RFID 401: Tag quality and reliability

When a radio frequency identification (RFID) system works well, it can increase the productivity of librarians and let them focus on the value-added tasks they were trained to do. RFID systems can also increase customer service and satisfaction. And they can help libraries control their costs.

However, RFID systems don't always work well. Like other complex electronic systems, RFID systems can suffer from breakdowns (and slowdowns) that result from equipment defects, corrupted software, environmental damage and normal wear and tear. However, and somewhat surprisingly, many RFID system problems are caused by one of the least expensive components: the tag.

Within a few years—or even a matter of months—the read range of some library tags will begin to shorten and the tag may fail. Naturally, such poor performance causes concern and bewilderment among the affected librarians. The purchases were usually very well researched (these are librarians, after all) and the vendors were typically reputable. In addition, the tags were often certified as being compliant with the requirements established by the International Standards Organisation (ISO).

The hard lesson learned by these librarians is that RFID tags can vary considerably. They are based on different designs, for different purposes and different lifespans. They use different materials and are fabricated using different methods. Consequently, some last longer and perform better than others.

RFID Tag Life

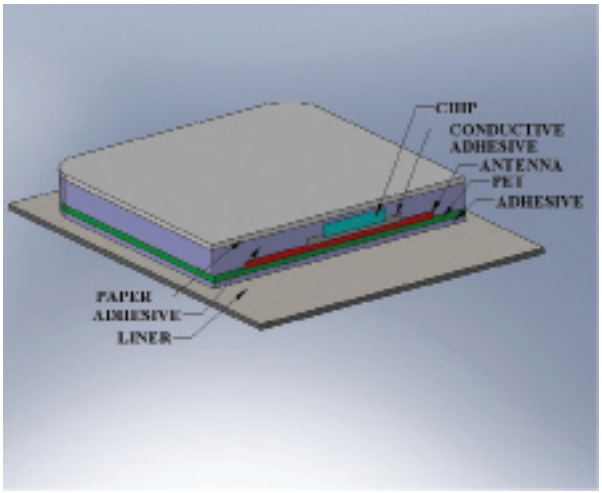
RFID tags are used in many applications, including ticketing for amusement parks and ski resorts, validating casino chips, validating money and tracking products through the supply chain. Depending on the application, the purchaser will have different expectations for tag cost, read range and durability.

One of the more demanding applications is in a library, where the tags should remain fully functional for 15 years or more. These library tags must survive far longer than the tags used in retail clothing stores, for example, and this added reliability could make them more costly to manufacture.

Unfortunately, some tag suppliers do not recognise or acknowledge the longer life requirements for tags that are attached to library items. These suppliers might recommend less durable and less expensive tags, similar to those used in inventory or retail operations. In certain cases, the issue has been confused by marketing literature that identifies the less durable tags as being compliant with an ISO standard for the library market. These assertions are generally accurate, but may be misleading. This ISO standard, which defines the way the tag communicates with the library reader, is important but does not imply or specify quality or reliability expectations.

Tag Construction

Tag reliability is based on the tag's design, materials and construction methods.



As shown in the cross-section above, a common RFID tag is a lamination of multiple categories of materials that can interact with each other. (Note that the layers are not drawn to scale.)

Under the protective top layer (usually made of paper or polypropylene) is a layer of adhesive. Adhesives can be hot melt or pressure sensitive and are either water or solvent based. The chip—also called an integrated circuit or IC—is attached to the antenna (which is typically aluminum or copper) using a conductive adhesive. Conductive adhesives

can be an epoxy, a paste or a tape. The antenna is attached to a substrate of plastic (usually PET, which is a form of polyester). Next is another layer of adhesive and finally the liner, which is typically a silicone-coated paper.

The choice of materials in these components can have a large impact on long-term reliability. Over time, for example, some adhesives can introduce or accelerate corrosion in the bond between the chip and the antenna.

For each application, tag designers choose materials that provide the best configuration of cost, performance and durability. Among other factors, they will consider the interactions between the tag materials.

The manufacturing process can also affect tag cost, performance and durability. Curing, lamination and the precise registration of RFID components are advanced processes that require sophisticated management and close monitoring. Slight variations in curing time or assembly speed, for example, can have significant impacts on consistency and longevity.

Common Failure Modes

Consideration of product failure modes is necessary in any discussion of tag reliability, tag durability and the differences among tags.

RFID tags fail in several ways. For example:

- High electrical resistance can develop between the chip and the antenna. Possible causes include corrosion or oxidation in the bond between the chip and conductive adhesive or the antenna and conductive adhesive.
- Integrated circuits can crack.
- The attachment between the chip and the antenna can fail.
- The antenna can fail on its own, due to metal fatigue.

Environmental exposure can also have deleterious effects on tags, producing corrosion, cracking or other damage.

One of the chief reasons for failure is mechanical stress: library items (and the tags attached to them) are often bent, twisted, impacted, subjected to pressure, and so on. To withstand such treatment, a library RFID tag must be constructed with high standards for durability.

System Impact

RFID tag failure can be gradual, resulting in a modest or a severe reduction in the read-range. It can also be catastrophic: with no warning, the tag can become suddenly unresponsive.

Tags are at the heart of every RFID system. They interact with all the other devices in the system, so when the tag fails, the system is seriously compromised or rendered useless.

If the read-range of the tag drops off, security detection system performance can be compromised because some tags will no longer be read by the detection system. Handheld readers won't pick up every item. Errors can occur during the reading of multiple items. Performance with CDs and DVDs will be especially impacted.

Testing for Durability

To estimate their RFID tags' durability, manufacturers must conduct sophisticated accelerated aging tests. These tests, which are routinely used in the electronics industry, can reliably predict long-term degradation and response to environmental stresses.

In typical accelerated aging tests, RFID tags are subjected to various configurations of heat and humidity over long periods, after which they are analysed. These experiments are closely monitored and can be reproduced with precision, so that the performance of one sample can be compared to another.

At 3M, for example, 10 to 60 sample tags are placed in three chambers for 15 weeks. (Sample size varies depending on the purpose of the test. Some tests are regular quality control assessments; others are designed to evaluate how different materials or components affect tag performance.) Each chamber has a different set of conditions, from high temperature and high relative humidity to high temperature and low humidity:

- Chamber 1: 65° Celsius (149 Fahrenheit) / 95% relative humidity
- Chamber 2: 49° Celsius (120 Fahrenheit) / < 5% relative humidity
- Chamber 3: 32° Celsius (90 Fahrenheit) / 90% relative humidity

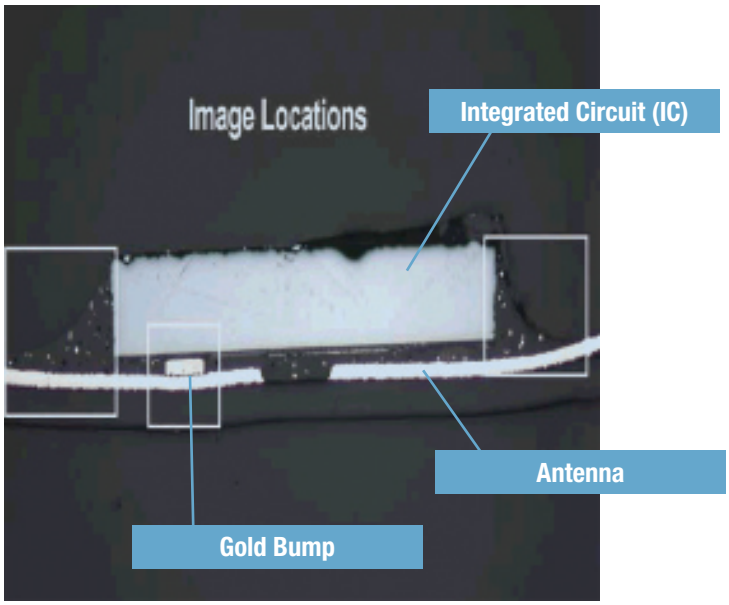
During the test, read-ranges are measured on a weekly basis; at the conclusion of the test, tags are analysed for changes in relative read-range and trends in read-range over time. The resulting data can be used to predict the tags' longevity and reliability in actual use.

Companies that have been active in the RFID industry for many years can compare these estimates against real-world experience. This process has led to some refinements in the accelerated aging tests; it has also confirmed that the tests provide accurate estimates of long-term reliability.

At 3M, accelerated aging predictions can be compared to field data from more than eight years of experience with installed library RFID tags. This analysis indicates that the company's RFID tags will last significantly longer than eight years in a library setting. (As a result, the company provides a warranty on its tags, guaranteeing them to last as long as the items to which they are attached.)

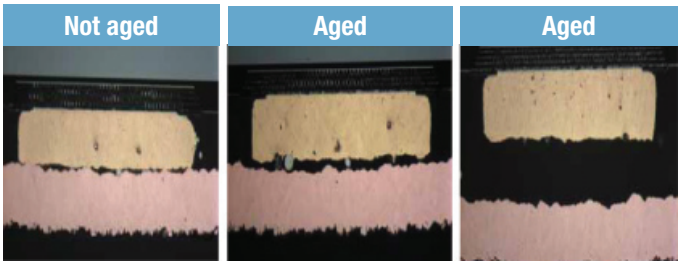
What Accelerating Aging Tests Reveal

Accelerated aging tests can reveal some of the common reasons for RFID tag failure.



This microscopy photo shows an RFID tag that has not been subjected to accelerated aging. It has been sliced to demonstrate the connection between the IC, the conductive adhesive, the antenna and the gold bump, which is the contact point between the antenna and the IC. Note that conductive adhesive covers the entire base of the IC. The gold bump is about 80 microns wide, approximately the same width as a human hair.

The following microscopy photos show details from three tags from the same manufacturer; the two on the right have been through an accelerated aging process.

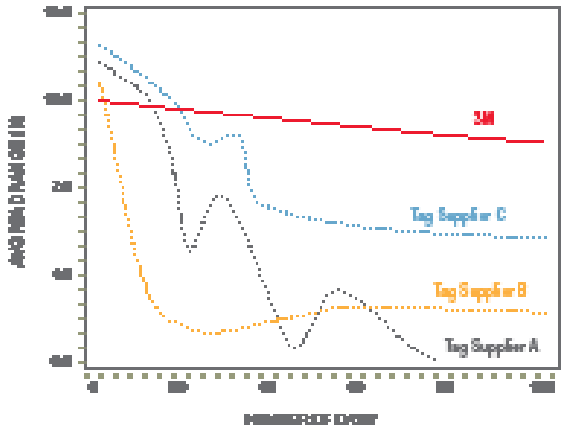


Note the size of the gap between the gold bump and the larger antenna.

There is a modest gap on the middle sample, which shows that it is beginning to degrade. (Small gray dots of conductive adhesive are bridging the gap between the bump and the antenna; this is a reminder of the value of the conductive adhesive.)

The aged sample on the far right has a much larger gap; not surprisingly, it also exhibited a reduced read-range when compared to the sample that had not been subjected to the accelerated aging process. This larger gap would introduce more resistance in the circuit and thus change the antenna tuning. It also affects the amount of power that is available to the chip.

The statistical results generated by accelerated aging tests are also revealing. This chart compares test data for 10-tag samples from four library RFID tag suppliers, including 3M. Note that all tags are ISO compliant. This data was collected by placing the tags for 15 weeks in a controlled chamber with 95 percent relative humidity and a temperature of 65º Celsius (149º Fahrenheit); read-ranges were monitored periodically over the length of the test.



These results show the average read-ranges from the suppliers' samples. The averages for suppliers A, B, and C dropped significantly over the 105-day test period, with supplier A's tags failing catastrophically and supplier B's tags dipping below 2 inches. Also note that the tags from supplier A exhibited a large degree of inconsistency. Test data available upon request.

What to ask a tag supplier

To a large degree, tag performance can determine the overall performance of a library RFID system. Tags can also be a significant investment. For both reasons, librarians should thoroughly research tag durability and reliability before investing in an RFID system. As part of that research, librarians should aggressively question tag suppliers.

Specifically, they should consider asking the following questions:

- Have you tested your tags for long-term durability?
- What test methods do you use?
- Is the test longer than a week?
- Can I see the data?

RFID is a very reliable and durable technology. RFID tags can be designed to function in extremely hostile environments, including aircraft engines and copper smelting operations. Tags for library RFID systems do not require such a high degree of durability, but they do need to be designed and built to meet the demands of the library environment.

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