

The Comprehensive Guide to AS9102 First Article Inspection: Requirements, Procedures, and Industry Best Practices

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In the high-stakes world of aerospace, defense, and space manufacturing, precision is not merely a goal but a regulatory imperative. The **AS9102 First Article Inspection (FAI)** standard serves as the cornerstone of quality assurance, ensuring that the manufacturing process is capable of producing parts that consistently meet design requirements. This article provides an exhaustive analysis of the AS9102 standard, detailing its evolution, the technical execution of its forms, and the critical role it plays in the broader **AS9100 Quality Management System (QMS)**.

Understanding the Theoretical Framework of AS9102

The AS9102 standard, maintained by **SAE International**, defines the requirements for performing and documenting a First Article Inspection. At its core, an FAI is a complete, independent, and documented physical and functional inspection process. Unlike routine inspections, the FAI is designed to verify that the production processes, documentation, and tooling are capable of producing parts and assemblies that meet every specification outlined in the engineering drawings and technical data.

The primary objective of AS9102 is to provide objective evidence that all engineering, design, and specification requirements are correctly understood, accounted for, verified, and documented. This process is mandatory when a new part is introduced or when significant changes occur in the manufacturing ecosystem. The standard focuses on the **process capability** rather than just the individual part, distinguishing it from standard quality control checks.

The Evolution from Rev B to Rev C

The transition from **AS9102 Rev B** to **AS9102 Rev C** introduced several critical updates aimed at streamlining the reporting process and clarifying the scope of the inspection. Rev C emphasizes the value of the FAI process as a risk management tool. Key updates include refined definitions for "First Article Inspection," improved clarity on when a Partial (Delta) FAI is required, and enhanced synchronization with the **AS9100 Rev D** quality management requirements. These changes ensure that the FAI remains a robust validation of the manufacturing chain, including the sub-tier supplier network.

The Three Essential Forms of AS9102

An AS9102 report (often referred to as a **FAIR - First Article Inspection Report**) consists of three mandatory forms. Each serves a distinct purpose in the verification hierarchy.

Form 1: Part Number Accountability

Form 1 is the summary sheet of the FAI. It identifies the part being inspected and the associated assemblies. It tracks the revision level, the drawing number, and the purchase order information. Crucially, Form 1 also lists all sub-assemblies or detailed parts that are part of the main assembly, ensuring a full bill-of-materials (BOM) reconciliation. This form serves as the "cover sheet" that requires final signatures from the inspector and, often, the customer representative.

Form 2: Product Accountability – Raw Material, Special Processes, and Functional Testing

Form 2 focuses on the "inputs" of the manufacturing process. It documents:
Raw Materials: Verification of material certifications (COAs) and compliance with specifications (e.g., AMS, ASTM).
Special Processes: Documentation of processes like heat treating, plating, or non-destructive testing (NDT), typically requiring **NADCAP** accreditation for aerospace suppliers.
Functional Testing: Evidence that the part meets performance criteria, such as pressure tests or electrical continuity checks.

Form 3: Characteristic Accountability, Verification, and Compatibility

Form 3 is the most technical and labor-intensive portion of the report. It requires the manufacturer to list every single "characteristic" of the part. A characteristic is defined as any dimension, tolerance, note, or attribute found on the engineering drawing. This process often involves **ballooning** (or bubbling) the drawing, where each characteristic is assigned a unique number that corresponds to a row on Form 3.

Technical Analysis: When to Conduct an FAI

One of the most frequent points of confusion in aerospace manufacturing is the timing of an FAI. Per AS9102 guidelines, a full FAI is required for a new part introduction. However, a **Partial (Delta) FAI** is often sufficient for subsequent changes. The following table outlines the triggers for both Full and Partial FAIs.

Trigger Event	Type of FAI Required	Technical Rationale
First production run of a new part	Full FAI	Validation of the entire manufacturing process and tooling.
Change in the design affecting fit, form, or function	Partial (Delta) FAI	Verification that the specific change does not negatively impact the assembly.
Change in manufacturing source(s), process(es), or location	Full/Partial FAI	Ensuring that environmental or systemic changes haven't introduced variables.
Change in tooling, CNC programs, or equipment	Partial (Delta) FAI	Verifying the integrity of the new hardware/software interface.
A natural or man-made event which may adversely affect the process	Full FAI	Risk mitigation after events like earthquakes or major facility fires.
A lapse in production for two years or more	Full FAI	Verification that tribal knowledge and process stability are still intact.

The Procedural Workflow: A Step-by-Step Field Guide

Executing a compliant AS9102 FAI requires a disciplined approach. Following these steps ensures technical accuracy and reduces the risk of rejection by the OEM (Original Equipment Manufacturer).

Step 1: Document Review and Preparation

Before any physical inspection begins, the quality engineer must gather the latest revision of the engineering drawing, the **Bill of Materials (BOM)**, and the **Manufacturing Router**. This ensures that the inspection is based on the "as-built" and "as-designed" configurations. Any discrepancies in revision levels at this stage will invalidate the entire FAI.

Step 2: Ballooning the Drawing

Using a transparent numbering system, the inspector must identify every dimension, geometric dimensioning and tolerancing (GD&T) symbol, and textual note on the drawing. This "ballooned drawing" serves as the roadmap for Form 3. Modern software like **InspectionXpert** or **Ideagen** can automate this process using OCR (Optical Character Recognition) to extract nominal values and tolerances.

Step 3: Metrology and Data Collection

The inspector measures the first article using calibrated equipment (CMM, calipers, micrometers, etc.). It is critical to record the **actual measured value**. Recording "OK" or "Pass" is not acceptable under AS9102. If a dimension is 1.500 +/- .005, and the measurement is 1.502, "1.502" must be recorded.

Step 4: Non-Conformance Disposition

If any characteristic is found to be out of tolerance, the FAI cannot be closed as "Complete." The manufacturer must document the non-conformance, determine the root cause, and implement corrective actions. A new FAI (usually a Delta FAI) must be performed on the corrected characteristic after the process has been adjusted.

Mathematical Principles in AS9102 Verification

In advanced aerospace applications, FAI data is often used to calculate **Process Capability Indices (Cp and Cpk)**. While AS9102 does not explicitly require a Cpk calculation for a single part, the data collected on Form 3 provides the baseline for statistical process control (SPC).

The formula for **Cpk** is:
$$Cpk = \min \left[\frac{USL - \bar{X}}{3\sigma}, \frac{\bar{X} - LSL}{3\sigma} \right]$$
 Where: **USL**: Upper Specification Limit
LSL: Lower Specification Limit
 $\bar{X}$: Process Mean
 σ : Standard Deviation

By analyzing FAI measurements against these statistical models, engineers can predict the likelihood of future non-conformances before the full production run commences.

Digital Transformation: Transitioning from Paper to Automated FAIRs

Traditionally, AS9102 reports were completed using Excel spreadsheets or paper forms. However, the complexity of modern aerospace parts—which may have hundreds or even thousands of characteristics—makes manual entry prone to error. Digital FAI solutions offer several advantages.

Comparison: Manual vs. Automated FAI Reporting

Feature	Manual (Excel/Paper)	Automated (Software)
Data Entry Speed	Slow; prone to transcription errors.	Rapid; OCR extracts data directly from PDFs.
Revision Control	Difficult to track changes across versions.	Centralized database with automated versioning.
Ballooning	Manual drawing with pens or basic PDF tools.	Automated ballooning linked to Form 3 rows.
Traceability	Requires physical filing and manual searching.	Instant digital retrieval and searchability.
Compliance Risk	High risk of missing notes or tolerances.	Validation rules prevent submission of incomplete forms.

Case Study: Atlantic Inertial and the Implementation of AS9102

Consider the case of a high-precision component manufacturer like **Atlantic Inertial**. When producing inertial sensors for aerospace navigation, the tolerances are often in the microns. An FAI at this level involves not just dimensional checks but also complex functional testing of the sensor's output under thermal stress.

In this scenario, a failure on Form 2 regarding a special process (e.g., an incorrect anodizing thickness) would necessitate a complete stop. The manufacturer must not only fix the part but also audit the sub-tier supplier who performed the anodizing. This illustrates that AS9102 is not just a checklist; it is a diagnostic tool for the entire supply chain.

Troubleshooting Common FAI Challenges

Even experienced quality departments encounter hurdles during the FAI process. Understanding these challenges is key to maintaining a smooth production timeline.

Incomplete Material Certifications: Often, suppliers provide COAs that lack specific heat lot numbers or fail to reference the correct specification revision. **Solution:** Implement a robust incoming inspection process to verify sub-tier paperwork before the FAI begins.

Ambiguous Engineering Notes: General notes on drawings (e.g., "Remove all burrs") are often overlooked. **Solution:** Every note must be ballooned and accounted for on Form 3 with a "Visual Inspection" or "Process Verification" result.

Signature Authority: Reports are frequently rejected because the individual signing Form 1 does not have the delegated quality authority from the customer. **Solution:** Maintain an updated matrix of authorized signatories.

Strategic Implications for Quality Management

The AS9102 First Article Inspection is much more than a regulatory hurdle; it is a foundational element of a mature **Quality Management System**. By meticulously verifying the first article, companies protect themselves from the catastrophic costs of scrap, rework, and product recalls. In the aerospace industry, where the cost of failure can be measured in human lives, the rigor of AS9102 provides the necessary assurance that design intent is translated into physical reality with 100% fidelity.

As manufacturing moves toward **Industry 4.0**, we can expect AS9102 to integrate more deeply with **Model-Based Definition (MBD)**. In an MBD environment, the 3D CAD model serves as the "master" for all inspection data,

potentially allowing for fully automated FAI processes where CMM data is compared directly against the digital twin of the part. Regardless of the technology used, the core principles of AS9102—accountability, verification, and documentation—will remain the standard by which aerospace excellence is measured.

Tags: #AS9102 #First Article Inspection #Aerospace Quality #FAIR #SAE International #Quality Engineering

