Rain Erosion Testing of Lightning Diverters

PO# 120610

Report Date: 14 January 2011

Revision 2

For Shine Wire Products, Inc.

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Contents

1. Background

This report has been prepared for Shine Wire Products, Inc., 25 Print Works Drive, Adams, MA, 01220, USA. It contains results of a set of rain erosion tests conducted at the University of Limerick (UL), Ireland in December 2010 using the WARER test facility. The work was performed under PO# 120610, 6th December 2010, using test specimens supplied by Shine Wire Products, Inc.

2. Whirling Arm Rain Erosion Rig (WARER) data

The WARER simulates rain erosion conditions that would be encountered during a normal flight profile. A nominal rainfall rate of 25.4 mm/h (1 inch/hr) is produced at a test speed of 178 m/s. This test speed is equivalent to 300 kts calibrated airspeed at 10,000 ft (ISA conditions). The test specimen/coupon is mounted on the rotating arm at a distance of 0.6 m. The coupons are circular and 27 mm diameter. The arm is accelerated up to speed before the droplet system is turned on. The duration of the test depends on the resistance of the material to droplet impact.

A test speed of 129 m/s (250 kts) was selected. This was used for all tests due to the possibility of the specimens failing prematurely as a result of the high normal acceleration forces, which are seen by the diverter during the test. One minute intervals were used initially and extended to two minute intervals thereafter.

The rainfall rate seen during the testing is approximately 72% of the 25.4 mm/h due to the reduction in the rotational speed from the maximum. This should be taken into account when comparing these results to other test results (i.e. the time to failure should be reduced to approximately 0.72 of the original value in order to allow for this).

3. Matrix of test specimens

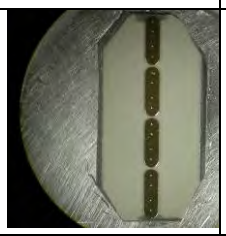
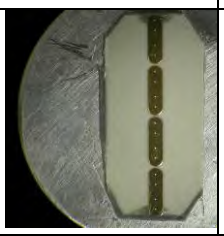
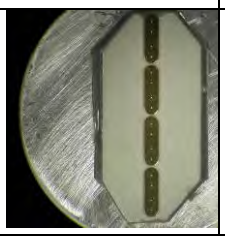
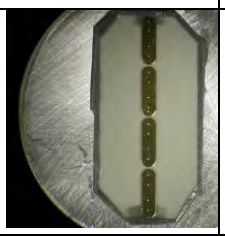
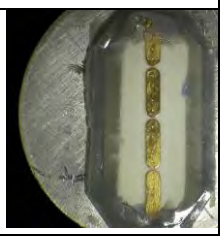
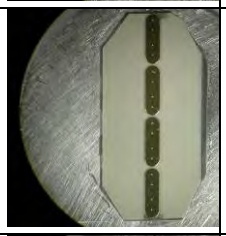
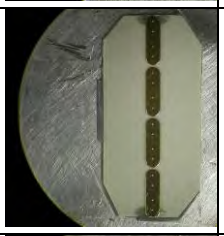
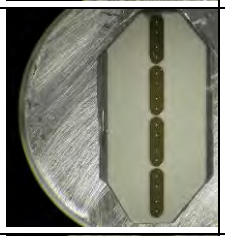
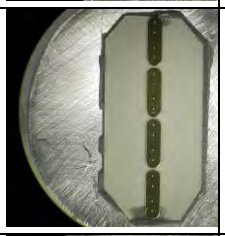
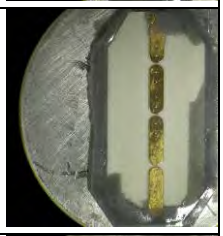
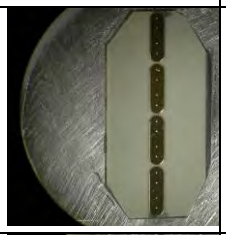
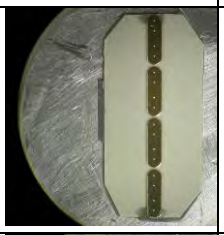
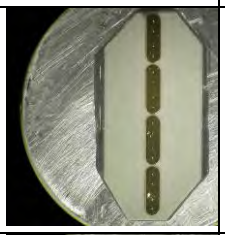
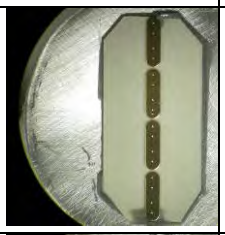
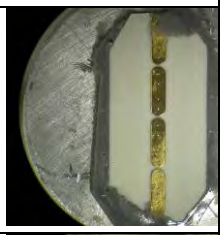
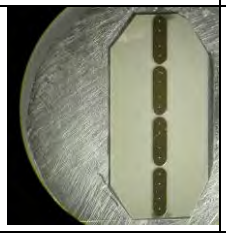
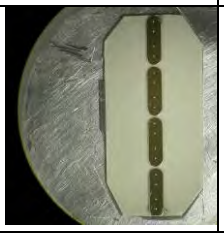
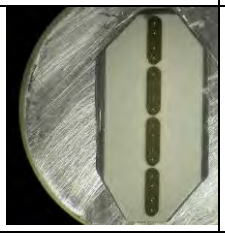
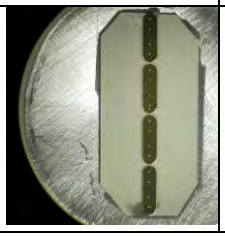
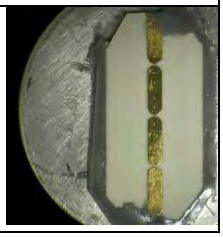
Thirteen specimens in total were to be tested and photographed for comparison (Tables 3.1). WXGuard specimens, W1-W5, were installed with 3M EA2216 adhesive. W5 had 3M EA2216 around the periphery. These specimens had gold plated buttons with plated “thru-holes”. Competitor’s specimens, L1-L5, were installed with 3M EA2216 adhesive. Specimens L5 had 3M EA2216 around the periphery. These specimens had nickel plated buttons with plated “thru-holes”.

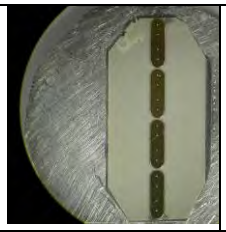
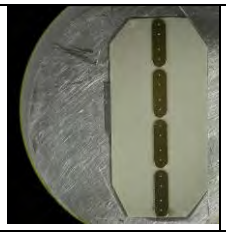
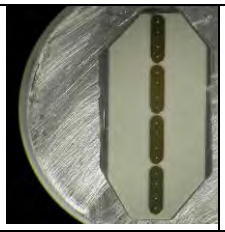
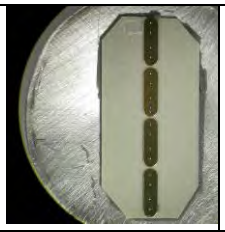
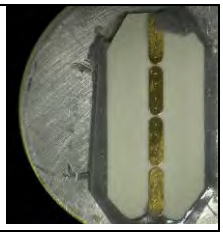
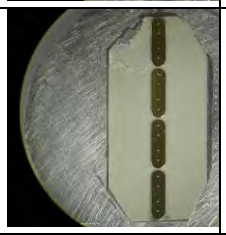
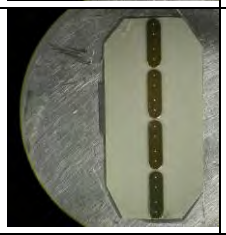
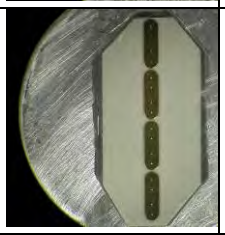
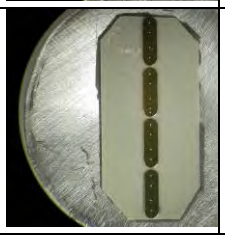
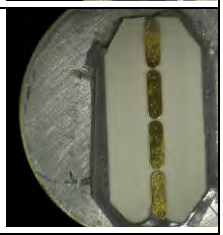
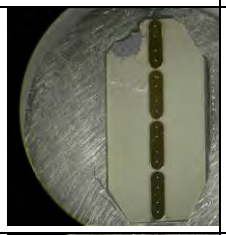
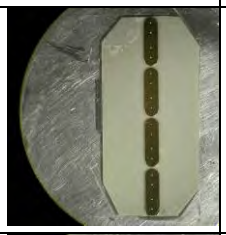
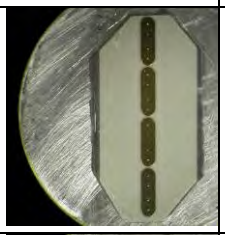
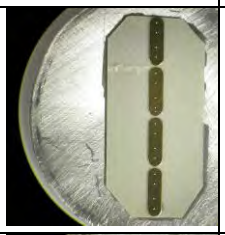
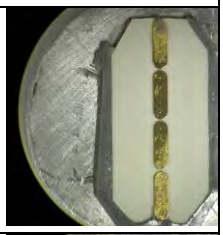
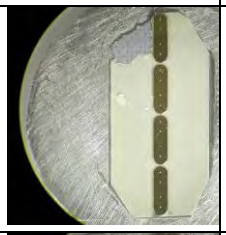
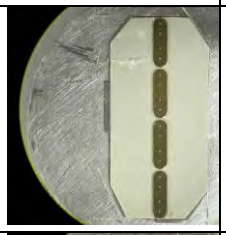
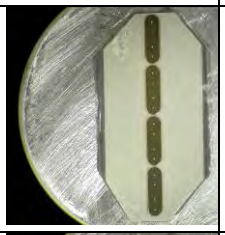
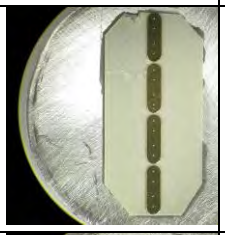
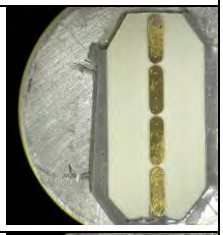
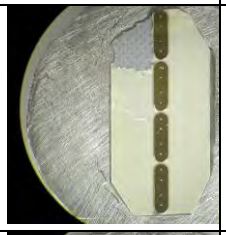
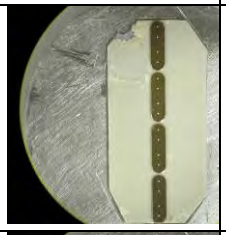
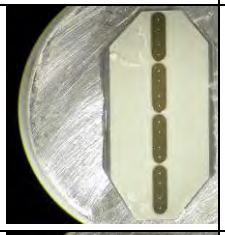
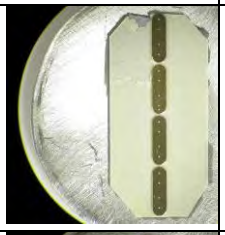
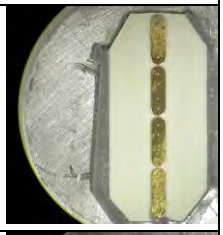
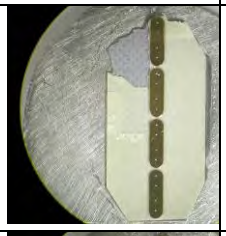
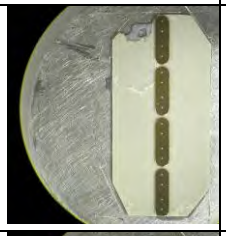
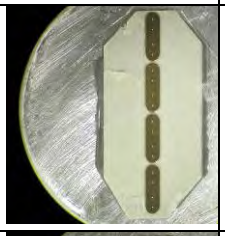
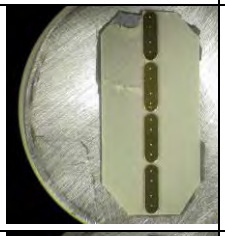
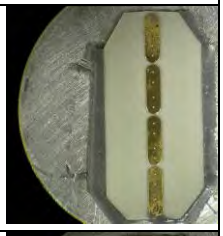
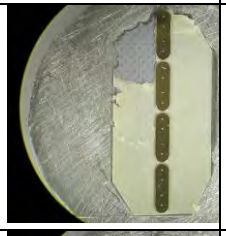
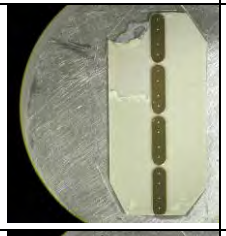
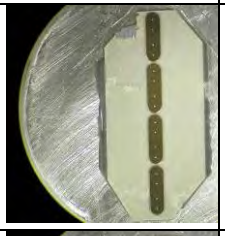
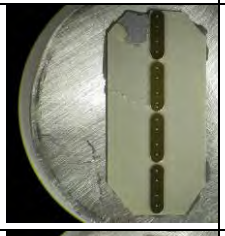
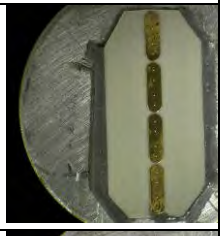
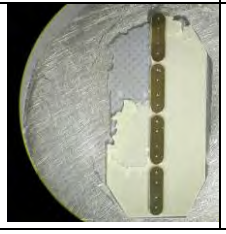
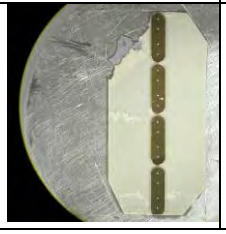
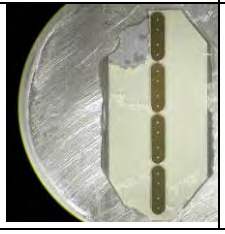
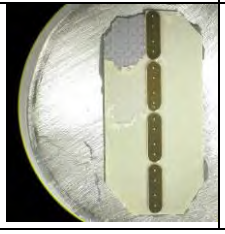
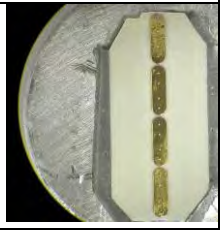
Table 3.1 Matrix of test specimens

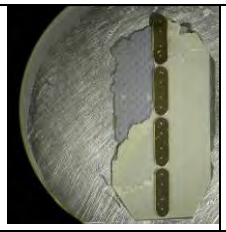
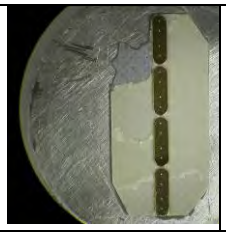
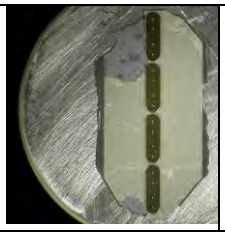
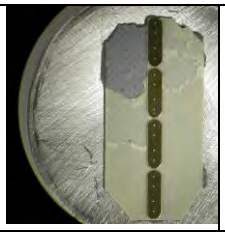
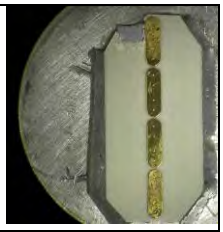
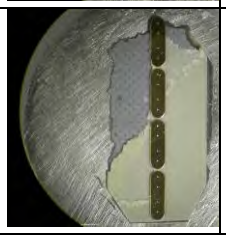
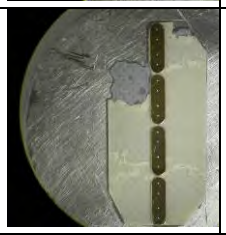
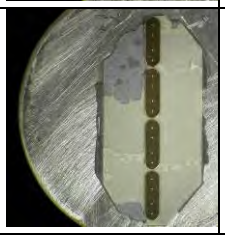
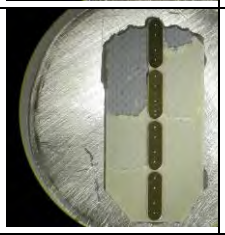
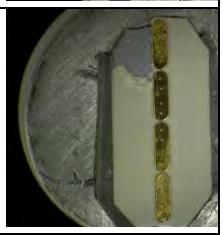
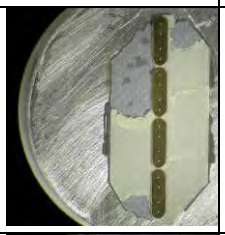
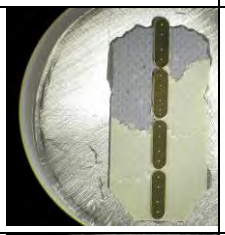
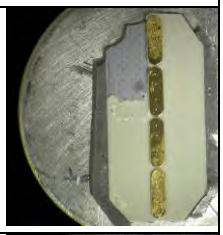
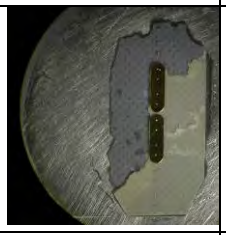
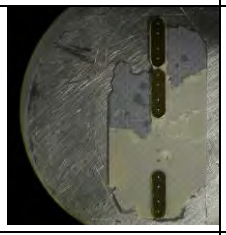
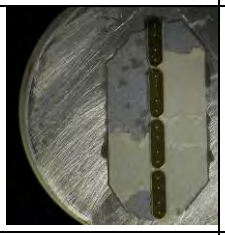
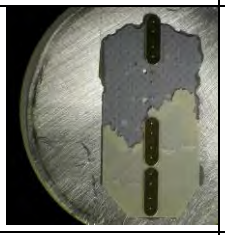
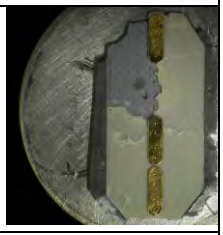
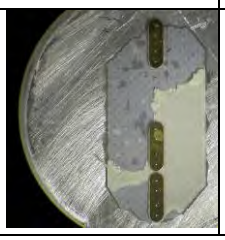
Specimen	1	2	3	4	5
WXGuard	W1	W2	W3	W4	W5
Competitor's product	L1	L2	L3	L4	L5

4. Results

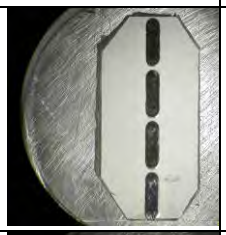
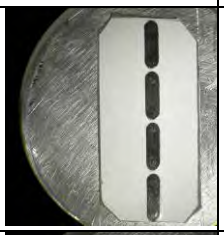
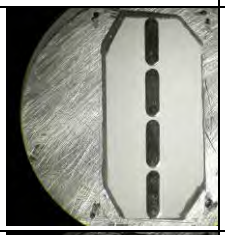
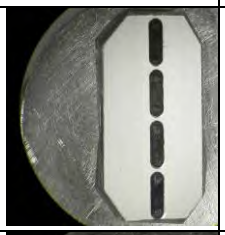
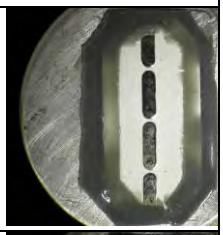
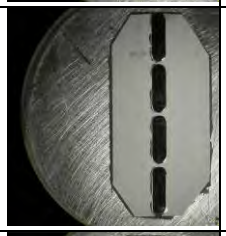
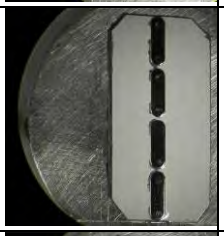
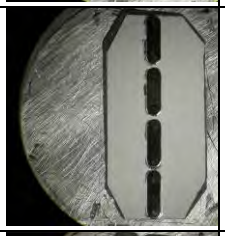
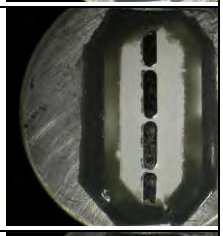
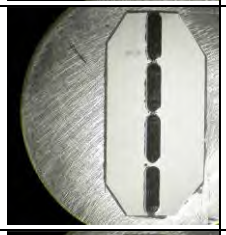
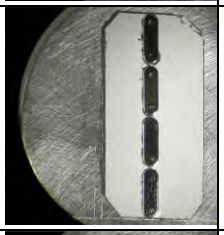
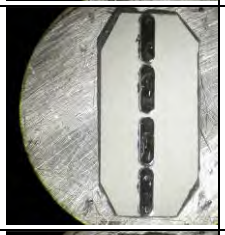
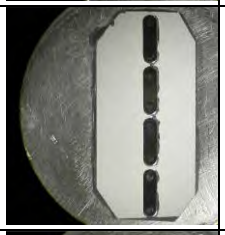
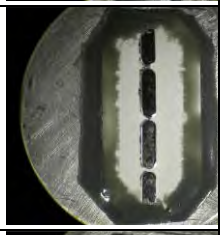
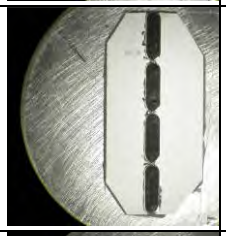
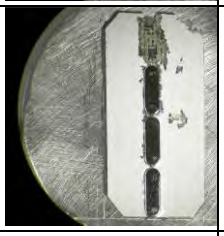
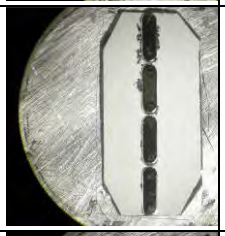
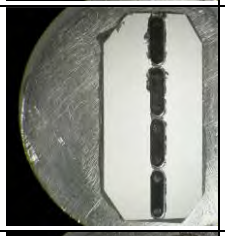
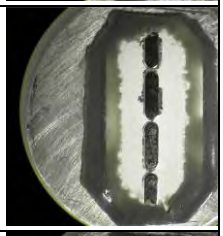
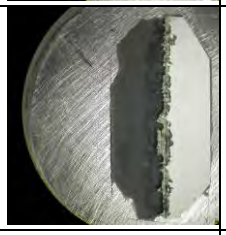
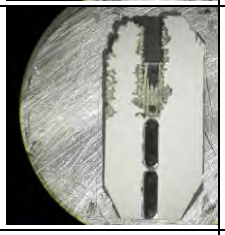
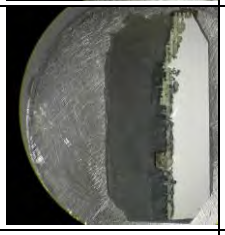
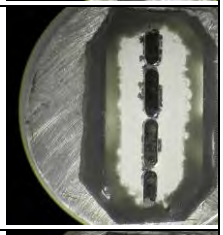
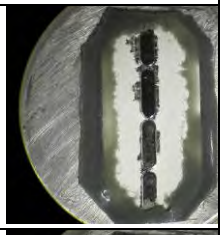
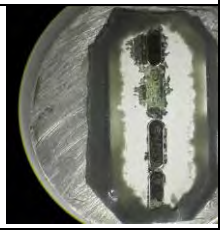
4.1 Test results: specimens W1-5

Duration	W1	W2	W3	W4	W5
0 min					
1 min					
2 min					
3 min					

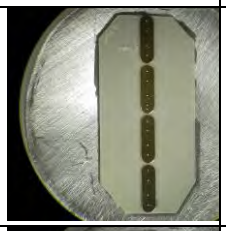
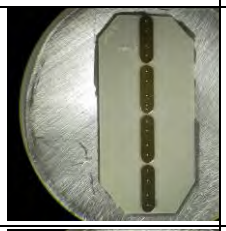
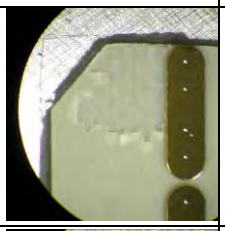
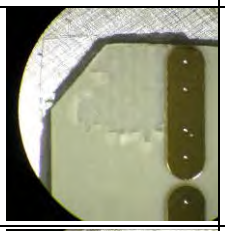
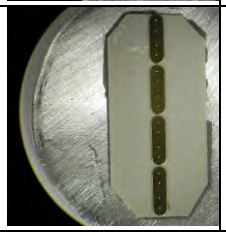
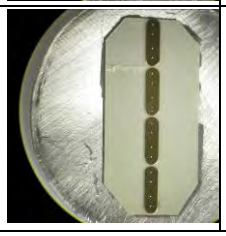
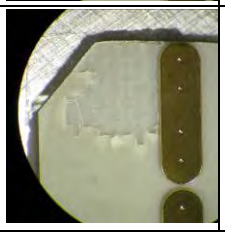
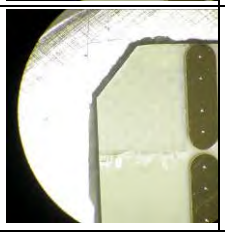
4 min					
5 min					
6 min					
7 min					
8 min					
9 min					
10 min					
12 min					

14 min					
16 min					
18 min	-	Test interrupted but no photo taken. Specimen still intact			
20 min					
22 min	-	-	Test interrupted but no photo taken. Specimen still intact	-	-
24 min					

4.2 Test results: specimens L1-5

Duration	L1	L2	L3	L4	L5
0 min					
1 min					
2 min					
3 min					
4 min		-			
5 min	-	-	-	-	
6 min	-	-	-	-	

4.3 Normal acceleration test

Duration	W4 no droplets	W4	W4 no droplets	W4	
Before					
After 1 min					

5. Discussion

The results of the above tests clearly show that the rain erosion resistance of the WXGuard specimens, W1-W5, is far superior to that of the competitor's specimens, L1-L5. The WXGuard specimens were seen to last 4 times longer in the simulated rainfall environment. The criteria used to indicate the end of the test was the removal of the lightning diverter buttons. It can be seen that 3 of the 5 competitor's specimens did not last beyond 3 minutes. Buttons were seen to be missing after 4 minutes testing in 4 of the 5 specimens. In comparison, WXGuard specimens lasted until 18 minutes intact. Four of the five specimens had failed after 20 minutes of testing.

The competitor's specimens L1-L5 were seen to fail in a number of ways. Firstly, the specimen laminate was seen to erode, in particular, around the buttons. This then led to either of two outcomes:

1. The loss of a one or two buttons at the top of the specimen where the erosion tends to be concentrated;

2. The failure of the laminate and the loss of all the buttons.

The second outcome is a much worse failure mode of the specimen. The L5 specimen was seen to last longer and this may have been due to the adhesive being placed around the periphery.

The WXGuard specimens W1-W5 showed a greater resistance to the droplet impact. These specimens tended to all fail in a similar way. The upper left corner of the specimens was the initiation site for the erosion of the laminate. The first layer was

then removed with the base layer proving harder to remove. The gold plated buttons were only removed when a large amount of the underlying laminate had been eroded. Specimen W5 showed little or no signs of damage and erosion initially but once the adhesive around the periphery was eroded, the laminated failed at a higher rate than the other specimens. It failed in the same time period as the other specimens, leaving an inconclusive result as to whether the extra adhesive would extend the in-service life of the specimen, as was shown with the L5 specimen.

A normal acceleration test was also carried out on specimen W4 and W5 with the results of W4 being photographed. These results show that the specimen did not deteriorate due to the normal acceleration force being placed on the specimens. The normal acceleration on the specimen was 27.6×10^3 m/s^2. The one minute interval without droplets after damage was initiated on the specimen showed no further progression of the damage. This compared with the subsequent one minute interval confirms that the damage was being caused by the droplet impacts.