



RAIN Manufacturing Quality Program

Pilot Report - First Round

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Executive Summary

This pilot program is the first building block in a longer-term effort to give the RAIN Manufacturing Quality Grade the depth of evidence, reproducibility, and industry-wide corroboration needed to support formal standards submission. Reaching that point, however, requires more backup data, broader participation, and independent corroboration than a single round pilot can provide.

This report consolidates the outcomes of the **first round** of a pilot research series and demonstrates the results of four independent RAIN Manufacturing Quality studies, each conducted by a different participating organization to validate the applicability, testability, and grading consistency of the previously published RAIN Alliance Manufacturing Quality criteria (RAIN-Manufacturing-Quality-Certification-Guideline-05052025). Together, the pilots covered a few examples of real-world RAIN RFID tag/inlay constructions and end-use applications — spanning general-purpose inlays, apparel/textile labels, and healthcare-related liquid-container labels.

In line with confidentiality commitments to the participants, this report identifies who took part in the pilot program but does not tie any specific test result, grade, or tag/product characteristic back to an individual participant. All findings below are presented in aggregate.

Across the pilot studies, tested tags consistently met or exceeded RAIN Alliance grades for Data Retention, Temperature Cycling, Temperature & Humidity, and Shear Force. The recurring gaps identified across the pilots were: (1) ambiguity in minimum sample-size requirements between development and production stages, (2) imprecise practices to define how to tie inline and offline testing together to guarantee stable produced far field performance (P-series), and (3) inconsistent interpretation of the Bend Durability (M-series), and Documentation (D-series) criteria. These are addressed in detail in sections below. This pilot also introduced a new type of supporting evidence: one participant conducted a statistically grounded, long-term manufacturing consistency analysis, comparing pilot-lot results against historical production data using one-way ANOVA (Analysis of Variance). This offers a promising model for strengthening the cross-lot reproducibility evidence needed to support future ISO recognition.

To advance this initiative toward a robust, industry-endorsed standard, the project will progress through stakeholder engagement, guideline refinement, expanded industry validation, and standards development activities. Key next steps include publishing anonymized pilot results for industry feedback, updating and strengthening the previously published RAIN Alliance Guideline, conducting a broader second-phase pilot with diverse industry participants, and consolidating findings into a final guideline. Independent laboratory validation and early engagement with ISO/IEC will further support credibility, repeatability, and eventual standardization of the methodology.

Pilot Participants

Four organizations voluntarily participated in the initial round of the RAIN Manufacturing Quality Pilot, contributing valuable data and feedback to evaluate the proposed methodology and guideline framework.

Participants are from the following organizations:

- BoingTech
- SML Group Limited
- SAG - Securitag Assembly Group Co., LTD.
- Xiamen Xindeco IoT Technology Ltd

Inlay Constructions and Applications Represented

To protect the confidentiality of each participant's proprietary product details, this pilot describes the range of tag constructions and use cases represented across the pilot program in aggregate, without linking any specific construction or application to an individual participant.

- Four general-purpose RAIN inlays used to validate the manufacturing-stage quality grading methodology itself.
- RAIN chips used across the pilot were sourced from two established RAIN RFID chip manufacturers, with rated data retention of approximately 20 years and operating frequency in the standard UHF bands. Specifically, the chips that were used in this round were not the latest generation. They were typical die sizes but not the smallest.
- Tested inlays were claimed to have potential applications in the following sectors:
 - Internal manufacturing process qualification (generic inlay).
 - Apparel and retail supply-chain tagging (textile-integrated label).
 - Healthcare and pharmaceutical traceability (liquid-container label)
- A long-established, high-volume production inlay was also evaluated, selected specifically for its long production history to test whether pilot-stage results remain representative of routine mass-production output over time.

Testing Basis

- Sample sizes across the program ranged from approximately 22 to 224 pieces per test category, depending on each participant's production tooling, batch size, and whether testing was performed at the development or production stage.
- One participant proposed a statistically grounded minimum sample-size threshold ($N \geq 30$, assuming an approximately normal data distribution) for random sampling,

scaled further according to production tooling capacity (e.g., number of thermode heads) offering a candidate basis for standardizing sample sizes across the program.

- All participants tested tags against the same core categories:
 - Data retention
 - Quality of Documentation
 - RF performance variation,
 - Bend durability,
 - Shear force,
 - Temperature cycling,
 - Temperature & humidity

One participant also validated an additional custom process specific to its application.

Pilot Results

Summary of the Reported RAIN Alliance Grades

The seven core RAIN Manufacturing Quality criteria previously published by RAIN Alliance ([RAIN-Manufacturing-Quality-Certification-Guideline-05052025.pdf](#) found at [Manufacturing Quality Workgroup](#)) were used to map each pilot's tested performance. Those include Data Retention, Documentation, RF Performance Variation, Bend Durability, Shear Force, Temperature Cycling, and Temperature & Humidity, plus any custom/special-process criteria. The goal of this pilot study was not to achieve a specific RAIN Alliance grade, but rather to evaluate the product performance against the RAIN Alliance criteria suggested previously by RAIN Alliance and assess its alignment, adaptability, and level of conformance. Results are pooled across all pilots without attribution to a specific participant or product, consistent with the confidentiality approach to this report.

RAIN Alliance Quality Requirement	RAIN Alliance Grades That Were Reported	Aggregate Outcome Across Pilots
Data Retention	R1 (≥15 yrs or error detection)	All tested tags and their corresponding chip datasheets across the pilot consistently indicated ~20-year data retention, comfortably exceeding the 15-year data retention and the ICs in question also had bit error detection both alone meriting a R1 grade.
Quality of Documentation	D1	Most pilots claimed to pass a D1 level by making full test data available upon request (e.g., under NDA). One pilot's documentation practice fell short of full

		D1 disclosure, raising a question of whether "available upon request" should qualify.
RF Performance Variation	P1 (± 2 dB)	Most pilots demonstrated performance within or better than the ± 2 dB, thus claiming P1. However, some pilot members performed inline tests, and some performed only offline tests. This ambiguity in the interpretation of the guideline requires clarity.
Bend Durability	M1 / M2	Least consistent criterion across the pilot. Bend test protocols varied widely in cycle count, applied force, and use of a compression roller — resulting in a mix of full M1 and M2 conformance. This is another source of grading inconsistency identified by this pilot and requires more standardization processes across the industry.
Shear Force	S1 / S2	All tested tags resulted in shear force generally well above the applicable RAIN threshold and claimed S1 and S2. In some cases, the threshold was passed by 2–8x, depending on chip type and internal acceptance criteria.
Temperature Cycling	TC1 / TCX	Cycling ranges used across the program varied slightly (e.g., $-40^{\circ}\text{C} \dots 85^{\circ}\text{C}$ vs. $-25^{\circ}\text{C} \dots 70^{\circ}\text{C}$), but most results stayed within the required $\pm$ dB variation tolerance and claimed TC1 grade. One of the reported results for TCX was based on an industry requirement of -25°C to 70°C for 50 thermal cycles, which was used as the benchmark for the evaluation.
Temperature & Humidity	TH1	All tested tags resulted within the tolerance of TH1 grade under the standard 85°C / 85% RH / 168-hour condition.
Special / Custom Process	Case-specific	One pilot included an additional test (textile-washing durability test) and claimed OWX grade. This was relevant to its specific end-use application, beyond the seven core RAIN Alliance criteria.

Key takeaway: Data Retention, Shear Force, Temperature Cycling, and Temperature & Humidity were reliably met across the program. Bend Durability was the most inconsistent criterion, followed by Documentation and RF Performance Variation, where differing internal test methodologies did not map cleanly onto the official RAIN Alliance grade bands. One pilot went beyond the seven core criteria by statistically comparing its pilot-lot results against multiple historical production lots (one-way ANOVA, 95% confidence) for RF performance and shear force. No statistically significant difference was found ($p > 0.05$ in both cases), indicating that pilot-stage results were representative of routine mass production for the evaluated product. This is a valuable methodological addition supporting the broader goal of building reproducible, statistically defensible evidence toward ISO recognition.

Pilot Recommendations

The pilots independently converged on the same core issues, reinforcing the need for the RAIN Alliance Manufacturing Quality Workgroup to clarify and standardize the following areas. These recommendations are presented collectively on behalf of the participating group.

Scope of the Manufacturing Quality Grade

- Clarify whether the grade should be certified at the inlay-model level or at the finished-product/SKU level.
- Define at which stage verification must be repeated — every production batch, or only once during the development/qualification stage.

Sample Size Standardization

- Define an exact minimum sample size per test item, rather than a range — proposals across the program ranged from ~22 pieces/batch for production to 50–120+ pieces/batch during development.
- Clearly distinguish sample-size requirements for the Development stage versus ongoing Production/Batch Quality Checks, so the same standard is not applied inconsistently across contexts.
- Consider adopting a statistically grounded minimum threshold of $N \geq 30$ samples (assuming an approximately normal data distribution), as proposed by one participant, scaled further by production tooling capacity — offering a candidate basis for resolving the sample-size range above.

Harmonize the Bend Durability (M-Series) Protocol

- Bend test protocols varied materially across the program in cycle count, applied force, and use of a compression roller, producing inconsistent grading outcomes. This is the single largest source of grading inconsistency and should be prioritized for standardization.
- Clarify the distinction between M1 (with compression), M2, and M3 (no compression) so that participants can self-assess and report an accurate, comparable grade.
- One pilot's bend protocol (9,000 cycles across nine rollers under 0.4 MPa, evaluated against a 98% pass-rate threshold) represents yet another variant, reinforcing the priority of this recommendation.

Specify the RF Performance (P-Series)

- Align RF Performance Variation Methodologies.
- Remind how inline testing and sample testing are both required and explain good practices how to tie both together to guarantee stable produced far field performance.

Clarify Documentation (D-Series) Requirements

- Define whether full test data must be published in the public datasheet to qualify for D1, or whether provision "upon request" (e.g., under NDA) is sufficient to meet the requirement.

Adopt Statistical Validation of Long-Term Manufacturing Consistency

- One pilot demonstrated, via one-way ANOVA comparison (95% confidence) against historical production lots, that pilot-stage RF performance and shear force results were not statistically different from routine mass production. Future pilots should be encouraged to adopt a similar statistical comparison where historical production data is available, to directly support the reproducibility evidence needed for ISO submission.

Expand Use-Case Coverage

- Continuing to encourage pilots across new verticals — the program's healthcare/pharmaceutical liquid-container use case demonstrated strong initial applicability and is an area of active strategic interest; additional pilots in this space would further validate the framework.

Next Steps & Call to Action

To keep this initiative moving toward a defensible, industry-endorsed standard, we are proposing the following specific commitments:

- Distribute the anonymized Round 1 pilot results to all RAIN Alliance members and formally solicit feedback and recommendations.
- Incorporate pilot findings and stakeholder feedback to refine and strengthen the RAIN Alliance Guideline.
- Publish the revised version of the RAIN Alliance Guideline for broader industry review and adoption.
- Launch a second pilot phase, recruiting at least four additional participating organizations representing a wider spectrum of tag constructions, IC suppliers, and industry applications, including apparel, healthcare, logistics, and industrial sectors.
- Consolidate and analyze all pilot data to support the development of the final RAIN Alliance Guideline.
- Collaborate with independent reference laboratory partners to conduct interlaboratory comparisons and independent third-party validation testing, ensuring the robustness and repeatability of the methodology.

- Initiate early engagement with ISO/IEC leadership to align on the most appropriate standardization pathway, whether through a companion Technical Specification (TS), Publicly Available Specification (PAS), or other suitable standards vehicle, prior to formal submission preparation.

Background and Contributors

Since its founding in 2014 the goal of the RAIN Alliance has been to accelerate global market adoption of RAIN RFID technology. From humble beginnings, the market has now grown to the extent that over 50 billion RAIN tag chips were shipped in 2024 and it's projected that over 100 billion RAIN tag chips will be shipped in 2028. RAIN technology is relied upon to provide massive business benefits in a wide variety of industry sectors including Retail, Luxury goods, Healthcare, Pharmaceuticals, Logistics, Automotive, Aviation and Manufacturing.

It's crucial for end user confidence in the technology that quality standards remain reliably high. The industry needs quality standards which are open, common and consistent around the world coupled with certification capabilities with adequate capacity and throughput speed to meet global demand as the industry continues to scale.

To facilitate this, the RAIN Alliance established a Manufacturing Quality Workgroup in August 2024 to develop the necessary global, openly available, transparent specifications and processes against which certification can be performed. We expect this document to underpin ongoing end-user confidence in technology and ensure technological companies all around the globe can prove their manufacturing quality in a consistent and transparent manner. This document is developed within the RAIN Alliance Manufacturing Quality Workgroup.

This document is developed within the RAIN Alliance Manufacturing Quality Workgroup. All Workgroup members listed in the table contributed to the shaping, editing, and review of this document.

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About the RAIN Alliance

The [RAIN Alliance](#) unites 200+ global organizations to drive universal adoption of RAIN technology. Serving as the collective voice of the industry, the Alliance influences policy and drives regulatory progress to realize a world where every item connects to the Internet of Things using RAIN technology.

RAIN (also known as UHF RFID) is a standards-based wireless technology built on the ISO/IEC 18000-63 protocol that enables businesses and consumers to identify, locate and authenticate billions of items connected to the Internet of Things, helping organizations improve traceability, effectiveness, and sustainability.

For more information, please visit therainalliance.org