Designation: F3704/F3704M – 24

Standard Practice for Nondestructive Testing (NDT), Inspection Levels and Acceptance Criteria for Parts Manufactured with Laser Based Powder Fusion[1]

This standard is issued under the fixed designation F3704/F3704M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides two NDT inspection levels, with acceptance criteria and applicable NDT method(s). It is not based on part driven engineering criteria but the practical inspection capability of properly applied NDT methods.[2] Flaw detection is based on the flaw's characteristic and relative orientation to the applied NDT method.

1.2 *Applicability*—This standard applies to parts that are processed using laser beam powder bed fusion (PBF-LB). Post processing of PBF-LB parts by hot isostatic pressing (HIP) can close (partially or completely) certain types of defects. NDT techniques applied to HIP'ed parts may not detect collapsed defects. It is the responsibility of the user of this standard to determine if this condition is rejectable and what NDT technique to use.

1.3 There are areas in this practice that may require agreement between the cognizant engineering organization and the additive manufacturing supplier, or specific direction from the cognizant engineering organization.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E127 Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks

E587 Practice for Ultrasonic Angle-Beam Contact Testing

E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiography

E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography

E1316 Terminology for Nondestructive Examinations

E1417 Practice for Liquid Penetrant Testing

E1742 Practice for Radiographic Examination

E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

E2375 Practice for Ultrasonic Testing of Wrought Products

E2534 Practice for Targeted Defect Detection Using Process Compensated Resonance Testing Via Swept Sine Input for Metallic and Non-Metallic Parts

E2698 Practice for Radiographic Examination Using Digital Detector Arrays

E2700 Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays

E3081 Practice for Outlier Screening Using Process Compensated Resonance Testing via Swept Sine Input for Metallic and Non-Metallic Parts

E3166 Guide for Nondestructive Examination of Metal Additively Manufactured Aerospace Parts After Build

E3213 Practice for Part-to-Itself Examination Using Process

[1] This practice is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.07 on Applications.

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[2] Used to reference radiographs for radiographic quality levels found in MIL STD 2175 in WL-TR-91-4049 X-Ray Computed Tomography of Castings.

[3] For referenced ASTM and ISO/ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Compensated Resonance Testing Via Swept Sine Input for Metallic and Non-Metallic Parts
E3375 Practice for Cone Beam Computed Tomographic (CT) Examination
E3397 Practice for Resonance Testing Using the Impulse Excitation Method

2.2 *ASNT Documents:*[4]
Nondestructive Testing Handbook, 2nd Edition, Vol 7 SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing
ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *Aerospace Industries Association Document:*[5]
NAS-410 Certification and Qualification of Nondestructive Testing Personnel

2.4 *ISO Standards:*
ISO 9712 Non-Destructive Testing – Qualification and Certification of NDT Personnel[6]
ISO/ASTM 52900 Additive manufacturing — General principles — Fundamentals and Vocabulary[3]
ISO/ASTM TR 52905 Additive Manufacturing of Metals — Non-Destructive Testing and Evaluation — Defect Detection in Parts[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For common NDT definitions of terms used in this practice refer to Terminology E1316 and for more detailed additive manufacturing terms used in this practice refer to ISO/ASTM 52900. Terminology related to technologically important flaw types detected by NDT can be found in Guide E3166 and ISO/ASTM TR 52905.

3.1.2 *contamination, n*—consolidated material that contains an amount of material non-conforming to the feedstock chemical composition.

3.1.2.1 *Discussion*—Contamination can be detected by radiographic and other methods/techniques as a local or full body condition. A common source of contamination comes from processing different alloys in proximity.

3.1.3 *crack, n*—separation of material, inter-granular or trans-granular, caused by shrinkage of the material.

3.1.3.1 *Discussion*—Sometimes called crack-like or hot tear. Cracks can be associated with solidification and delamination conditions.

3.1.4 *inclusion, n*—individual or multiple unintended foreign objects.

3.1.4.1 *Discussion*—Foreign object which is based on the measurable detected size and less frequent as compared to contamination which is widespread and may be less pronounced.

3.1.5 *lack of fusion (LOF), n*—material that has not been consolidated by heat source.

3.1.5.1 *Discussion*—Lack of fusion is a condition where material is not fully consolidated, melted or fused into the previously deposited substrate by the heat source or post-build thermal processing. Sometimes called incomplete fusion or build layer separation, this condition can lead to a through-wall separation if the LOF dimension extends from one side to the other of a build structure.

3.1.6 *porosity, n*—See ISO 52900.

3.1.6.1 *Discussion*—NDT methods have characterized additive manufactured porosity as spherical, keyhole, or faceted shaped anomalies. These anomalies can be intermittent, elongated, interconnected, or chained. A further characterization of "elongated anomalies" is discussed under the subject of lack of fusion in Guide E3166.

3.1.7 *unconsolidated or residual powder, n*—powder remaining in the part after the part fabrication is complete.

3.1.7.1 *Discussion*—Unconsolidated powder is sometimes referred to as trapped powder and can result where there is no exit point for the powder. Hot isotropic pressing may consolidate "trapped" powder forming an unplanned blockage. It is distinct from lack of fusion because the laser or power source never attempted to melt the unconsolidated powder.

3.1.8 *voids, n*—an empty space filled with shielding gas, process chemical reaction gas, or vacuum depending on the PBF machine architecture.

3.1.8.1 *Discussion*—Voids may contain powder that can reflect ultrasound energy or appear as a different density in radiography if the parts are inspected prior to HIP. Voids are often seen as irregularly shaped or elongated cavities (process-induced porosity, LOF, skipped layers, large cracks, or delamination) and spherically shaped cavities (gas-induced and keyhole porosity).

3.1.9 *witness line, n*—an externally visible demarcation along build layer planes indicating a planned or unplanned change in steady-state operation of the AM process.

3.1.9.1 *Discussion*—Visual indicators include a geometry shift or a change in surface texture or coloration. The typical source of witness lines is a build stop. Witness lines may also be created when there is a large change in melted area (fill grade) within a small number of layers. Witness lines can also form if the build environment is altered (planned or unplanned).

4. Summary of Practice

4.1 Nondestructive testing methods applying industry standard practices, in proper alignment for suspected flaws, and demonstrating the required inspection sensitivity levels should be capable of detecting at the levels as shown in Section 8 and Table 2. Three general types of laser powder bed fusion flaws are: low laser energy (lack of fusion between build layers), high energy laser (keyhole porosity throughout the cross section) and internally trapped powder.

4.1.1 These three flaw types have been created through the lowering and raising of laser power and preventing powder

[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.