Failure Analysis Associates

Exponent®

Electromagnetically Opaque Shield Testing Program – Identity Stronghold RFID Blocking Card Protector

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Exponent
Failure Analysis Associates®

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Executive Summary

On June 8, 2012, Exponent Failure Analysis Associates completed an evaluation of a set of Identity Stronghold RFID Blocking Card Protector electromagnetic shield (EMS) wallet-size sleeves provided by DMDC. This testing was performed consistent with the previously issued document RFQ 02FL9790811. The tests performed and results are listed in Table 1.

Table 1. Summary of tests performed on Identity Stronghold sleeves.

Evaluation	Test result
Resistance to Chemicals	PASS
Supplemental Resistance to Chemicals	PASS
Adhesion/Blocking	PASS
Surface Abrasion	PASS
Elevated Temperature & Humidity	PASS
Plasticizer-Induced Dye Migration	PASS
Structural Integrity	FAIL[1]
Extreme Temperature Exposure	PASS
Environmental Exposure: Water	PASS
Environmental Exposure: Salt Mist	PASS
Insertion Cycling	PASS
Basic Shielding Functionality	PASS
Additional Shielding Functionality	PASS

Pass/Fail criteria are defined in the appropriate test standard. When no criteria are defined, they are based on comparison to other samples Exponent has tested.

The sleeves were evaluated for functionality, durability, and reliability in accordance with the following standards or documents as appropriate: ANSI INCITS 322, ISO/IEC 10373-1, ISO/IEC 14443-2, FIPS201, ISO 9227, and DoD/DMDC RFQ 02FL9890811.

This report describes the details of the tests performed and results obtained.

[1] Note that the conditions encountered by the card sleeve samples during the Structural Integrity test are extremely severe. In prior testing of EMS sleeves in 2009, a majority of samples also failed this test.

1 Introduction

1.1 Normative References

[R1] DMDC EMS Request for Quote 02FL9890811

[R2] ANSI INCITS 322-2008, Card Durability Test Methods, 2008

[R3] ISO/IEC 10373-1 International Standard: Identification Cards – Test Methods – Part 1: General Characteristics

[R4] FIPS201 Evaluation Program-Electromagnetically Opaque Sleeve Test Procedure, Version 3.0.0, July 03, 2007

[R5] ISO 9227-2006 Corrosion Tests in Artificial Atmospheres – Salt Spray Tests

[R6] ISO 14443-2 Identification cards – Contactless integrated circuit(s) cards – Proximity Cards – Part 2: Radio frequency power and signal interface

1.2 Tests and Relevant Test Standards

A summary of the sleeve tests conducted, and the relevant test standards that were followed, is given in Table 2. All sleeve samples were tested in their as-received condition.

Table 2. Summary of sleeve tests

Test Description	Test Standard	Reason for Test	# of Sleeves Tested
Resistance to chemicals	ISO 10373	Sleeves may be exposed to common chemicals including artificial perspiration	3 per chemical x 9 chemicals
Supplemental resistance to chemicals	DMDC RFQ	Sleeves may be exposed to DoD-specific chemicals	3 per chemical x 6 chemicals
Adhesion/blocking	ISO 10373	Sleeves need to be able to be easily separable without damage when stacked during storage and shipping	5
Surface abrasion	ANSI INCITS 322	Sleeve may be abraded during use	3
Elevated temp. and humidity	ANSI INCITS 322	Sleeves may be exposed to hot and humid environments	3
Plasticizer-induced dye migration	ANSI INCITS 322	Wallets and vinyl pouches sometimes contain plasticizers that can leach inks from inserted cards or sleeves	3
Structural integrity	ANSI INCITS 322	This test simulates a harsh usage environment and is the most brutal and abrasive test run	3
Extreme temp. (-10°F)	DMDC RFQ	Sleeves may be used in cold environments	3
Extreme temp. (125°F)	DMDC RFQ	Sleeves may be used in hot environments	3
Environmental exposure: water (7 days)	DMDC RFQ	Sleeves may be used in wet conditions	3
Environmental exposure: salt mist	ISO 10373-1, ISO 9227	Salt mist testing simulates a potentially corrosive environment	3
Insertion cycles (10,000)	DMDC RFQ	10,000 cycles represents the maximum anticipated usage of a sleeve and represents more than five daily insertions over a five-year card life span; most sleeves will not be used this frequently	3
Supplemental resistance to chemicals	DMDC RFQ	Sleeves may be exposed to DoD specific chemicals	3 per chemical x 6 chemicals
Basic shielding function	FIPS201 Test Procedure	Sleeves are expected to provide shielding against unauthorized interrogation attempts by standard readers	2
Additional shielding function	DMDC RFQ	Sleeves are expected to provide shielding against unauthorized interrogation attempts by enhanced/tunable readers	2

1.3 Test Environments

Unless otherwise specified, all tests were performed in an environment with a temperature of 23°C ± 3°C and a relative humidity of 25-40%.

1.4 Sample Preparation

A total of 85 wallet-size (Form Factor A) Identity Stronghold RFID Blocking Card Protector sleeve samples were received from DMDC. Each sample was a printed pouch with a silver-colored foil interior. The samples were numbered consecutively by Exponent. Samples were taken at random for testing. Representative images of a sleeve in the as-received condition are shown in Figure 1.

Figure 1. Representative images of an Identity Stronghold RFID Blocking Card Protector sleeve in the as-received condition.

1.5 Functionality Check

Prior to testing, all card sleeves were examined to verify that the RFID blocking capability was functional in the as-received state. The functionality of the sleeves was confirmed using an SCM Microsystems, Inc. SDI010 Contactless Reader and SmartPCSCDiag Version 2.04 software. An ATR response was first confirmed from a card with a contactless PIC when placed on the reader; the card was then inserted in the sleeve and the sleeve was placed on the reader. Functionality of the sleeve was confirmed if no ATR response was observed from the inserted card.

2 Durability Tests

This section describes the durability and reliability tests that were conducted on received sleeves in accordance with [R1]-[R4].

2.1 Resistance to Chemicals

A total of 45 sleeves underwent testing for chemical resistance. The purpose of these tests is to determine any adverse effects of a range of chemical contaminants, according to [R3].

Each sample was visually inspected to establish its appearance prior to chemical exposure. Samples were then exposed to either short-term (1 minute) or long-term (24 hours) contamination. Different sleeve samples were used for each chemical solution. Each sample was rinsed and dried before evaluation. A sample passed this test if, following chemical exposure, the sleeve continued to provide RFID blocking capability and showed no significant signs of degradation.

2.1.1 Results

All 45 samples submitted for the chemical resistance tests passed. The results of these tests are summarized in Table 3 and Table 4. All solution percentages are by mass. Some warpage was observed for the sleeves exposed to Fuel B, gasoline, Jet A, and mineral spirits, as shown in representative images in Figure 2. RFID blocking capability was maintained for all tested samples. No signs of sleeve degradation or inner foil delamination were observed.

Table 3. Summary of the results of the card sleeve chemical resistance tests for chemicals specified by [R3].

Sleeve ID	Chemical solution	Term	Test result
15			Pass
50	5% sodium chloride	short	Pass
78			Pass
18			Pass
43	5% acetic acid	short	Pass
71			Pass
07			Pass
35	5% sodium carbonate	short	Pass
77			Pass
08			Pass
30	60% ethyl alcohol	short	Pass
60			Pass
14			Pass
48	10% sucrose	short	Pass
59			Pass
09			Pass
47	Fuel B (ISO 1817)	short	Pass
64			Pass
02			Pass
34	50% ethylene glycol	short	Pass
83			Pass
19			Pass
42	artificial perspiration, alkaline	long	Pass
75			Pass
10			Pass
36	artificial perspiration, acid	long	Pass
68			Pass

Table 4. Summary of the results of the card sleeve chemical resistance tests for the supplemental chemicals specified by [R1].

Sleeve ID	Chemical solution	Term	Test result
21			Pass
49	2% soap solution	short	Pass
82			Pass
03			Pass
39	gasoline – 87 octane	short	Pass
63			Pass
22			Pass
51	Jet A	short	Pass
72			Pass
20			Pass
46	mineral spirits	short	Pass
81			Pass
24			Pass
53	hydraulic fluid per MIL-H5606	short	Pass
80			Pass
26			Pass
54	90% DEET insect repellant	short	Pass
84			Pass

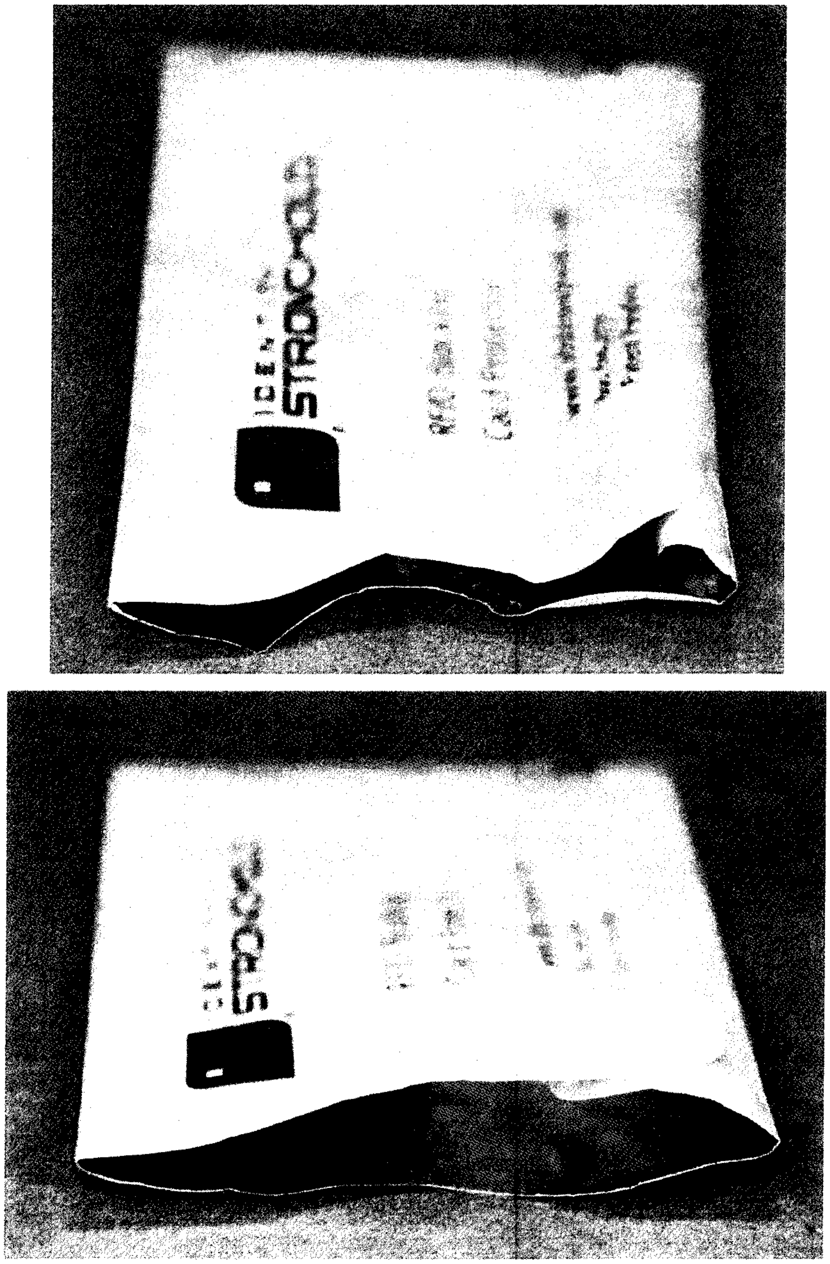

Figure 2. Representative images showing sleeve warpage after exposure to Jet A (upper image) and mineral spirits (lower image).

2.2 Adhesion/Blocking

A total of five sleeves were tested for adhesion/blocking to determine any adverse effects when the sleeves are stacked together, according to [R3].

Each sample was visually inspected to verify that the individual sleeves could be separated by hand. The five sleeves were then stacked in a group, all in the same orientation with the front side facing up. A uniform pressure of 0.362 psi (2.74 lbf) was applied over the top sleeve surface, and the stack was placed in an environmental chamber at 40°C and 50% RH for 48 hours. At the end of the 48-hour period, the stacked sleeves were returned to the ambient lab conditions and inspected to determine if the individual sleeves could be easily separated by hand or if the sleeves had suffered any adverse effects such as delamination, discoloration, material transfer between adjacent sleeves, changes to the surface finish, or deformation. A sleeve sample passed this test if it could be easily separated by hand from adjacent sleeves and suffered no adverse effects.

2.2.1 Results

All five samples submitted for adhesion/blocking testing passed. A summary of the results is shown in Table 5. Inspection of the sleeves showed no evidence of delamination, discoloration, changes in surface finish, transfer of materials, or other degradation. RFID blocking functionality was maintained following testing.

Table 5. Summary of qualitative results from adhesion/blocking testing.

Sleeve ID	Separated by Hand	Adverse Effects	Test Result
06	Yes	No	Pass
23	Yes	No	Pass
45	Yes	No	Pass
56	Yes	No	Pass
74	Yes	No	Pass

2.3 Taber Abrasion

A total of three sleeve samples underwent testing to determine susceptibility to abrasion using a Taber abraser. A Taber 5130 Abraser equipped with Taber Calibrase CS-10F standardized abrasion test wheels was used for this test, according to [R2]. A total of 500 cycles were conducted on each sample, with an applied test load of 250 g. The test wheels of the Taber Abraser were resurfaced before each test and after 250 cycles using Taber Abraser Refacing Discs. Samples were photographically documented after 250 and 500 cycles. A sleeve sample passed this test if it retained RFID blocking capability.

2.3.1 Results

For all three tested sleeve samples, wear was observed after 250 and 500 cycles, but RFID blocking capability was retained after 500 cycles. A summary of the qualitative test results from abrasion testing are given in Table 6. Representative images of the abrasion wear observed are shown in Figure 3.

Table 6. Summary of qualitative results from Taber abrasion testing to 500 cycles.

Sleeve ID	RFID blocking functionality	Test Result
17	Yes	Pass
37	Yes	Pass
65	Yes	Pass

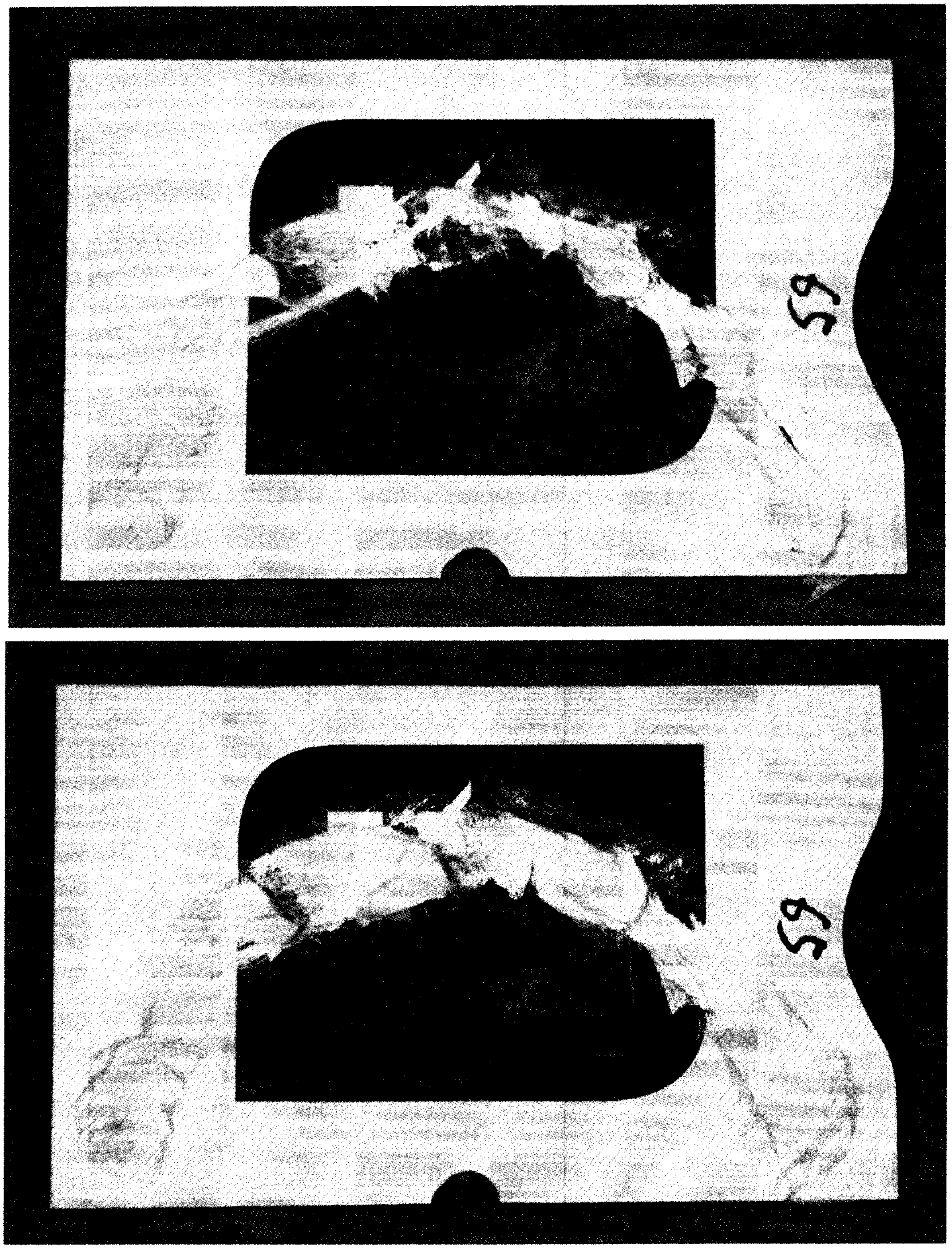

Figure 3. Representative images showing wear as a result of Taber abrasion testing after 250 cycles (upper image) and 500 cycles (lower image).

2.4 Elevated Temperature and Humidity

A total of three sleeve samples were submitted for elevated temperature and humidity exposure testing. The purpose of this test is to evaluate the card sleeve's ability to withstand an elevated temperature and humidity environment, according to [R2].

Each sample was visually inspected to establish its appearance prior to temperature and humidity exposure. The sleeves were then exposed to a temperature of 50°C and a relative humidity of 95% ± 5% for seven days. Following temperature and humidity exposure, the samples were visually inspected and photographically documented for signs of degradation. A sample passed this test if it suffered no adverse effects from the temperature and humidity exposure and retained RFID blocking capability.

2.4.1 Results

No signs of degradation were observed for all tested sleeves after seven days of exposure to elevated temperature and humidity, as summarized in Table 7. RFID blocking capability was retained. A light gray-colored corrosion product was observed on the inner foil, as shown in Figure 4.

Table 7. Summary of qualitative results from elevated temperature and humidity exposure.

Sleeve ID	RFID blocking functionality	Observations	Test Result
11	Yes	Corrosion product on inner foil	Pass
40	Yes	Corrosion product on inner foil	Pass
69	Yes	Corrosion product on inner foil	Pass

Figure 4. Representative image showing corrosion product on the inner foil of a sleeve sample following elevated temperature and humidity exposure.

2.5 Plasticizer-Induced Dye Migration

A total of three sleeves were tested for plasticizer-induced dye migration according to [R2].

The sleeves, with ID cards inserted, underwent flexure with 300 cycles performed on each axis (length and width), both face up and face down, for a total of 1,200 cycles. Following the flexure cycles, the test sleeves with inserted cards were stacked together and a 2 N load was applied to the stack. The stacked sleeves and cards were allowed to relax in this condition for 24 hours. Dioctyl phthalate (DOP) plasticizer liquid was then evenly coated on the front surface of each card. The DOP-coated cards were then re-inserted into the sleeves and exposed to 40°C for 48 hours. Following exposure, the cards were washed with soap and water to remove the plasticizer and any dissolved dye and examined for image blurring, a characteristic of dye migration. RFID blocking functionality of the sleeves was then tested.

A sleeve sample passed this test if it retained RFID blocking capability and suffered no significant adverse effects from plasticizer exposure.

2.5.1 Results

For all three tested samples, no significant degradation was observed following testing. RFID blocking capability was retained for all samples. A summary of the test results is given in Table 8.

Table 8. Summary of results from plasticizer induced dye migration test using unlaminated cards

Sleeve ID	RFID blocking functionality	Test Result
27	Yes	Pass
52	Yes	Pass
62	Yes	Pass

2.6 Structural Integrity Test

A total of three sleeves were submitted for structural integrity testing. The purpose of this test is to evaluate the card sleeve's resistance to delamination when subjected to elevated temperature and humidity and a wet abrasion and impact environment, according to [R2].

With ID cards inserted, the sleeves were exposed to a temperature of 50°C and 95% relative humidity for six days. The sleeves and cards were then placed in a one-gallon paint can along with 10 grams of 120 grit sand, 30 mL of distilled water, and 13 additional blank cards. The gallon can was sealed and agitated for three hours using a commercial paint shaker. The sleeves and cards were then removed, washed, and dried. The sleeves were examined for signs of degradation and examined for RFID blocking functionality. A card sleeve sample passed this test if it retained RFID blocking capability and suffered no significant degradation.

2.6.1 Results

All of the tested card sleeves showed evidence of significant degradation after structural integrity testing. A summary of the qualitative test results are given in Table 9. The foil sleeves delaminated, as shown in Figure 5. RFID blocking capability was not retained. Note that the conditions encountered by the card sleeve samples during this test are extremely severe.

Structural integrity testing conducted in 2009 resulted in significant degradation to the tested sleeves, with a majority of samples failing to retain RFID blocking capability.

Table 9. Summary of results from the structural integrity test.

Sleeve ID	Observations	RFID blocking functionality	Test Result
13	Foil delamination; severe degradation	No	Fail
31	Foil delamination; severe degradation	No	Fail
67	Foil delamination; severe degradation	No	Fail

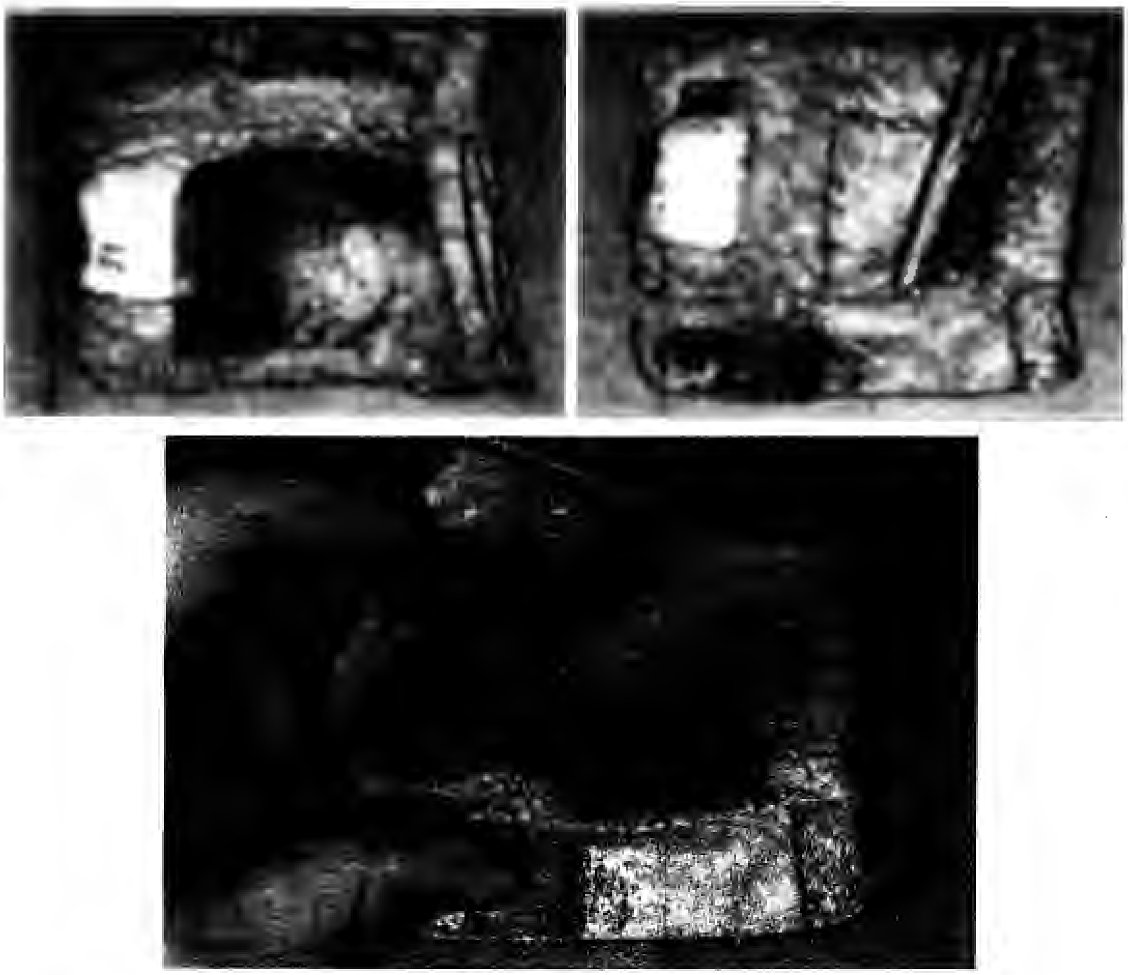

Figure 5. Representative images showing severe card sleeve degradation as a result of structural integrity testing.

2.7 Extreme Temperature Exposure (-10°F)

Three card sleeves were tested for exposure to extreme cold temperature at -10°F, in accordance with [R1]. Each sample was exposed to a temperature of -10°F for 24 hours. Upon removal from this environment, the sleeve was tested for RFID blocking functionality. A sleeve sample passed this test if it suffered no adverse effects from the extreme temperature exposure and retained RFID blocking capability.

2.7.1 Results

All three sleeves passed the extreme temperature exposure test with no signs of degradation, as summarized in Table 10.

Table 10. Summary of test results from -10°F extreme temperature exposure.

Sleeve ID	RFID blocking functionality	Test Result
05	Yes	Pass
33	Yes	Pass
70	Yes	Pass

2.8 Temperature Extreme Exposure (+125°F)

Three card sleeves were tested for exposure to extreme hot temperature at +125°F, in accordance with [R1]. Each sample was exposed to a temperature of 125°F for 24 hours. Upon removal from this environment, the sleeve was tested for RFID blocking functionality. A sleeve sample passed this test if it suffered no adverse effects from the extreme temperature exposure and retained RFID blocking capability.

2.8.1 Results

All three sleeves passed the extreme temperature exposure test with no signs of degradation, as summarized in Table 11.

Table 11. Summary of test results from +125°F extreme temperature exposure.

Sleeve ID	RFID blocking functionality	Test Result
12	Yes	Pass
44	Yes	Pass
79	Yes	Pass

2.9 Environmental Exposure: Water

A total of three card sleeves were tested for exposure to distilled water for a seven-day duration, in accordance with [R1]. Card sleeves were immersed in distilled water for seven days. Upon removal, the sleeves were dried, examined for signs of degradation, and tested for RFID blocking functionality. A sleeve sample passed this test if it suffered no adverse effects from the environmental exposure and retained RFID blocking capability.

2.9.1 Results

All sleeves tested passed the water exposure test showing no signs of degradation, as summarized in Table 12.

Table 12. Summary of test results from the seven-day water exposure.

Sleeve ID	RFID blocking functionality	Test Result
16	Yes	Pass
41	Yes	Pass
76	Yes	Pass

2.10 Insertion Cycling (10,000 Cycles)

A total of three sleeves were submitted for insertion cycling testing in accordance with [R1]. For this test, an ID card was repeatedly inserted and removed into the sleeve by hand for a total of 10,000 cycles. Every 1,500 cycles and at the completion of the test, the card sleeves were inspected for any signs of degradation. At the completion of the 10,000 cycles, each sleeve was tested for RFID blocking functionality. A card sleeve sample passed this test if it suffered no adverse effects from the card insertion cycling and retained RFID blocking capability.

2.10.1 Results

All three card sleeves passed the insertion cycling test. A summary of the qualitative test results are given in Table 13. RFID blocking capability was maintained. Slight wrinkling at the mouth of the pouch was observed on all tested sleeves, as shown in Figure 6. This wrinkling did not affect the ability to properly insert the ID card. Spalling of the inner foil was not observed.

Table 13. Summary of test results from insertion cycling to 10,000 cycles.

Sleeve ID	Observations	RFID blocking functionality	Test Result
04	Slight wrinkling	Yes	Pass
38	Slight wrinkling	Yes	Pass
66	Slight wrinkling	Yes	Pass

Figure 6. Representative image showing wrinkling around the mouth of the pouch after 10,000 insertion cycles.

2.11 Environmental Exposure: Salt Mist

Three card sleeve samples were tested for exposure to salt mist for 24 hours according to [R3] while mounted in a cabinet in accordance with ISO 9227 [R5]. The neutral salt spray (NSS) test specifications were used. The test operating conditions are summarized in Table 14.

Table 14. Salt mist exposure test operating conditions.

Test Condition Item	Settings	Standard Spec for NSS Method
Temperature	35°C	35°C ± 2°C
Average collection rate for a horizontal collecting area of 80 cm^2	1.6 mL/h	1.5 ± 0.5 mL/h
Concentration of sodium chloride (collected solution)	50 g/L	50 g/L ± 5 g/L
pH (collected solution)	6.93	6.5 to 7.2
Salt used	Sodium chloride	Sodium chloride
Test duration	24 hours	24 hours

2.11.1 Results

All three card sleeves submitted for salt mist exposure testing passed with no signs of degradation. The test results are summarized in Table 15. RFID blocking capability was maintained.

Table 15. Summary of test results from the 24-hour salt mist exposure test.

Sleeve ID	Observations	RFID blocking functionality	Test Result
28	No effects	Yes	Pass
57	No effects	Yes	Pass
85	No effects	Yes	Pass

3 Shielding Testing

This section summarizes the shielding evaluation tests conducted on received card sleeves. The test cards used for all shielding tests were Gemalto GemCombi 'Xpresso R4 72K cards with the SafesITe FIPS 201 applet. An X-ray image of one of the test cards is shown in Figure 7 and shows the antenna layout. The antenna consists of 4 concentric wire loops with some manufacturing-induced asymmetry. A cross-sectioning of the card shows the antenna is approximately at the center of the plastic card thickness as shown in Figure 8. Consequently, the minimum distance between the antenna and shielding material is approximately the same from both sides of the card.

Figure 7. X-ray image of the test card used for shielding evaluations.

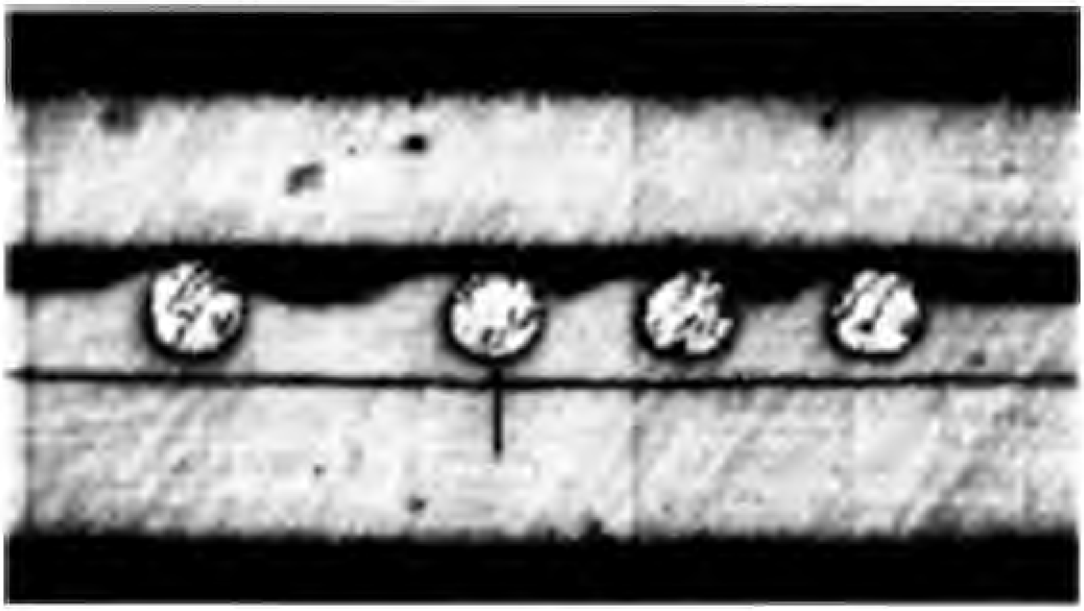

Figure 8. Cross-section of the test card used for this evaluation.

3.1 Basic Shielding Evaluation

Two card sleeve samples were tested for basic shielding functionality with a FIPS 201-approved SCM SDI010 dual-interface card reader. The ability of the contactless interface to be read was examined while the card was enclosed in the card sleeve at any distance from the reader. Shielding performance of the sleeve was evaluated in each of the six possible orientations relative to the reader as well as 4 possible placements of the card within the sleeve. In some cases, the testing of some orientations was deemed unnecessary due to minimal field coupling or due to the symmetry of the shielding material around the card.

3.1.1 Results

Both card sleeves tested passed the basic shielding evaluation. The test results are summarized in Table 16. As shown in Figure 9, a shift of the card of more than 5 mm out of the sleeve can result in the loss of RFID shielding functionality.

Table 16. Basic shielding functionality test results for all types of sleeves received

Sleeve ID	Test Result	Observations
25	Pass	RFID card is readable when card removed from sleeve for distances greater than 5 mm.
73	Pass	RFID card is readable when card removed from sleeve for distances greater than 5 mm.

Figure 9. A slight shift of the card of approximately 5 mm within the sleeve can result in the loss of shielding functionality.

3.2 Additional Shielding Evaluation

Two card sleeve samples were tested for electromagnetic shielding ability at frequencies above 13.56 MHz. It is known that the resonant frequency of the card enclosed in the sleeve is higher than the standard operating frequency (13.56 MHz ± 7 KHz) of the card itself. The tunable RFID reader shown in Figure 10 was developed with a FIPS 201-approved SCM SDI010 dual-interface card reader and a tunable antenna. The antenna was tuned to 18.32 MHz and a field strength of 7.5A/m, the maximum field strength defined by [R6]. Four combinations of card and sleeve orientations were tested:

- P1 Sleeve front surface facing up, card chip-side facing up
- P2 Sleeve front surface facing down, card chip-side facing down
- P3 Sleeve front surface facing down, card chip-side facing up
- P4 Sleeve front surface facing up, card chip-side facing down

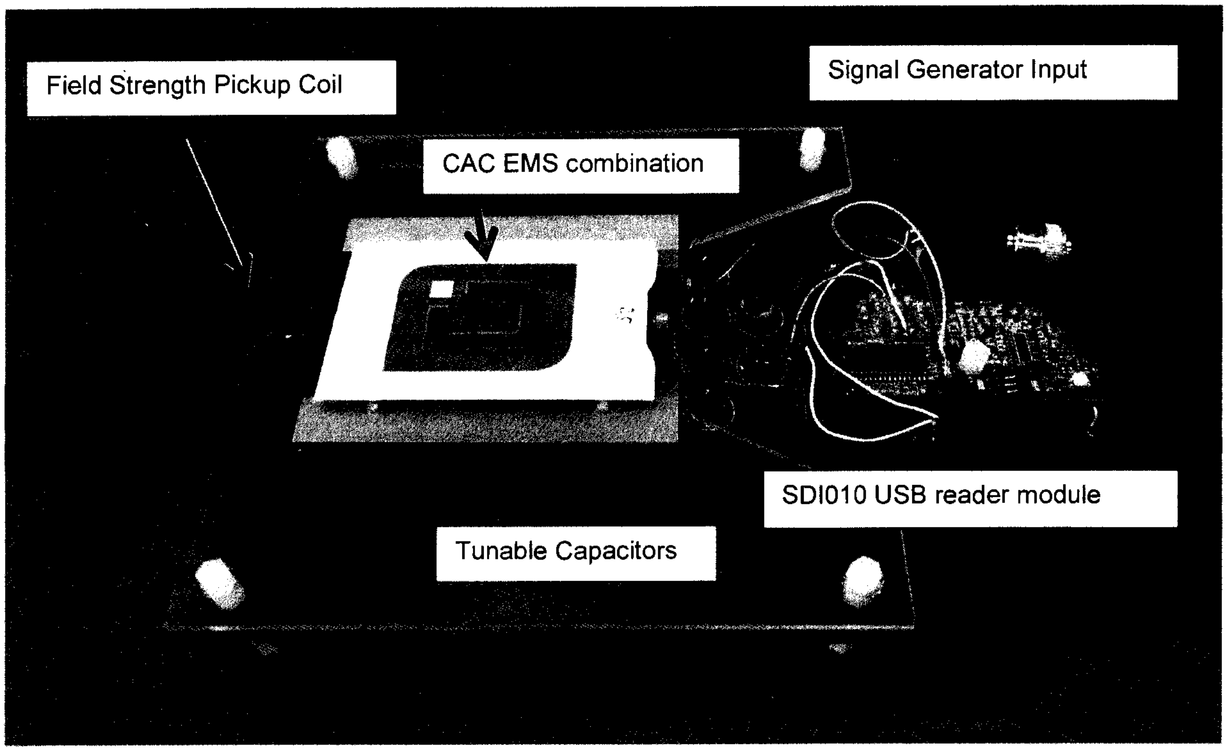

Figure 10. Tunable RFID reader test setup used for the additional shielding evaluation.

3.2.1 Results

A summary of the test results is given in Table 17.

Table 17. Summary of test results for extended frequency testing.

Sleeve ID	Position P1	Position P2	Position P3	Position P4
25	Pass	Pass	Pass	Pass
73	Pass	Pass	Pass	Pass

3.3 Induced Voltages at New Tuned Frequency

The two sample sleeves were subsequently tested to determine the potential of an external field to power the RFID chip while inserted inside the shielding sleeve. The antenna from a reference PICC (Model ISO 10373-6/7) was placed inside each sleeve, as shown in Figure 11. The output of the reference PICC is a rectified voltage that indicates the voltage available to power the microchip in the card. The peak output voltage was measured for Positions P1 through P4, with the reader tuned at an unloaded field strength of 7.5A/m.

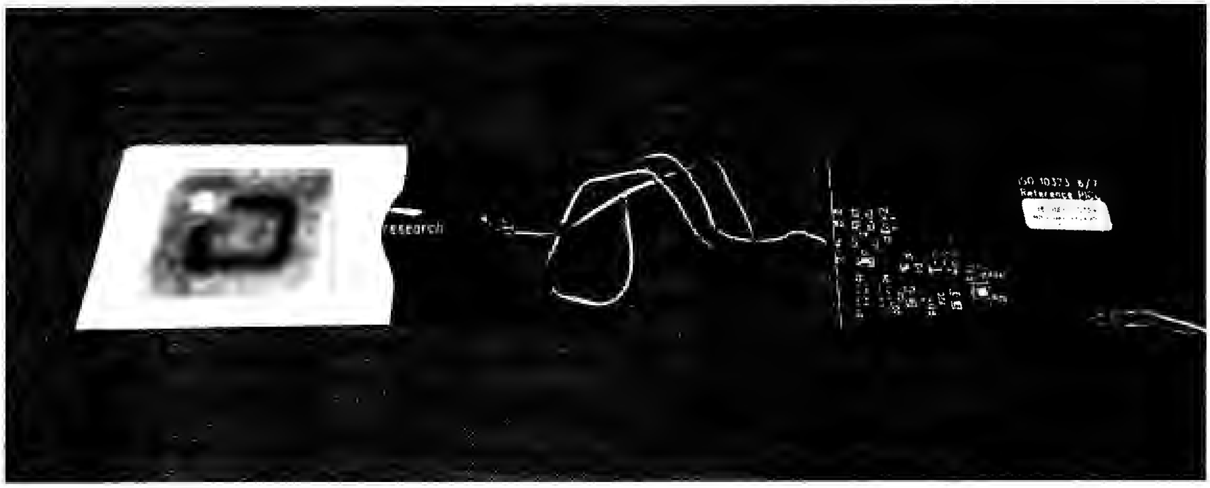

Figure 11. Test setup showing the PICC reference antenna placed inside the sleeve.

3.3.1 Results

A summary of results is given in Table 18. For reference, the unshielded PICC antenna voltage was measured to be 6.2 Vdc. The sample length is shown in Figure 12, comparable to samples with similar construction submitted to DoD in 2009.

Table 18. Summary of test results for induced voltages on a reference PICC antenna inserted into the sleeve.

Sleeve ID	Position P1 (V)	Position P2 (V)	Position P3 (V)	Position P4 (V)
25	0.44	0.35	0.37	0.37
73	0.50	0.44	0.45	0.44

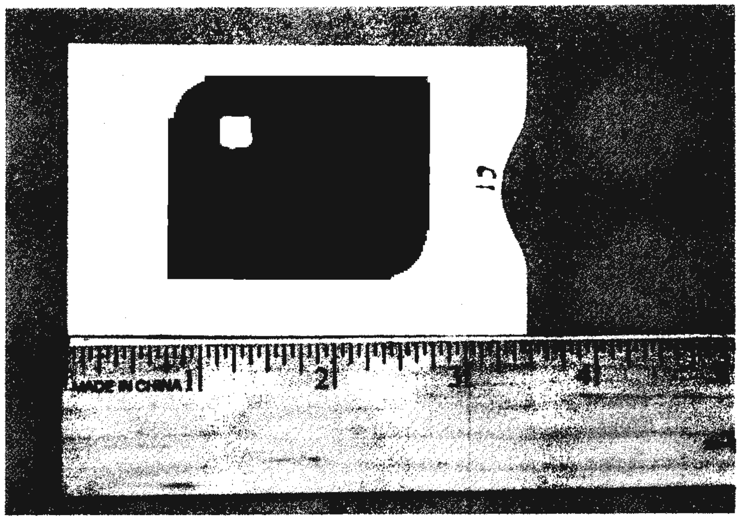

Figure 12. Sample length dimension.