BRADY RFID INTEGRATED LABELS FOR FLYABLE ASSET MANAGEMENT

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New Heights for a Proven Solution

Since 2009, the aviation industry has successfully pioneered the use of radio frequency identification (RFID) tags on replaceable airplane parts, such as life jackets and seats in the main cabin. This has resulted in considerable benefits in value chain automation, component tracking and aircraft inspection time.

The industry is now looking to expand the RFID program to more demanding parts and surfaces both inside and outside of an aircraft's main cabin, where identification labels face much harsher conditions. Brady's solution for this ambitious RFID program expansion is a durable, state-of-the-art identification solution.

Soon, RFID integrated labeling solutions will replace current barcode-only nameplates and paper-based part tracking, leading to opportunities for lean improvements and cost savings for all stakeholders in the aircraft assembly value chain. In the long-term, RFID labeling solutions can offer supply-chain security, visibility, quality and authenticity for manufacturers, as well as simplified repair, management and operations configuration for airlines. Brady's innovative RFID solution for all flyable parts supports this long-term vision, offering a unique combination of materials for harsh environments, a global manufacturing footprint, and an unrivalled customer experience and technical support.

Long-term, RFID labeling solutions can offer supply-chain security, visibility, quality and authenticity for manufacturers, as well as simplified repair, management and operations configuration for airlines.

B-1000 RFID Integrated Label Highlights

Brady's B-1000 RFID integrated labels function well on a wide variety of surfaces, including metal, and withstand both the controlled environments of the main cabin and exterior locations with challenging fluctuations in temperatures, pressures and humidity. Brady's RFID labels integrate rugged, high-memory chip technology into high-performance, durable label materials that can withstand the extreme environments experienced during flight. The parts fully comply with ATA Spec 2000 data standards and go well beyond the basic requirements listed for passive UHF tags in the SAE AS5678 standard for flyable parts. In developing the labels, Brady focused on creating a solution that endures extreme testing for accelerated aging, chemical exposures, altitude and the environmental shock required for aircraft part marking and electronic equipment.

Brady's B-1000 RFID integrated labels are designed to last the lifetime of the aircraft. This allows airplane parts and their histories to be tracked throughout their lifecycle, resulting in significantly reduced manual routines and paper administration. Maintenance workers and airline personnel can use a handheld reader to gather information about asset and component age, repair history and maintenance schedules – No need to manually check hundreds of individually labeled components for each aircraft before takeoff and landing. This leads to considerable maintenance efficiency gains that could easily influence future aircraft purchasing decisions. Likewise, life-cycle RFID labels allow for complete, automated value chain visibility and real-time receipt confirmation, enabling optimized cost control for all value chain stakeholders.

Design

Designing a part marking solution that integrates RFID functionality for the cradle-to-grave tracking of flyable parts is no easy feat. Brady's engineering team designed the SAE AS5678 Compliant B-1000 series labels around four critical design features.

- **Surface Independence:** The solution must work equally well on and off metal for both RF performance and durability.
- **Light Weight and Conformable:** The solution must be flexible and light weight.
- **Marking Permanence:** The print-durability must survive exposure to contaminants and abrasion both inside and outside of the aircraft.
- **Data Permanence:** The data must be incorruptible.

Brady's B-1000 RFID Integrated Labels are light weight, flexible, robust, permanent, and work on any surface.

Surface Independence

Brady has gone through great lengths to develop one RFID label capable of identifying all aircraft parts. One of the most difficult challenges facing RFID technology in an aircraft is RF readability when mounted onto metal surfaces. This is because the electronic properties of metal reflect back incident radio waves creating destructive interference that reduces the effective RF readability to zero. Traditional RFID tags become effective only at one quarter wavelength from the surface. This implies that the active layer of the RFID device would require a spacer of 4-8 cm in order to function for UHF bands. To overcome this limitation to traditional ultra-high frequency RFID labels, without sacrificing the desirable size, thickness, and weight parameters, the RFID labels were engineered based on an inductive loop design with a meander slot. This design allows for RF waves to be picked up in a fully-closed conductive loop, regardless of the surface on which the part is mounted. This surface independence is illustrated for a variety of surfaces found in the Aerospace Industry in Figure 1: Surface Independent RFID Technology.

The second challenge facing one, multi-surface and self-adhesive RFID label solution was finding the right kind of pressure-sensitive adhesive. The adhesive had to firmly attach to both high-energy surfaces found on common aircraft metals (titanium, steel and aluminum) and low-energy surfaces found on fiber reinforced composites (polyether ether ketone (PEEK) composites and polystyrene sulfonate (PSS) composites). At the same time, the adhesive must also be extremely resistant to chemicals and thermally stable over very long time scales.

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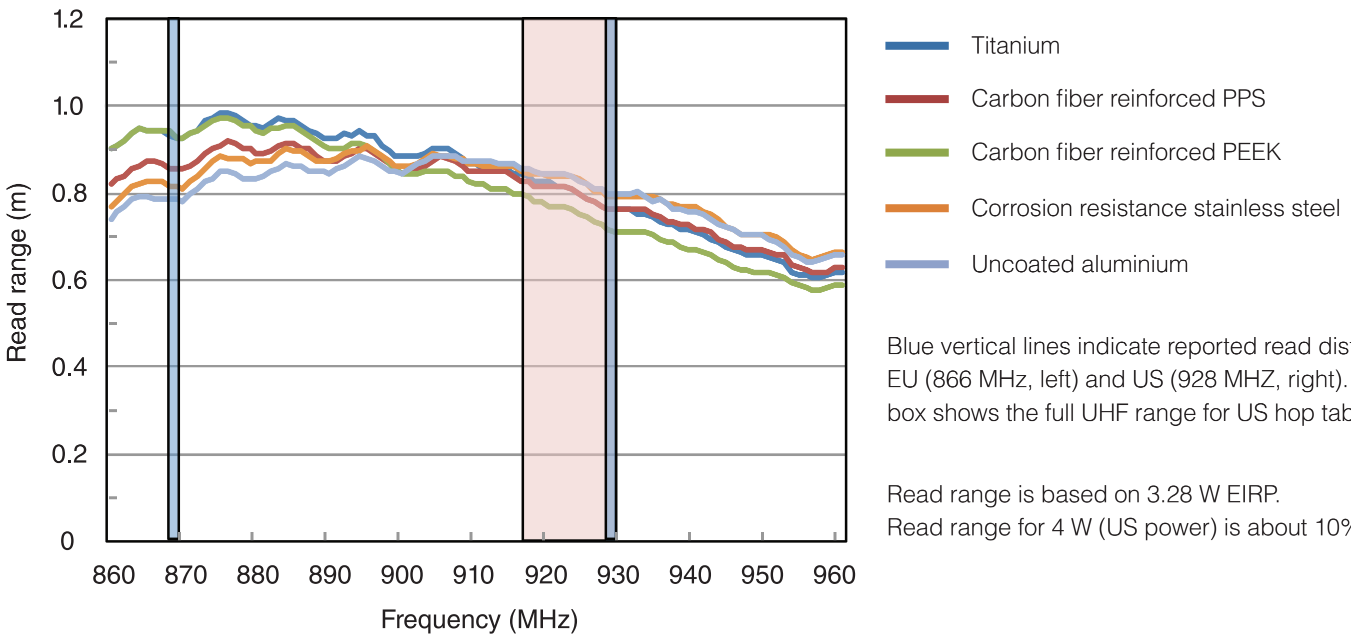
The solution lies in Brady's experience designing fluid-line tape that adheres directly to aluminum pipes and can withstand days of immersion in Skydrol LD-4, a fire-resistant hydraulic fluid based on phosphate esters known to chemically attack and solubilize many polymer materials. The Brady adhesive used on the B-1000 series labels is a similar, acrylic-rubber hybrid that balances adhesion for performance on both high and low surface energy substrates (see Figure 2: Peel Adhesion), maintains adhesion above 200 °C and offers superior protection against harsh fluids used in aircraft operation and maintenance.

B-1000 Read Range on Aircraft Surfaces



Blue vertical lines indicate reported read distance for EU (866 MHz, left) and US (928 MHZ, right). The red box shows the full UHF range for US hop tables.

Read range is based on 3.28 W EIRP.
Read range for 4 W (US power) is about 10% farther.

Figure 1: *Surface Independent RFID Technology*

Light Weight and Conformable

Brady's RFID integrated labels are designed with weight and flexibility in mind. It takes roughly one gallon of fuel to move 100 lbs/45kg on an average short distance flight. That may not sound like a lot for labels that weigh less than 5 g, but when you consider over 10,000 flight cycles, fuel costs quickly add up. A 5 g part label, for example, will consume roughly 1.1 gallons of jet fuel over its lifetime. At today's fuel prices, that would cost airlines anywhere from $4-8 USD per RFID label. By using light-weight, aerospace durable foams, even our largest B-1000 series RFID labels weigh less than 2 g, saving airlines $2-5 USD on fuel costs per label over their lifetime . Additionally, the flexible foam interior adds another benefit for labeling complicated parts: flexibility. Brady B-1000 labels are flexible enough to bend around a 30 mm diameter pipe without loss of function or durability, allowing more parts to be identified with human-readable, machine-readable and digital information.

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Peel Adhesion

Chemical	Classification	Result
Grease brush	Machine fluid	Pass
FE36Spray	Fire extinguishant	Pass
H2O immersion	Cleaning solvent	Pass
IPA brush	Cleaning solvent	Pass
Kerosene brush	Jet fuel	Pass
MEK brush	Cleaning solvent	Pass
Oil brush	Machine fluid	Pass
PG dunk	Antifreeze	Pass
RF11 brush	De-icing fluid	Pass
Skydrol brush	Machine fluid	Pass
Skydrol dunk	Machine fluid	Pass

Figure 2: *Peel adhesion*

Print Durability

Chemical	Classification	Result
Grease brush	Machine fluid	No effect
FE36Spray	Fire extinguishant	No effect
H2O immersion	Cleaning solvent	No effect
IPA brush	Cleaning solvent	No effect
Kerosene brush	Jet fuel	No effect
MEK brush	Cleaning solvent	No effect
Oil brush	Machine fluid	No effect
PG dunk	Antifreeze	No effect
RF11 brush	De-icing fluid	No effect
Skydrol brush	Machine fluid	No effect
Skydrol dunk	Machine fluid	No effect

Figure 3: *Print Durability*

Marking Permanence

While several industries are moving to fully RF based identification, there is still a strong need to manually locate parts with human-readable information. Traditional part labels often contain information on the manufacturer, part number and unique serial number for each part in printed text as either 1D or 2D barcodes. Even with the new ability to track this information wirelessly with RFID scanners, technicians and operators will still be required to visibly locate and identify unique parts to perform inspections and maintenance in certain contexts. Today, this information is typically laser etched or engraved with specialized printers to maintain durability when faced with a variety of chemicals, shock and environmental conditions.

The Brady B-1000 series RFID labels leverage high-performance thermal heat transfer (THT) ribbons that allow printed information to withstand these harsh environments. Brady's top-coat and ink ribbon chemistry optimized in the print-on-demand process, ensures that the printed information does not fade, scratch or bleed upon exposure to cleaning solvents or harsh chemicals widely used in aircraft maintenance and operations (see Figure 3: Print Durability). Brady's advanced printing technology eliminates the need to further protect the printed information with over-laminates, sprays or varnishes that complicate assembly processes and lead to further compatibility, weight and flammability concerns. In addition to the robustness of the printed information on each one of the Brady RFID integrated labels, the reliability of printed information guarantees compatibility with current MRO activities until such time that the airlines can fully exploit the advantages of wireless asset management.

Data Permanence

Typical RFID tags, as used by retailers, are intended to last only for a couple of years. To create an RFID label that lasts for 30 years, Brady scientists engineered a rugged label material, physically protecting the integrated RFID chip against all the hardships of flight. To also ensure the incorruptible data lasts for the lifetime of the part, Brady has integrated one-time-programmable memory into the RFID integrated circuit, based on resistive, programmable read-only memory (PROM). The fuses that make up the backbone of this memory technology can be read even after exposure to temperatures in excess of 500 °C and after exposure to radiation in excess of 200 kGy. PROM counters the limitations of commonly used electrically-erasable programmable

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read-only memory (EEPROM) based chips. The EEPROM floating gates used to store the ones and zeros that make up the memory map are susceptible to data corruption through exposure to elevated temperatures and elevated doses of gamma and cosmic radiation experienced during flight.

The incorruptible information carried on Brady's B-1000 series RFID integrated labels is also protectable by passwords supporting NSA level encryption schemes. The permanence and authenticity of digital part markings is a key differentiator, compared to paperless tracking and management of critical aircraft parts from cradle to grave, that will realize savings across the entire supply chain.

Conclusions

While it is challenging to combine all of the aforementioned features into a single product offering, Brady has gone a step further to ensure its labels could withstand the rigors of flight. Brady, in collaboration with RFID engineers and quality engineers from the aerospace industry, developed a rigorous testing protocol for evaluating the flight readiness of its RFID solutions. Testing included exposure to thermal shock, pressurization, mechanical shock, chemical contamination, vibration and flammability, to name a few. The results of these tests, along with the relevant standards, are provided in Figure 4: Standards Compliance Test Results.

Smart RFID part marking is the answer to the growing need for efficient and error-proof identification and management of aircraft components throughout their life. The scope of improved efficiency and savings generated by RFID labeling is realized at all levels of the aerospace industry, from fully traceable part-creation in aircraft manufacturing and assembly to faster airliner maintenance, repair and overhaul. This initial product offering is expected to safely, securely, and reliably enable large-scale adoption of RFID labeling for the next generation of aircraft.

Standard Compliance Test Results

Test	Result	Reference
Operating Temp	Pass	DO-160E Section 4 Category A2
Survival Temp	Pass*	DO-160E Section 4 Category A2 & D2
Altitude	No Effect	DO-160E Section 4 Category A1 & D2
Decompression	No Effect	DO-160E Section 4 Category A2
Overpressure	No Effect	DO-160E Section 4 Category A1 & D2
Humidity	No Effect	DO-160E Section 6 Category A & C
Chemical Resistance	No Effect	DO-160E Section 11 Category F
Mechanical Shock	No Effect	DO-160E Section 7 Category E
Vibration	No Effect	DO-160E Section 8 Category R Curve D & D1
Waterproofness	No Effect	DO-160E Section 10 Category W
Fungus	No Fungal Growth	DO-160E Section 13 Category F
Corrosion	No Effect	EN2591-307
Flammability	Pass	14 CFR 25.853 App. F Part I, II **
Smoke Density	Pass	14 CFR 25.853 App. F Part V ***
Toxicity	Pass	14 CFR 25.853 App. F Part V
Radio-magnetic Effect	No Deflection	DO-160E Section 15 Category Z
Electrostatic Discharge	No Effect	ABD0100.1.2 G Category B
Peel Resistance (dry)	All test surfaces greater than 12 N/25mm	ISO4578
Peel Resistance (exposure)	Greater than 9 N/25 mm for exposures	ISO4578
Storage testing	No Effect	ASTM 3611

* Labels unaffected by short term exposure to temperatures as high as 150 °C, not intended for continual operation above 85 °C.
** 12 second vertical burn test.
*** These tests were not conformed with the FAA.

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