



AEROSPACE INFORMATION REPORT

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Additively Manufactured Component Substantiation

RATIONALE

This Aerospace Information Report (AIR) was prepared in order to provide users with an overview of the scope of tasks and requirements associated with substantiating additively manufactured components. This document is informational only and not formal guidance.

1. SCOPE

This AIR is applicable to components fabricated using additive manufacturing (AM) processes. The discussion is generic with respect to specific additive processes as much as possible. Each additive process has unique considerations that should be addressed in any effort to substantiate additively manufactured components. This specification is written for metallics but conceptually could be applied to non-metallics.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS4954	Titanium Alloy, Welding Wire, 6Al-4V
AMS7000	Laser-Powder Bed Fusion (L-PBF) Produced Parts, Nickel Alloy, Corrosion and Heat-Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb, Stress Relieved, Hot Isostatic Pressed and Solution Annealed
AMS7001	Nickel Alloy, Corrosion and Heat-Resistant, Powder for Additive Manufacturing, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb
AMS7002	Process Requirements for Production of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts
AMS7003	Laser Powder Bed Fusion Process

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Documents
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AMS7004 Titanium Alloy Preforms from Plasma Arc Directed Energy Deposition Additive Manufacturing on Substrate, Ti - 6Al - 4V, Stress Relieved.

AMS7005 Wire Fed Plasma Arc Directed Energy Deposition Additive Manufacturing Process

AS9100 Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations

2.1.2 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 9001 Quality Management Systems - Requirements

2.1.3 Other Documents

CMH-17 Composite Materials Handbook

Metallic Materials Properties Development and Standardization (MMPDS), Battelle Memorial Institute for the Federal Aviation Administration, William J. Hughes Technical Center, Battelle, Columbus, OH.

2.2 Definitions

2.2.1 KEY PROCESS VARIABLE

Aspects of the manufacturing process that may impact the capability to meet the specified requirements. These include chemical, physical, metallurgical, dimensional, or mechanical properties of the part.

2.2.2 SUBSTANTIATION

The process of assessing the ability of a given component to meet the requirements of a specific application and to satisfy all relevant requirements is variously called qualification, certification, substantiation, validation, and compliance within different documents used within different engineering organizations and involving different regulatory authorities. This AIR provides an overview of the scope of tasks and requirements associated with substantiating the integrity of AM components in this context.

2.2.3 QUALIFICATION

Is generally associated with the activities related to materials, process, machines, and operators that show each are capable of meeting the requirements in a reliable and consistent manner.

3. NARRATIVE

Engineering organizations define standards, specifications, drawings, and other documents that provide the framework and necessary details for development and production of additively manufactured hardware within the organization and among vendors and subcontractors supplying components to the organization. While the details within such standards are specific to the organization, process, and application, many of the fundamental requirements and considerations generally apply to AM hardware across organizations and processes.

This document has been developed to provide a brief, top level overview of the broadly applicable requirements, steps, and considerations to substantiate AM structural components. The discussion is organized by general recommendations, process control considerations, part design and production control considerations, and establishing material design values.

AM component quality should be assured from initial process development through operational performance throughout the service life.

3.1 Additive Manufacturing Process Control Documentation

Process control documentation (PCD), described in SAE AM specifications (e.g., AMS7000, AMS7002, and AMS7003) document fixed process requirements for feedstock production, AM processes, and post processing of AM parts. The PCD addresses all aspects of the manufacturing process necessary to produce parts that consistently meet design requirements, including the identification of key process variables. It is established by the producer, substantiated with respect to the specified requirements, and authorized by the Cognizant Engineering Organization (CEO). Once substantiated, all aspects of the PCD are considered to be a fixed process and any changes to the PCD shall require substantiation prior to the change being implemented into production. Changes to the PCD that can affect a key process variable must be authorized by the CEO.

3.2 Quality Management System

AM component reliability requires significant reliance on process controls. A Quality Management System (QMS) conforming to SAE AS9100, ISO 9001, or equivalent is required to ensure necessary process controls and mitigate risks associated with non-compliance.

3.2.1 Vendor Compliance

All vendor-provided products and services should comply with the implemented PCD and be insured through an applicable QMS because the quality of parts may be compromised at any stage of the process. The CEO must have configuration controlled procedures that defines how manufacturing and supplier control is established for initial process approval and maintained for subsequent changes such that parts produced continue to meet the approved design. If the CEO uses designees to act on their behalf, the designee must inform the CEO of all changes that can affect a key process variable.

3.3 Qualified Material Process

Parts should be produced to a qualified material process developed in accordance with controlled specifications to establish and maintain the fixed process. The process should be developed and defined with respect to material feedstock, process controls for the AM method chosen, and post-processing requirements. The specific process definition for an individual component is described in the PCD.

3.4 AM Specifications

- 3.4.1 Feedstock material specifications contain technical requirements and quality assurance provisions for feedstock material such that the AM process consistently produce parts with known and predictable material properties. AMS7001 is an example of a powder feedstock material specification and includes requirements for chemistry, powder size distribution, and feedstock manufacturing methods. AMS4954 is an example of a welding wire specification that may be used in additive manufacturing applications.
- 3.4.2 AMS7002 contains the process requirements to produce metal powder feedstock. This specification defines the PCD requirements, including the identification of key process variables, and the melting process environment.
- 3.4.3 AM process specifications contain technical and quality assurance requirements for the specific AM process to produce consistently sound parts. The AM process specification includes the required elements of a PCD, machine approval, and process approval. Process specifications are typically not specific to a material or part geometry. SAE AM process specifications, such as AMS7003 and AMS7005, contain an appendix identifying known key process variables.
- 3.4.4 AM part or preform specifications, such as AMS7000 and AMS7004, define the technical and quality assurance requirements for the final part or preform, as applicable. This includes requirements such as defining the feedstock and process specifications, chemistry, PCD, definition of post AM build processing requirements, and material properties (e.g., grain size, microstructure, anomaly limitations, and tensile properties).