

## General explanation and Data for LS-1000

### 1.0 Material Background and Purpose

Integument's LS-1000 is designed for application on composite and metallic substrates for the purpose of providing high performance protection against corrosion and environmental weathering. In addition, LS-1000 is fabricated with a metallic expanded foil that is embedded within the system so that the metallic foil is protected from corrosion and weathering while providing excellent capabilities for protecting underlying materials from direct lightning strikes and other electromagnetic environmental effects. LS-1000 is designed with a peel and stick adhesive backing which allows it to bond to almost any surface with associated dimensional stability, mechanical performance, environmental durability and thermodynamic stability over the typical life cycle of the structure or equipment it is bonded to. LS-1000 is designed as a sacrificial lightning strike protective layer that can be easily maintained and repaired upon damage from lightning or mechanical damage.

**Specification data sheets on current products which meet the above criteria are described below.**

### APPLIQUÉ TESTING AND TEST PROTOCOLS

#### ADHESION:

**1. Test coupon surface preparation:** aluminum 2024 QQ-A-250/4 – T3, thickness T = 0.071”

- test coupons were 1” x 12” x 0.071” and were thoroughly cleaned using alkaline cleaner with scotch brite (per Mil-C-87937).
- Test coupons were chem.-filmed according to application spec Mil-C-5541 (the material used to prepare chem.-film solution conformed to Mil-C 81760, class 3, form II) and were air dried.
- Test coupons were primed with water reducible, low density, epoxy primer Mil-PRF-85582C or DEFT 44-GN-36 to a dry thickness of 0.8 to 1.2 mils. Primer was cured at RT for at least 10 hours.

#### 2. Application of candidate appliqué:

- primed test coupons were sand scuffed with sand paper grit 220 or finer to remove the gloss, then cleaned with cheesecloth moistened with isopropyl alcohol, followed by a cleaning with dry cheesecloth.
- candidate appliqué were applied (with **NO adhesion promoter**) according to PSTC-1. Test coupons were allowed to dry via letting them set undisturbed for at least 24 hours prior to test.

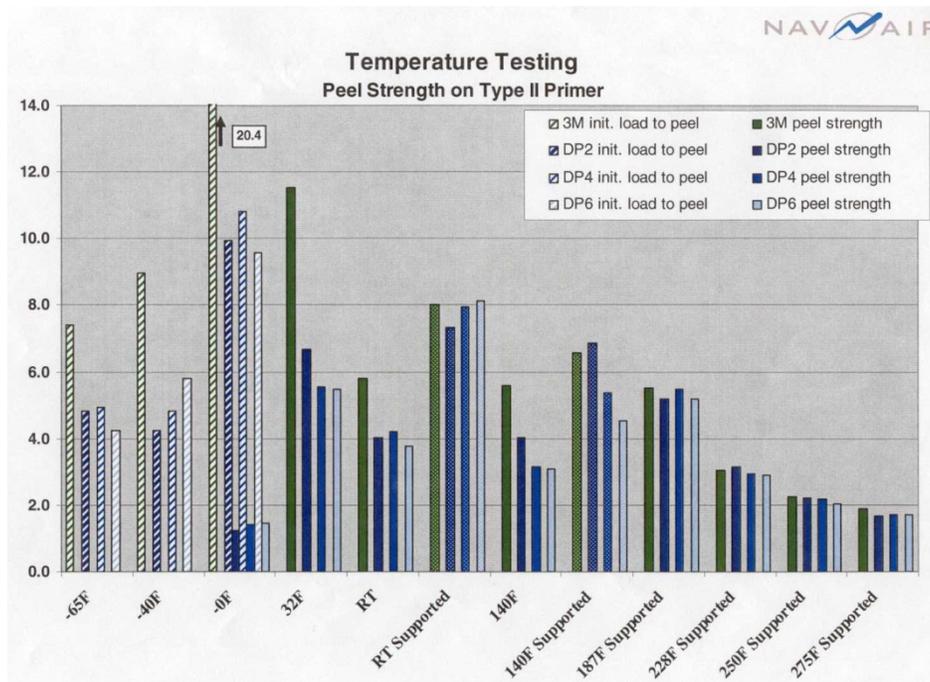
#### 3. Testing: all tests were performed per PSTC-1, with 3 coupons per temperature or condition.

- **Adhesive strength determination:** 180° peels were performed as per PSTC-1 at –65°F, 0°, RT, 185°, 285°, 300°, and 325°F. The required PLI adhesion values and failure modes have been described above.

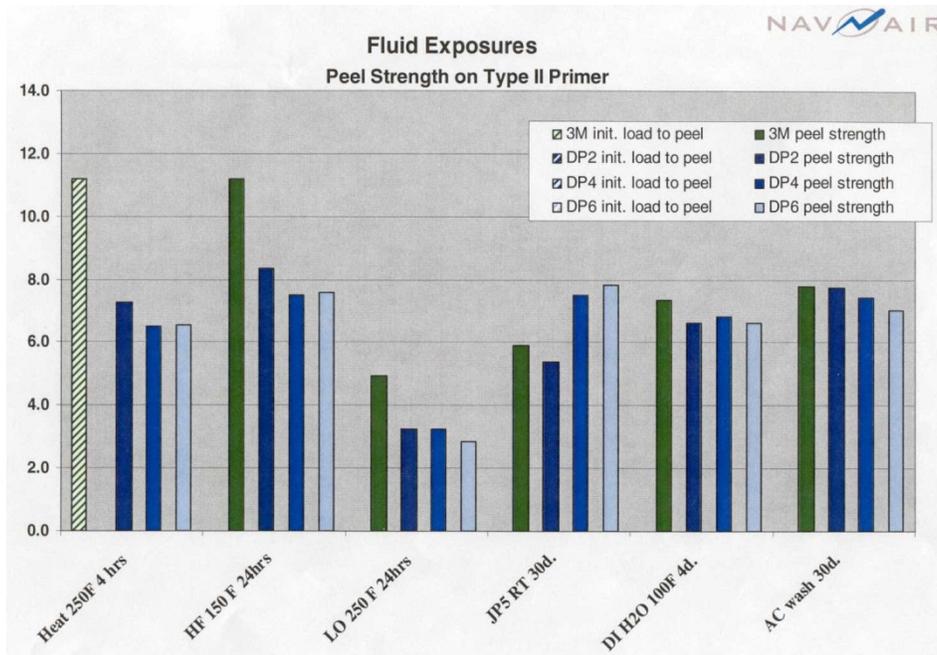
- **Fluid resistance:** test coupons were totally immersed in test fluids and tested as per the legend on Figure 2. Requirements are that the Appliqué/PSA show no signs of degradation or softening. Test fluids included:
  - o hydraulic fluid Mil-H-23699
  - o synthetic hydraulic fluid Mil-H-83282
  - o engine lube oil Mil-I-7808
  - o JP-5
  - o DI H<sub>2</sub>O
  - o AC wash
  
- **Environmental Testing: Test coupons were peel tested after exposure to:**
  - o QUV 500hrs and 2000hrs
  - o Salt Fog 500hrs and 2000hrs
  - o Humidity 30 days
  - o SO<sub>2</sub> Fog 250 hrs and 500hrs
  - o Weathering tests 500 hrs

Figures 1-3 illustrate (1) Adhesion/temperature, (2) Fluid stability, and (3) Environmental stability results obtained on several different fluoropolymer/acrylic PSA appliqué systems developed by Integument Technologies, Inc. The results of the appliqué systems in Figures 1-3 were obtained using proprietary polyurethane modified acrylic PSA's. Specifically, the modified PSA's were made from base PSA's obtained from 3M and Dielectric Polymer (DP). The DP adhesive results are shown as DP2, DP4 and DP6 that refer to the concentration of organic corrosion inhibitor within the DP adhesive system.

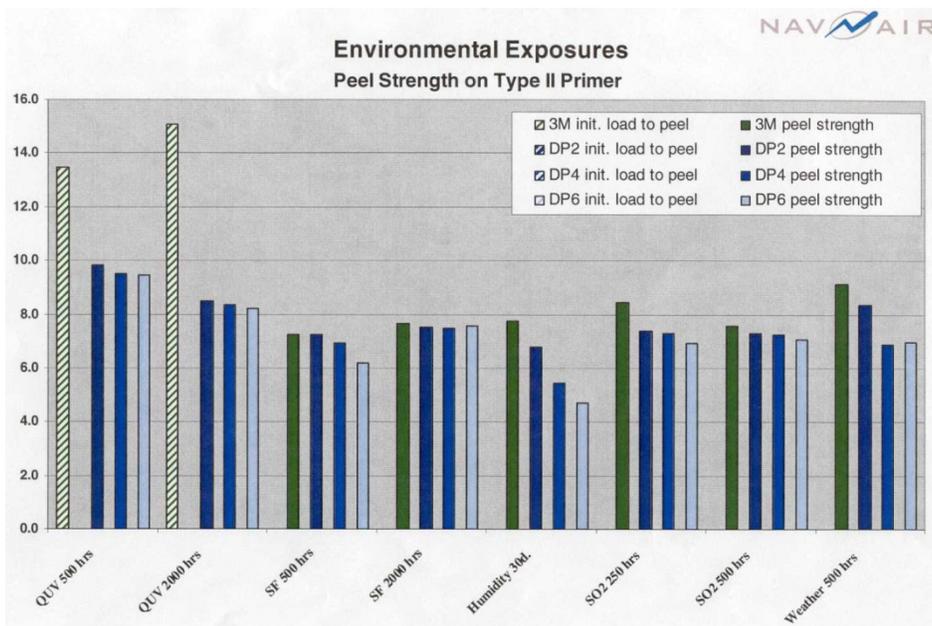
The cross-hatched lines relate to peels that resulted in an even break of the appliqué from the test substrate with adhesive remaining 100% on the appliqué film. "Supported" indicates that at temperature the fluoropolymer film stretched thus convoluting the actual peel strength. Thus, the measurement was made using a thin copper or metal foil backed appliqué material in order to reduce stretching of the film.



**Figure 1: Temperature Peel Strength Testing**



**Figure 2: Fluid Exposure Testing**



**Figure 3: Environmental Exposure Testing**

Based on the above pre-flight qualification testing, Integument's fluoropolymer appliqué/PSA system has been flight tested on several platforms with the following results:

1. No loss of appliqué (100% retention) during multiple flight cycles at sub (up to) 0.95 Mach speeds.
2. Appliqué removed from all aircraft with 100% removal of both appliqué and adhesive, i.e., 100% of adhesive came off with appliqué. The removal and restoration of original condition of aircraft was facilitated within 1-2 days.

## 2.0 Material Properties

As depicted in Figure 4, Integument's current Lightning Strike Protection appliqué system is comprised of a multilayered applique having an ECTFE FluoroGrip topcoat film, 2-4 mil acrylic PSA, expanded metallic foil, and a 2-4 mil acrylic PSA.

# Integument LS 1000 Lightning Strike Protection And Paint Replacement Appliqué

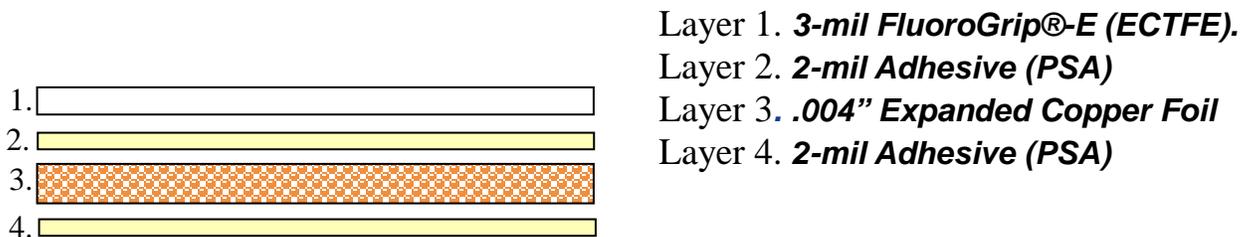


Figure 4

The application of the LSP applique used in previous and ongoing field trials uses simple overlapping of the applique at the seams without any direct electrical contact between the copper foil contained in each segment. Because the current that passes through the LSP material via a lightning strike hit is substantial, it easily jumps from one segment of the appliqué to the next, the increased electrical resistance at the joint is sufficient to result in heat and electrical discharge capable of burning the edges or the joint. Altogether this system minimizes the damaged area and restricts the damage only to the outer applique material.

## 2.2 Material Variation

The overall uniformity, consistency and quality of LS-1000 i.e., physical, chemical, mechanical, electrical properties as well as appearance, is often critical to design performance and visual aesthetics and therefore can be custom fabricated to meet the needs of any customer.

Integument's LS-1000 applique is easily customized to meet:

1. Surface uniformity
2. Required Color
3. Weight
4. Gloss
5. Electrical and shielding requirements

### 2.3 Material Performance Targets

The materials can be fabricated to meet all of the following targets listed in Tables I and (Reports from past Lightning Strike evaluation testing can be requested).

**Table I Surface Protection Material Physical/Chemical Targets**

Test Number	Property	Target Requirement
	Areal Weight	≤ 0.115 lbs/ft <sup>2</sup>
	Thickness	< 0.010 inch
	Melt Temperature (if applicable)	>800°F

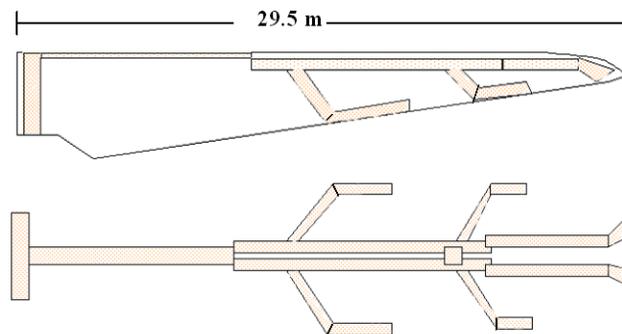
### Selected Examples: Field Demonstrations:

**Note: In General the major use of LS-1000 and variations is for composites made of fiberglass, carbon, or other non-electrically conductive materials. The Adhesive systems developed for this product have been designed for long term applications on metallic, ceramic, and composite surfaces.**

#### 1. Lightning Strike Protection Applique for Application on Wind turbine blades.

Integument is working with an international Wind turbine manufacturer and has provided a customized LSP kit for application to turbine blades. Figure 1 illustrates the kit and Figure 2 shows the results that successfully protected the underlying blade composite from lightning strike damage.

**Wind Turbine Blade LSP Tape Layout Design**



**Figure 1**

Based on laboratory testing and team design a full field demonstration was performed. In this field test, Integument's LSP appliqué tape was kitted and applied onto four composite blades for testing on two turbine towers. Integument worked closely with this company with respect to application and design of the final LSP appliqué prototype. Figure 1 shows the appliqué design and Figure 2 illustrates the application of the LSP system to the wind turbine blades.

## Installation of LSP Appliqué



**- At the blade hub**



**At the blade tip**

**Figure 2**

The LSP appliqué was applied to four blades (two per tower), erected onto the wind towers, and field tested for over 1 year. Figure 3 illustrates the results after achieving a lightning strike hit onto one of the blades.



Initial Point of Strike



Damage to Tape and Peeling  
At End of Blade



Damage Observed at Joints Where Tape Was



**Figure 3**

## **2. LSP for Application on USAF Aerostat**

Integument has provided its LSP applique for installation on the composite Gondolas on a USAF funded Aerostat program. Figure 1 illustrates the composite gondola that was coated for this project. Flight demonstrations will proceed this year.



**Figure 3**

### **3. Applications on Composite Based Aircraft:**

Integument currently has several large aerospace customers who are actively testing our LS-1000 product for applications on their carbon composite based aircraft. Non-disclosure Agreements prohibit Integument from mentioning specifics however a report detailing a long term collaboration with the United States Navy and Bell Textron Helicopter can be accessed upon request.