different acceptance criteria for different areas on a component, the drawing shall be zoned with the acceptance criteria 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 radiographic coverage.

An example of a radiographic inspection note for welded flight hardware is given in figure 1.

PERFORM RADIOGRAPHIC INSPECTION OF WELDS PER JSC PRC-6503, ACCEPTANCE CRITERIA PER AWS D17.1, CLASS A.

Figure 1: Example of a radiographic inspection note.

An example of Standard radiographic inspection note for welded flight hardware is given in figure 2.

PERFORM STANDARD RADIOGRAPHIC INSPECTION OF WELDS PER JSC PRC-6503, ACCEPTANCE CRITERIA PER AWS D17.1, CLASS A.

Figure 2: Example of a standard radiographic inspection note for welded flight hardware.

Another example of Standard radiographic inspection note for welds is given in figure 3.

PERFORM STANDARD RADIOGRAPHIC INSPECTION OF WELDS PER JSC PRC-6503, ACCEPTANCE CRITERIA PER PRC-0010 CLASS A.

Figure 3: Second example of Standard radiographic inspection note for welds.

Another example of Standard radiographic inspection note for welds is given in figure 4.

PERFORM STANDARD RADIOGRAPHIC INSPECTION OF WELDS PER JSC PRC-6503, ACCEPTANCE CRITERIA PER NAS1514 CLASS I.

Figure 4: Third example of Standard radiographic inspection note for welds.

An example of radiographic inspection note for casting is given in figure 5.

PERFORM RADIOGRAPHIC INSPECTION OF CASTING PER JSC PRC-6503, ACCEPTANCE CRITERIA PER SAE AMS2175, CLASS 1 GRADE B.

Figure 5: Example of radiographic inspection note for casting.

3.1 INSPECTION SEQUENCE

The stage in the manufacturing process where radiographic inspection is performed should be specified on the engineering drawing or in the referencing document. Factors to be considered when specifying the inspection sequence are: the accessibility of both sides of the component; the size and weight of the component, the complexity of the assembly as it relates to optimal alignment of the radiation beam; loading of the component or assembly (compressive loads reduce cracks detectability); and the need for subsequent manufacturing processes that could generate discontinuities. Radiographic inspection may be performed before heat treatment, provided liquid penetrant or magnetic particle inspections are performed after heat treatment. Flight hardware shall be handled and stored with care according to the hardware owner's instructions. Radiographic inspections of welds may be performed before and after proof load/pressure tests as invoked by responsible engineering authority.

3.2 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 NOE shall appear in the inspection note as shown in figure 6. When Special NOE is required, the specific inspection procedure and inspector shall be qualified in accordance with Section 7.0.

PERFORM RADIOGRAPHIC INSPECTION OF WELDS PER JSC PRC-6503, ACCEPTANCE CRITERIA PER AWS D17.1, CLASS A. SPECIAL NDE CERTIFICATION REQUIRED.

Figure 6: Example of special NOE that shall appear in the inspection note.

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. The Standard x-ray requirements given here shall meet or exceed NASA-STD-5009 requirements. In the case of conflict between this specification and the technical requirements cited in other referenced documents, the requirements of this document take precedence.

ASTM E 1742	Standard Practice for Radiographic Examination
NASA-STD-5009	Nondestructive Evaluation Requirements for Fracture Critical Metallic Components
NAS 410	NAS Certification & Qualification of Nondestructive Test Personnel
SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing
NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware
SSP 30558	Fracture Control Requirements for Space Station

The following references were used to develop this process specification:

SOP-007.1	Preparation and Revision of Process Specifications (PRC's).
JSC 8500	Preparation and Revision of Process Specifications.

5.0 MATERIAL REQUIREMENTS

Film and film processing solutions shall be in accordance with ASTM E1742.

6.0 PROCESS REQUIREMENTS

6.1 GENERAL

Radiographic inspections shall be performed in accordance with ASTM E1742 except as modified by this specification.

6.2 WRITTEN PROCEDURES

A specific written procedure or a general written procedure with a written part specific technique shall be prepared for each part to be inspected. The procedures shall meet the requirements of this specification and shall ensure the consistency and reproducibility of the inspection at the required radiographic quality level. 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. At a minimum, the part specific procedure or the general procedure and part specific technique shall cover all of the information required by ASTM E1742.

For work performed at JSC facilities, specific or general written procedures should consist of Detailed Process Instructions (DPIs) selected for use from the DPI-6503-XX series of work instructions.

6.3 OPTICAL DENSITY

Optical density of film in the area of interest shall be in the range from 2.5 to 4.0 (inclusive). Optical densities greater than 4.0 are permitted when approved by the JSC Materials and Processes Branch (ES4). Densities less than 2.5 are permitted only when items not requiring an Image Quality Indicator (IQI) are inspected.

6.4 APPLICABLE AREA

For components requiring an Image Quality Indicator (IQI), only the area of the film that falls within a 10 degree cone of radiation (10 degree total solid angle, apex at the radiation source, central axis of the cone equal to the central axis of the radiation beam) shall be considered valid for interpretation.

6.5 SOURCE-TO-FILM DISTANCE

For applications, requiring 1T Penetrameter sensitivity, the minimum allowable source-to-film distance for flight hardware shall be calculated using a maximum geometric unsharpness (Ug) of 0.003 inch, except for applications requiring detection of volumetric flaws with diameter "D" smaller than 0.01O" in diameter, the geometric unsharpness (Ug) should not exceed D/3.

6.6 FRACTURE CRITICAL COMPONENTS

Radiographic inspections of fracture- critical components shall be performed in accordance with the process requirements in NASA-STD-5009. Standard X-ray assumes to detect volumetric and cracklike flaws reliably. For radiographic inspections of butt welds, cracks are assumed to be oriented in circumferential (weld length) direction or axial (weld width) direction. X-ray techniques shall be tailored to detect above orientations of cracklike flaws and any other orientations of flaws specifically identified on the inspection callout. Standard x-ray inspections are assumed to include single wall and double-wall exposures. Tangential shots are not covered by Standard x-ray requirements. The Standard x-ray requirements in NASA-STD-5009 not otherwise covered in this specification are included in the following:

a. The Radiographic Quality Level shall be at least Level 1 (2 - 1T};

b. Optical density in the area of interest shall be in the range from 2.5 to 4.0 (inclusive);

c. For Standard x-ray inspection of welds the radiation beam intersecting an assumed cracklike flaw shall be within ±5 degrees of the assumed crack plane orientation. Film region meeting above condition is considered to be valid for film interpretation. For other than Standard and Special x-ray inspections, requirements for x-ray angle, shots and coverage shall be per para. 6.0 except paragraph 6.6 is excluded.

e. Film shall be placed in close contact with the component. For applications, requiring use of 1T hole Penetrameter sensitivity with the 1T, the minimum allowable source-to-film distance for flight hardware shall be calculated using a maximum geometric unsharpness (Ug) of 0.003 inch, except for applications requiring detection of volumetric flaws with diameter "D" smaller than 0.01O" in diameter, the geometric unsharpness (Ug) should not exceed D/3.

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, NASA-STD-5019, or SSP 30558 requires formal demonstration of NDE reliability to at least 90/95 to detect flaws of a specific size given in the intended acceptance criteria. The radiography crack detectability size is given as the depth of the crack as a fraction of the part thickness. The crack plane is assumed to be oriented approximately normal to the part surface. The special radiography crack size is frequently chosen to be 0.6 times the part thickness. . Each procedure, procedure application, and operator must demonstrate the required capability. Requests for Special NOE qualification/certification 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, 11, 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 111, 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.

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

10.0 REVIEW OF RADIOGRAPHIC DATA

Radiographic inspection report and image identification data of criticality 1 hardware shall be reviewed for accuracy by a minimum of two personnel, one of the persons

shall be a radiographic inspector gathering the data and the other person shall be a cognizant engineer. Both persons shall sign on the inspection report acknowledging the review of the data.

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% lower confidence bound.
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.
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.
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.
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.
Indication	Evidence of a discontinuity that requires interpretation to determine its significance.
Optical Density	The quantitative measure of diffuse optical light transmission (optical density, blackening) through a developed film.