Evaluation Report **Report No. AFRL/RXS 21-060**

Evaluation of Solvay's FusePly™ For Prebond Composite Surface Preparation (CRADA 17-307-RX-01 Task 2 Project 1)

27 December 2021

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AFRL-2022-0016

EXECUTIVE SUMMARY

Adhesive bonding processes must be repeatable and reliable for use in the aerospace industry, necessitating thorough and costly qualification testing. Driven by the need to find materials and processes that enable consistency, the Air Force Research Laboratory's Materials Integrity Branch (AFRL/RXSA) and The Boeing Company jointly investigated the use of Solvay's FusePly technology under CRADA 17-307-RX-01 (Task 2 Project 1). Use of FusePly™ has the potential to remove the defined interfaces found in cobonded and secondarily bonded joints, enabling more consistent bonded joint performance. If FusePly can eliminate interfacial failures and allow secondary bonds to be considered more like cocured joints, it could reduce the risk associated with bonded composite structures and, perhaps, allow certification authorities to more readily approve safety-of-flight bonded structures. AFRL/RXSA tested double lap shear specimens fabricated and provided by Boeing. Results show FusePly 100 has the potential to aid in creating consistent bonds, but significant further investigation is required.

ACKNOWLEDGEMENTS

This work was conducted as part of Task 2 Project 1, "Bonding Interfaces and Adhesives-FusePly™" under Cooperative Research and Development Agreement (CRADA) 17-307-RX-01, entitled "Collaborative Development of Process Models for Aerospace Thermosets, Thermoplastics, and Bonding Interfaces," which is an agreement between Boeing and the Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/RX). Gail Hahn, Robert Funke, Rozlyn Chambliss, and Daniel Ferriell from Boeing provided technical insight and supplied the fabricated specimens. Dalip Kohli and Len MacAdams from Solvay provided technical input and materials for specimen fabrication.

This work was conducted under Contract FA8650-17-5650, Task Order 0003, Project 3-036, by the University of Dayton Research Institute (UDRI) and Contract FA8650-14-2-5800, Project 0228, by the Strategic Ohio Council for Higher Education (SOCHE). Specimens were prepared and tested by Mike Nickell, Colton Meade, Corey Kondash, and Paul Childers of UDRI, and Kevin Tomlin of SOCHE. Kevin Tienda and Kara Storage (AFRL/RX) provided technical support along with Tara Storage (formerly AFRL/RX).

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1.0 BACKGROUND

The use of adhesive bonding in lieu of fasteners to join composite components enables advantages in manufacturing and design. Elimination of fasteners can lead to reduced manufacturing cost, optimized structures, and fewer parts. Adhesive joining benefits are realized due to reduced stress concentrations around holes and distribution of structural loads across a larger area as compared to traditional fastening methods. Additionally, adhesive joining can potentially reduce manufacturing flow time. However, the certification of bonded structures is challenging, in large part due to risks associated with defined interfaces in cobonded and secondarily bonded joints. Surface preparation is critical; if not sufficient, adhesion failure at one of these interfaces can cause structural failure at lower than expected loads. Documents such as the Federal Aviation Administration (FAA) Advisory Circular No. 20-107B, "Composite Aircraft Structure [1]," and the United States Department of Defense (DoD) Joint Service Specification Guide (JSSG)-2006, "Aircraft Structures [2]," state a qualified adhesive bonding process must be repeatable and reliable, leading to thorough and costly testing.

If the failure mode and strength of an adhesive joint are not consistent, it is challenging to design a bonded structure that can be relied upon for continued airworthiness; therefore, materials and processes (M&P) that enable consistency are essential. Solvay's FusePly™ technology has the potential to remove the defined interfaces found in cobonded and secondarily bonded joints and render them more like cocured joints. FusePly is a resin-rich (wet) peel ply that enables direct chemical bonding at the interface by providing chemically active epoxy functional groups on the bond surface. Thus, this new product appears to have the potential to help resolve a bonded joint concern for certification authorities. FusePly 100 is designed to be used with 350 °F-curing epoxy prepregs and adhesives[3].

The Boeing Company and the Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/RX) established Cooperative Research and Development Agreement (CRADA) 17-307-RX-01, entitled "Collaborative Development of Process Models for Aerospace Thermosets, Thermoplastics, and Bonding Interfaces" that includes "Bonding Interfaces and Adhesives" as Task 2, Project 1[4]. During the 2020 CRADA reporting year, Boeing fabricated FusePly double lap shear (DLS) specimens and provided them to AFRL/RX for testing. With support from the University of Dayton Research Institute (UDRI) and the Strategic Ohio Council for Higher Education (SOCHE), AFRL's Materials Integrity Branch (AFRL/RXSA) performed DLS testing in accordance with ASTM D3528 – 96 (2016)[5].

2.0 TEST MATRIX

Boeing provided 207 DLS specimens consisting of precured carbon-reinforced epoxy composite substrates adhesively bonded using 350 °F-curing epoxy adhesives. Some specimens were fabricated from Solvay Cycom® IM7/5320-1 substrates bonded with Solvay's FM® 309-1M (0.080 psf) film adhesive and others were manufactured from Hexcel HexPly® AS4/3501-6 substrates and Solvay's FM 300 (0.10 psf) film adhesive. The specimens were fabricated roughly in accordance with ASTM D3528 for Type B specimens, shown in Figure 1, with a gap between the two parent adherends, which were joined by straps bonded above and below.

Figure 1. DLS Specimen

Table 1 provides specimen M&P details, as well as temperatures for DLS testing. As can be seen, 12 different specimen configurations resulted from the combinations of substrate, adhesive, and surface preparation variables investigated.

Table 1: Test Matrix

Substrate Material	Adhesive	Surface Preparation	Parent Adherend Ply Orientation	Strap Ply Orientation	Test Conditions		
					CTD (-65 °F)	RTD (75 °F)	HTW (220 °F)
IM7/ 5320-1	FM 309-1M	Peel Ply and Sanding	$[90,0,90,0,45,-45]_{2s}$	$[45,-45,0,90,0,90]_s$	6	6	6
			$[0,90,0,90,45,-45]_{2s}$		6	6	6
			$[45,-45,0,90,0,90]_{2s}$		6	6	6
		FusePly	$[90,0,90,0,45,-45]_{2s}$	$[45,-45,0,90,0,90]_s$	6	6	6
			$[0,90,0,90,45,-45]_{2s}$		6	6	6
			$[45,-45,0,90,0,90]_{2s}$		6	6	6
AS4/ 3501-6	FM 300K	Peel Ply and Sanding	$[90,0,90,0,45,-45]_{2s}$	$[45,-45,0,90,0,90]_s$	6	6	6
			$[0,90,0,90,45,-45]_{2s}$		6	6	6
			$[45,-45,0,90,0,90]_{2s}$		3	3	3
		FusePly	$[90,0,90,0,45,-45]_{2s}$	$[45,-45,0,90,0,90]_s$	6	6	6
			$[0,90,0,90,45,-45]_{2s}$		6	6	6
			$[45,-45,0,90,0,90]_{2s}$		6	6	6

Notes: CTD – cold temperature dry
RTD – room temperature dry
HTW – hot temperature wet

2.1 Specimen Fabrication Details

Boeing's panel fabrication and bonding procedures differed for each material system and are detailed in the following sections. Figure 2 shows the configuration for bonded DLS panels. Nine 1-inch wide specimens were machined from each panel. The panels included two parent adherends (skins), 5 by 11 inches, consisting of 24 plies laid up in accordance with the specified ply orientation (Table 1). A 0.125-inch thick by 0.12-inch wide Teflon® insert placed between the two skins was used to control the gap size and prevented any adhesive squeezeout from entering the space. Two straps, 3.12 by 11 inches, were bonded to the skins. Metallic shims, 0.063-inch thick and at least 3.5 by 11 inches in dimension, were used to support the skins during bonding.

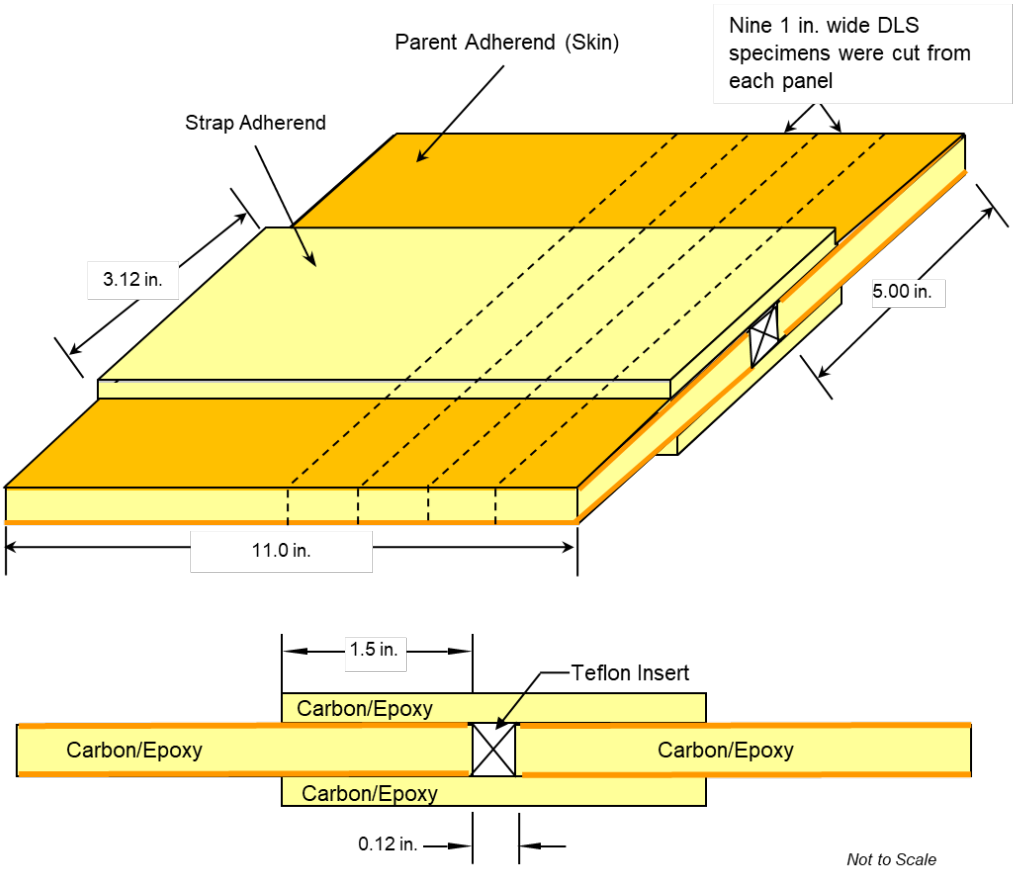

Figure 2. DLS Panel Configuration

2.1.1. IM7/5320-1/FM 309-1

Boeing provided 108 DLS specimens fabricated using IM7/5320-1 prepreg and FM 309-1M adhesive. These included baseline and FusePly specimens. The 0.080 psf areal weight adhesive was used for bonding because it is the highest weight available and was expected to provide better performance.

The baseline panel surface preparation used a wet peel ply with Cycom 5320-1 resin (Cycom 5320-1/Diatex 1500EV6). This material was incorporated as the outer plies of the skin and strap laminates and was cocured with the 5320-1 resin of the laminate following the cure cycle detailed in Table 2. After peel ply removal, bond surfaces were hand sanded using 120 to 240 grit abrasive paper to remove resin high spots and any gloss. Abraded surfaces were wiped with clean wipers (cheesecloth) or vacuumed to remove abrasion debris. New wipers were used for each pass, and wiping continued until no residue was visible on a new wiper.

FusePly panels were prepared for bonding by incorporating FusePly 100 (F100) as the outer plies of the skin and strap laminates, cocuring with the 5320-1 resin of the laminate following the cure cycle detailed in Table 2. Nothing further was done to prepare the FusePly bond surfaces other than keeping them protected from contamination prior to bonding.

After the bond surfaces of baseline and FusePly skins and straps had been prepared, FM 309-1M film adhesive was used to bond the straps to the skins following the same cure cycle used for the laminates (Table 2).

Table 2: IM7/5320-1 DLS Laminate Cure Cycle and FM 309-1 Bonding Cycle

1	Apply full vacuum of 24 in. Hg, minimum
2	Apply 30 ± 5 psig pressure
3	Heat at 3° F/min maximum free-air heat rate (minimum part heat-up rate of 0.5 °F/min) to 250 ± 10 °F (based upon coldest thermocouple). Begin hold period when coldest thermocouple reaches 240 °F.
4	Hold isothermally for 120 ± 5 min based on coldest thermocouple. Maintain full vacuum (20 in. Hg, minimum).
5	Heat at 0.5 -1° F per min (based on coldest thermocouple) to 350 ± 10 °F. Begin hold period when coldest thermocouple reaches 340 °F.
6	Hold at 120 ± 5 min. while maintaining 20 in. Hg vacuum, minimum.
7	Cool at 1-5 °F/min to 140 °F
8	Vent vacuum and positive pressure when part temperature is below 140 °F

2.1.2. AS4/3501-6/FM300

Boeing provided 99 DLS specimens fabricated with AS4/3501-6 prepreg and FM 300K adhesive on polyester tricot knit carrier (0.10 psf areal weight – the highest available). These included baseline and FusePly specimens. A dry polyester peel ply (Precision Fabrics 60001) was used to prepare skins and straps of baseline panels for adhesive bonding. After peel ply removal, bonding surfaces were hand sanded using 120 to 240 grit abrasive paper and wiped with clean wipers (cheesecloth) or vacuumed to remove abrasion debris. Wiping used new wipers for each pass and continued until no residue was visible on a new wiper.

FusePly panels were prepared for bonding by incorporating F100 as the outer plies of the skin and strap laminates, cocuring with the laminate 3501-6 resin following the cure cycle detailed in Table 3.

After the bond surfaces of baseline and FusePly skins and straps had been prepared, FM 300K film adhesive was used to bond the straps to the skins following the cure cycle provided in Table 4.

Table 3. AS4/3501-6 DLS Laminate Cure Cycle

1	Apply ≥10 in. of Hg vacuum
2	Apply 85 ± 5 psig pressure
3	Heat to 240 ± 10 °F in 20-120 min
4	Hold Isothermally for 65 ± 5 min
5	Increase pressure at 2.5 psig/min to 100 ± 5 psig while venting vacuum at 1-5 in. Hg/min
6	Heat to 350 ± 10 °F in 15-120 min
7	Hold isothermally for 375 ± 15 min
8	Cool to 200 °F in 30 min, minimum, under 10 psig, minimum
9	Vent positive pressure when part temperature is below 200 °F

Table 4. AS4/3501-6 DLS Bonding Cycle

1	Apply vacuum 9 ± 3 in. Hg
2	Apply 50 ± 5 psig pressure
3	Vent vacuum at 10 -5/+35 psig
4	Heat to 350 ± 10 °F in 35-200 min
5	Hold isothermally for 80 ± 20 min
6	Cool to 200 °F in 30 min, minimum, under 10 psig, minimum
7	Vent positive pressure when part temperature is below 200 °F

2.2 Mechanical Test Procedures

2.2.1. Double Lap Shear

DLS testing was conducted per ASTM D3528 on six specimens per configuration (with one exception, as shown in Table 1) under each of the following testing conditions: room temperature dry (RTD) at 75 ± 10 °F, cold temperature dry (CTD) at -65 ± 5 °F, and hot temperature wet (HTW) at 220 ± 5 °F.

For RTD testing, ambient laboratory temperature and humidity were reported at the time of the test. For test coupons designated for testing at CTD and HTW conditions, test specimen temperature was monitored using a thermocouple secured to the surface of the specimen at the overlap area. For HTW testing, the chamber and fixture were preheated to within ±10 °F of the specified test temperature before inserting the specimen. CTD specimens were placed in the test chamber at ambient laboratory temperature and cooled inside to within ±10 °F of the specified test temperature.

The test chamber could be preheated above or below the test temperature to accelerate specimen heating. Care was taken to prevent the specimen temperature from exceeding the desired test temperature by more than ±5 °F. When the specimen reached ±5 °F of the desired test temperature, temperature was maintained for 10 ± 3 minutes before testing, regardless of prior conditioning.

2.2.2. Moisture Conditioning Procedures for HTW Specimens

For HTW conditioning, specimens were dried and then placed in an environmental chamber at 160 ± 5 °F for the desired time and specified relative humidity (RH). Procedures for the two substrate types differed, with AS4/3501-6 specimens receiving additional conditioning (desorption phase) at 82% RH after conditioning at 95% RH. Details for the procedures are provided below.

2.2.2.1. IM7/5320-1 Substrates with FM 309-1M Adhesive

The IM7/5320-1 HTW specimens were dried for 6 days in an air-circulating oven at 220 ± 5 °F. After drying, the specimens were stored in a sealed MIL-B-131[6] moisture-proof bag at ambient conditions until ready for conditioning (about 1 day). The specimens were weighed and then placed into a 160 ± 5 °F and 95 ± 5 % RH humidity chamber for 30 days. Three specimens were designated for intermediate weight measurements, which were conducted at 7, 14, 21, 24, and 27 days. After 30 days of hot/wet conditioning, specimens were weighed, kitted by configuration, and then sealed in MIL-B-131 bags and stored at 0 °F, maximum, until ready for testing.

2.2.2.2. AS4/3501-6 Substrates with FM 300 Adhesive

The AS4/3501-6 HTW specimens were dried for 6 days in an air-circulating oven set at 220 ± 5 °F. After drying, the specimens were stored in a sealed MIL B-131 bag at ambient conditions until ready for the conditioning (about 1 day). The specimens were weighed and then placed into a 160 ± 5 °F and 95 ± 5% RH humidity chamber for 75 days. Three specimens were designated for intermediate weight measurements, which were conducted at 7, 14, 21, 28, 35, 40, 45, 50, 55, 60, 63, 66, 69, and 72 days. If these specimens had shown 1% weight gain, conditioning would have been discontinued before 75 days elapsed. After the first stage of conditioning, the humidity level in the chamber was lowered to 82 ± 5% RH, with temperature maintained at 160 ± 5 °F. The specimens remained in the chamber under these conditions for 25 days. The same specimens designated for intermediate weighing during the first stage were weighed during this phase at 5, 10, 15, and 20 days of conditioning, as well as at the completion of moisture conditioning at 25 days in the 82% RH chamber. After the conditioning, the specimens were sealed in MIL-B-131 moisture-proof bags and stored at 0 °F, maximum, until ready for testing.

Specimen weight measurements were taken as close to the proscribed intervals as possible. However, some adjustments were made to avoid taking measurements outside of standard workdays (i.e., weekends). The weight change data for the specimens over the conditioning periods are reported in Appendix A. The 5320-1 specimens with FusePly weighed approximately 2 grams more than those without, while the 3501-6 specimens with FusePly weighed approximately 4 grams more than those without.

3.0 RESULTS

This work focused on bond performance associated with the different surface preparation methods. For this reason, failure types and failure modes are arguably more important than the shear strengths generated from the DLS specimens, though failure details are not necessarily meaningful without knowledge of shear strength. Failed DLS joints were visually inspected, the location of the primary failure determined (if possible), and the observed failure modes for relevant lap joints recorded as a percentage, as discussed in the following sections. From the failure mode data, some observations on the performance of the use of FusePly as a composite prebond surface preparation could be made.

Along with the failure modes, the shear strengths of the bonded joints were calculated. Per ASTM D3528, the specimen dimensions, average bondline thicknesses, and peak loads were captured. When visual inspection could determine a primary failure location(s), the shear strength was calculated. Specimen photo documentation is provided in Appendix B and specimen datasheets can be found in Appendix C. The specimen IDs seen on the photographs are linked to the datasheets, where details can be found regarding surface preparation and testing, as well as bondline thicknesses, shear strengths, and failure modes for the individual specimens.

3.1.1. Failure Modes

There were three distinct modes in which the adhesively bonded DLS joints could fail:

- Cohesive (Coh) – failure within the adhesive bondline
- Laminate (Lam) – failure within a composite adherend (skin or strap)
- Interfacial (Int) – adhesion failure between a composite adherend and adhesive.

To understand the dominant failure mode for a specimen, the percentage of each type of failure over the bond area was calculated at the lap(s) that resulted in the primary failure. To measure the areas of cohesive and laminate failure, a 1/10 inch transparent grid was overlaid onto the bondline of the failed lap. The area of each failure mode was rounded to the nearest ½-grid cell. Using those area measurements, the percent area was calculated using the following:

$$Area\% = \frac{Sum\ of\ grid\ cells\ for\ failure\ mode\ of\ concern}{Total\ number\ of\ grids\ cells\ in\ bondline}$$

Given the cohesive and laminate failure areas, the area of interfacial failure was calculated as follows:

$$Area\%(Interfacial) = 100\% - Area\%(Cohesive) - Area\%(Laminate)$$

3.1.2. Types of Failure

In order to adequately describe failures and meaningfully discuss performance of the bonded joints, it was necessary to identify the four lap joints associated with each DLS specimen. These were labeled on each specimen, with the orientation presented in Figure 3. Lap 1 and Lap 2 are associated with one bonded strap, while Lap 3 and Lap 4 are formed by the other bonded strap. Typically, one of the lap joints will be the location of primary failure for a DLS specimen and be of most importance for analysis. In some cases, when the primary failure location could not be ascertained, multiple locations could be examined to understand failure mode and generate shear strength data.

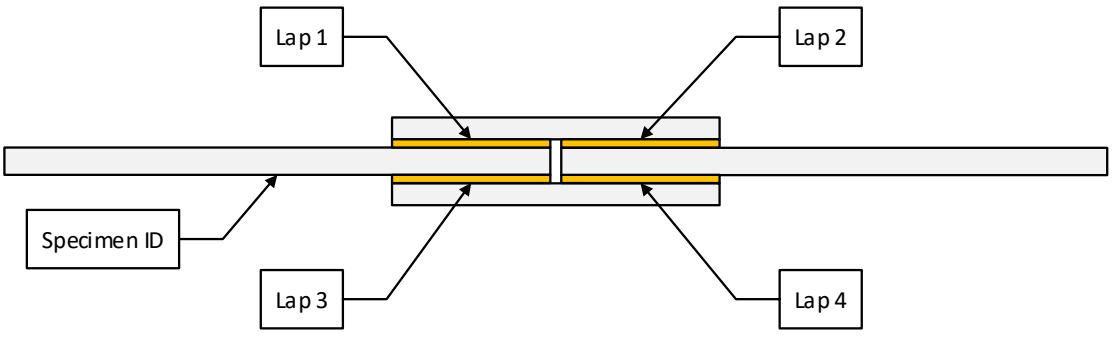

Figure 3. Specimen Orientation

Figure 4 illustrates the typical ways the joints came apart when loaded to failure. As can be seen, four different end states were observed and designated as types of failure. Type 1 failures were the most common and, by their nature, specimens exhibiting this failure type provided the most meaningful failure mode and shear strength data. Type 4 failures were also common and provided meaningful data. Type 3 failure specimens were much less common, but were used to generate shear strength data. Specimens exhibiting Type 2 failures were also much less common. These were the least informative and could not be used to generate shear strength data.

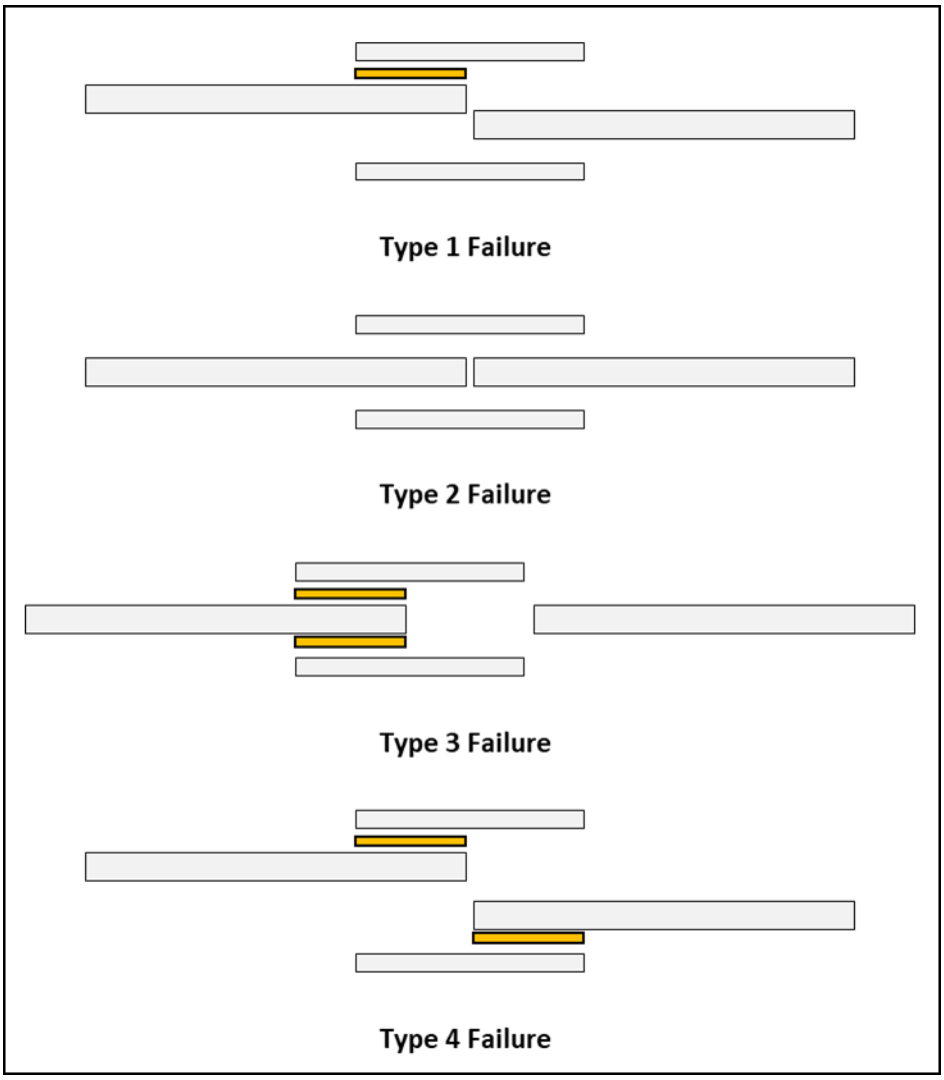

Figure 4. Types of Failures Seen in DLS Specimens

Type 1 failures have a lap joint that is readily identified as the primary failure location, which enables straightforward determination of failure mode and shear strength. As shown in Figure 5, failure at this primary joint overloads the strap on the opposite side of the specimen, causing it to separate. Failure mode information of interest is only associated with the primary failure location for these specimens, because the loading changes when the opposite-side strap separates

to create the two additional failed lap joints. The area associated with the primary failure lap joint can be used calculate shear strength.

The primary failure location could not be positively determined for failures other than Type 1. However, the two failed lap joints could be examined for Type 3 and Type 4 failures, and could often provide the necessary information. The areas associated with the two failed laps for specimens having these types of failures were averaged for determining shear strength of the specimen.

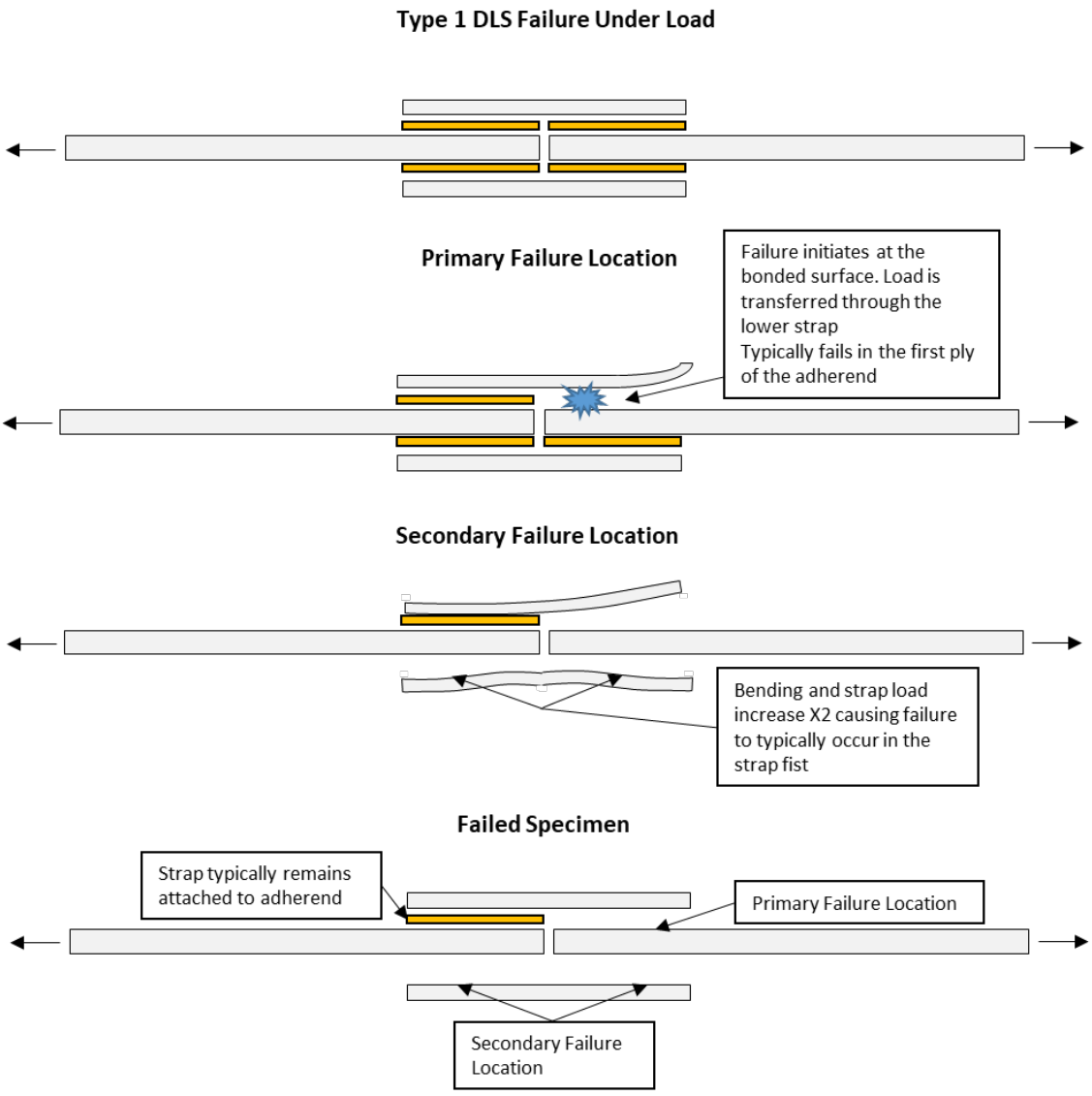

Figure 5. DLS Specimen with Type 1 Failure

3.2 Shear Strength Calculations

Specimen shear strength was calculated using the following equation:

$$F_{s1} = \frac{P}{LW}$$

where P is the load at failure, L is the sum of the length of the two lap joints associated with the failure, and W is the width of lap joint. For Type 1, where one lap joint is clearly the primary failure location and the opposite strap fails secondarily, the lap joint directly across from the primary lap was used to determine L in the equation (i.e., if Lap 3 was the primary failure lap, Lap 1 would be the adjacent lap, and the lengths of these two would be added – see Figure 3).

When the primary site of failure was positively known (Type 1 failures only), an additional method for calculating the shear strength was used. This calculation is reported in the datasheets but excluded from the summarized results for the sake of consistency since the summarized data also include results for specimens exhibiting Type 3 and Type 4 failures.

The alternative shear strength calculation method for Type 1 specimens used the following equation:

$$F_{s2} = \frac{0.5P}{L_c W}$$

where P is the load at failure, L_c is the length of the primary failure lap joint, and W is the width of lap joint.

3.3 Mechanical Tests

Datasheets for the various mechanical tests performed are provided in Appendix C. Summaries of the individual mechanical test results are provided in the following subsections. As mentioned in Section 3.1.2., identifying the primary failure site for specimens could be difficult. For this reason, shear strengths and failure mode calculations were not captured for some specimens. Those specimens have been excluded from the results summary and are noted.

3.3.1. Room Temperature Dry Double Lap Shear Tests

3.3.1.1. AS4/3501-6/FM 300

Specimens made from AS4/3501-6 composite substrates and FM 300 adhesive tested under RTD conditions mostly resulted in Type 1 failures. Only one F100 specimen for a substrate having a 0° outer ply orientation at the adhesive interface (0° surface ply) had a Type 2 failure, and three 90° surface ply baseline PPS specimens exhibited Type 4 failures. All tested specimens showed primarily laminate failure modes. However, the 0° surface ply baseline PPS specimens included some specimens with interfacial and laminate failure modes. An example of a failed specimen can be seen in Figure 6.

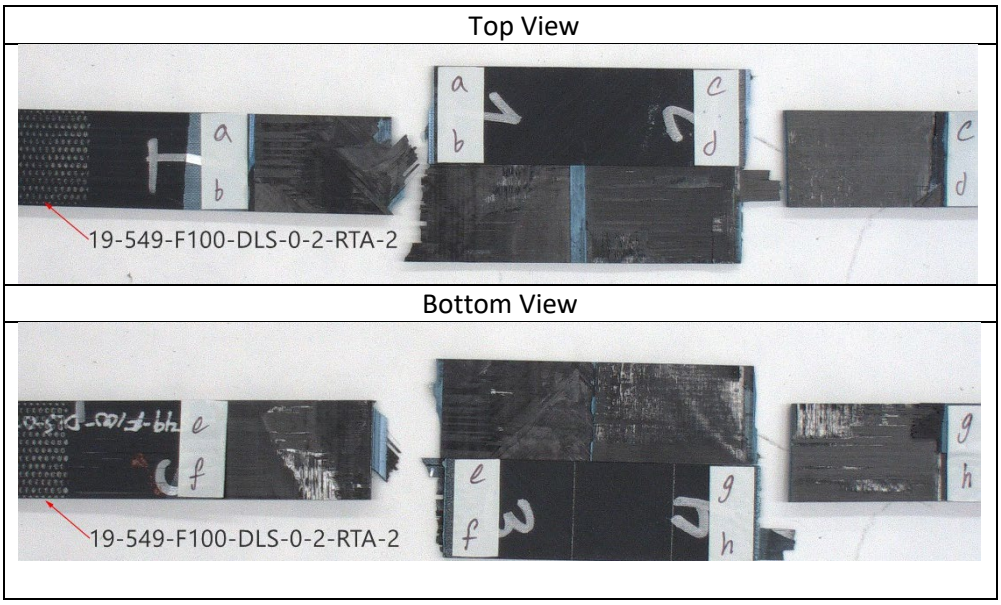

Figure 6. Example of a Failed AS4/3501-6/FM 300 DLS Specimen Tested at RTD

The average shear strength, bondline thicknesses, and failure mode percentages for these specimens are reported in Table 5 and Figure 7. Results for the 90° surface ply orientation exhibited the lowest average DLS strength.

Table 5. AS4/3501-6/FM 300 DLS Results Tested at RTD

Surface Ply Orientation/ Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0°/PPS	2033	0.0064	1	49	50
0°/F100	2696	0.0098	0	100	0
45°/PPS	2000	0.006	0	100	0
45°/F100	2225	0.0094	0	100	0
90°/PPS	1302	0.0067	0	100	0
90°/F100	1807	0.0096	0	100	0

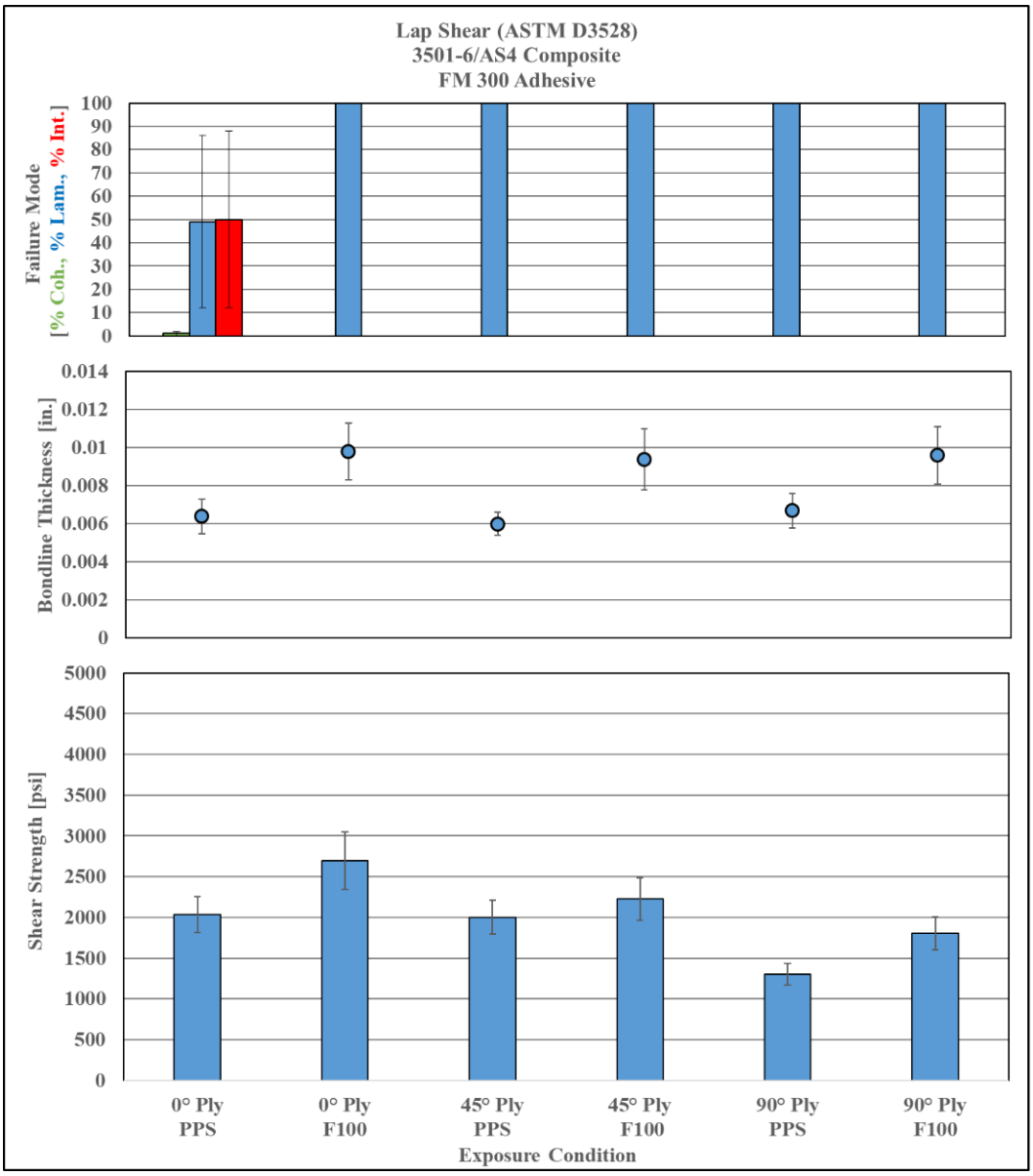

Figure 7. AS4/3501-6/FM 300 DLS Results for RTD

3.3.1.2. IM7/5320-1/FM 309-1

Results for specimens fabricated from IM7/5320-1 composite substrates bonded with FM 309-1 adhesive tested under RTD conditions showed the majority were of Type 1 failure. Testing of one 90° surface ply F100 specimen resulted in a Type 2 failure, and two 90° surface ply PPS specimens exhibited Type 4 failures. All Type 2 and Type 4 failures had laminate failure modes.

Testing under RTD conditions for all 90° surface ply IM7/5320-1/FM 309-1 specimens with both PPS and F100 surface preparations resulted in laminate failure modes. The 45° surface ply specimens exhibited primarily laminate failure mode with some cohesive failure. The 0° surface ply specimens exhibited different failure modes for the two surface preparation methods, with those prepared via the baseline PPS showing larger variation in failure modes. For 0° surface ply specimens using F100 surface preparation, the failures were primarily cohesive in nature. Figure 8 shows a typical example of a Type 1 failure for a 45° surface ply PPS specimen.

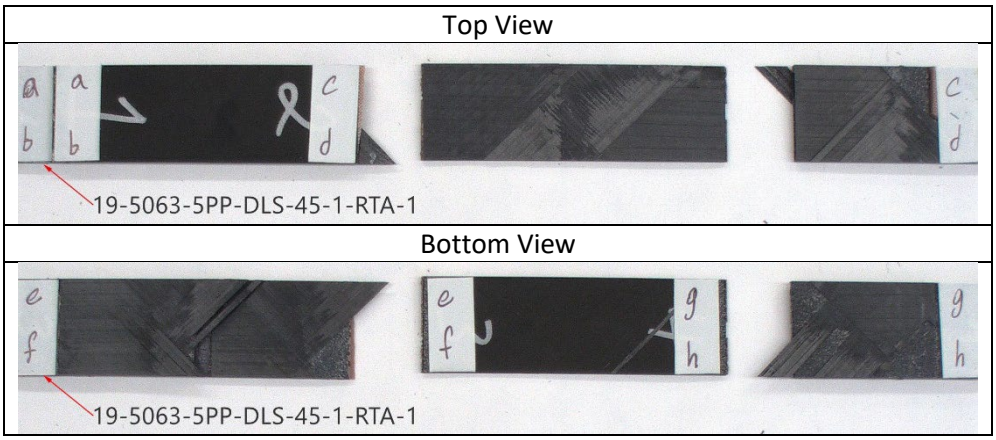

Figure 8. Example of a Failed IM7/5320-1/FM 309-1 DLS Specimen Tested at RTD

The average shear strength, bondline thicknesses, and failure mode percentages are reported in Table 6 and Figure 9. The shear strength could not be calculated for the one 90° surface ply F100 Type 2 failure specimen and was excluded from the average. The 90° surface ply specimens yielded the lowest average DLS strength. The F100 specimens exhibited the least scatter in the results.

Table 6. IM7/5320-1/FM 309-1 DLS Results Tested at RTD

Surface Ply Orientation/ Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0°/PPS	3851	0.0053	59	15	26
0°/F100	3878	0.0081	99	1	0
45°/PPS	3405	0.0052	8	92	0
45°/F100	2926	0.0088	4	96	0
90°/PPS	1544	0.0058	0	100	0
90°/F100	1845	0.0093	0	100	0

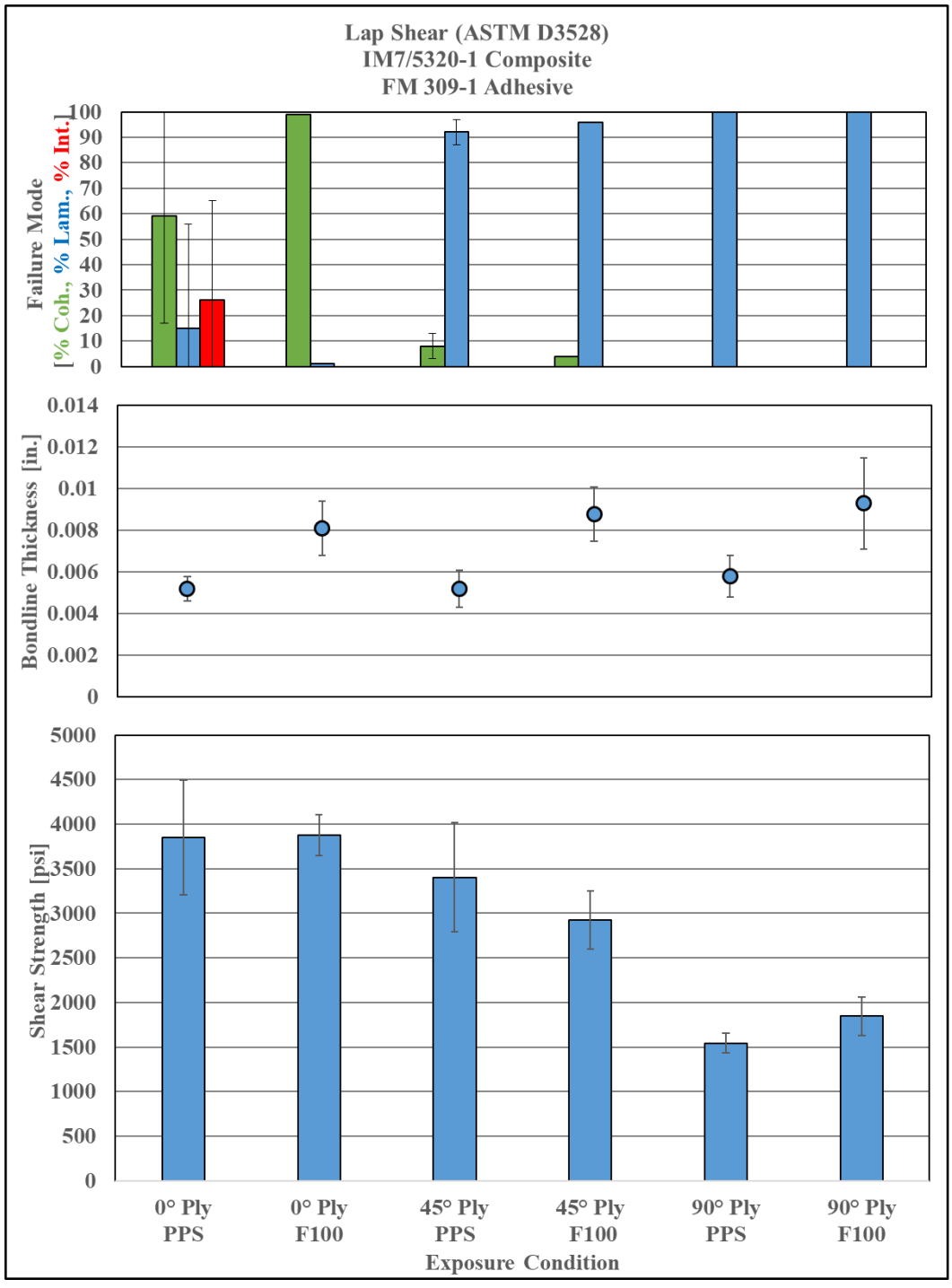

Figure 9. Graph of IM7/5320-1/FM 309-1 DLS Results Tested at RTD

3.3.2. Hot Temperature Wet Double Lap Shear Tests

3.3.2.1. AS4/3501-6/FM 300

Testing of AS4/3501-6/FM 300 panels at HTW yielded primarily Type 1 failures. Type 4 failure was observed in one 0° surface ply F100 specimen that had inconsistent failure modes between the two failed laps, so it was excluded from the summery data but can be seen in the datasheets. The results showed primarily cohesive failure for 0°, 45°, and 90° surface ply specimens prepared with F100. The baseline PPS specimens yielded more interfacial and laminate failures. Figure 10 is an example of a Type 1 failure for a 0° surface ply PPS specimen.

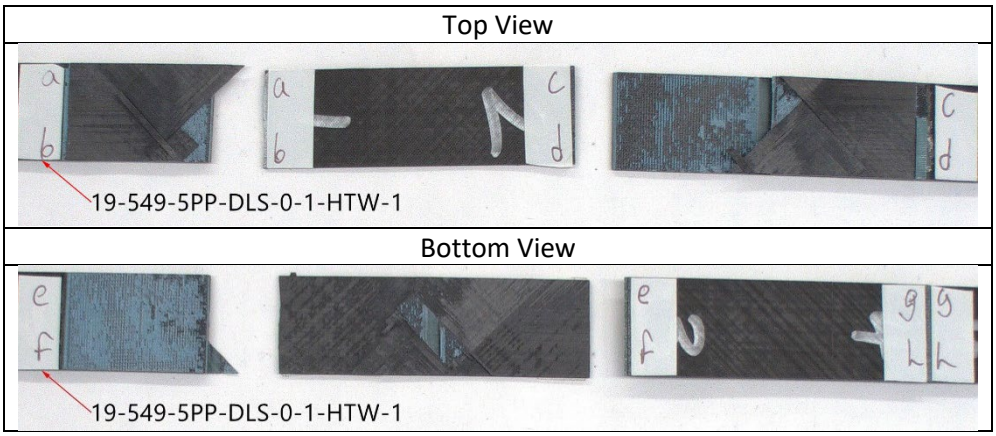

Figure 10. Example of a Failed AS4/3501-6/FM 300 DLS Specimen Tested at HTW

The average shear strength, bondline thicknesses, and failure mode percentages for these specimens are reported in Table 7 and Figure 11. The F100 specimens yielded lower strengths than their PPS counterparts, with the 45° surface ply orientation specimens prepared for bonding using F100 having the lowest average DLS strength.

Table 7. AS4/3501-6/FM 300 DLS Results Tested at HTW

Surface Ply Orientation/Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0°/PPS	2942	0.0061	23	12	65
0°/F100	2443	0.009	84	0	16
45°/PPS	3122	0.0061	11	29	60
45°/F100	2371	0.0087	91	0	9
90°/PPS	3009	0.0065	4	88	8
90°/F100	2506	0.0091	85	12	3

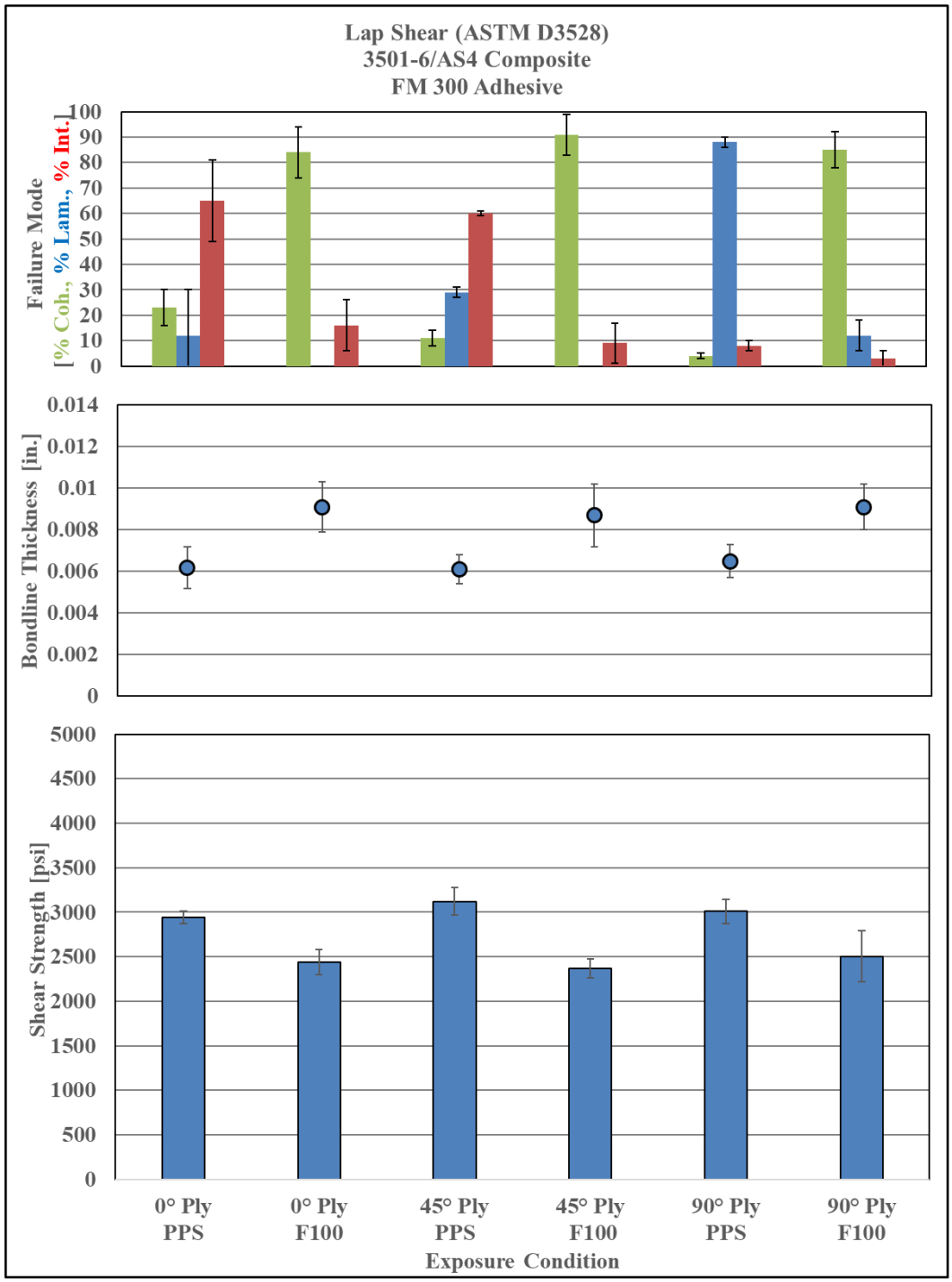

Figure 11. Graph of AS4/3501-6/FM 300 Results Tested at HTW

3.3.2.2. IM7/5320-1/FM 309-1

Specimens fabricated from IM7/5320-1 bonded with FM 309-1 adhesive primarily exhibited Type 1 failures. Three 0° surface ply F100 specimens failed in Type 3, with inconsistent failure modes between laps, and were excluded from the summery table but are reported in the datasheets. Test specimens exhibited large percentages of cohesive failure for the 0° surface ply orientation with both PPS and F100 surface preparations when tested at HTW. For the 45° surface ply orientation, the PPS-prepared specimens showed more cohesive failure than those prepared for bonding using F100. In the 90° surface ply orientation, laminate failure was predominant. Figure 12 shows an example of a Type 1 failure for a 0° surface ply PPS specimen.

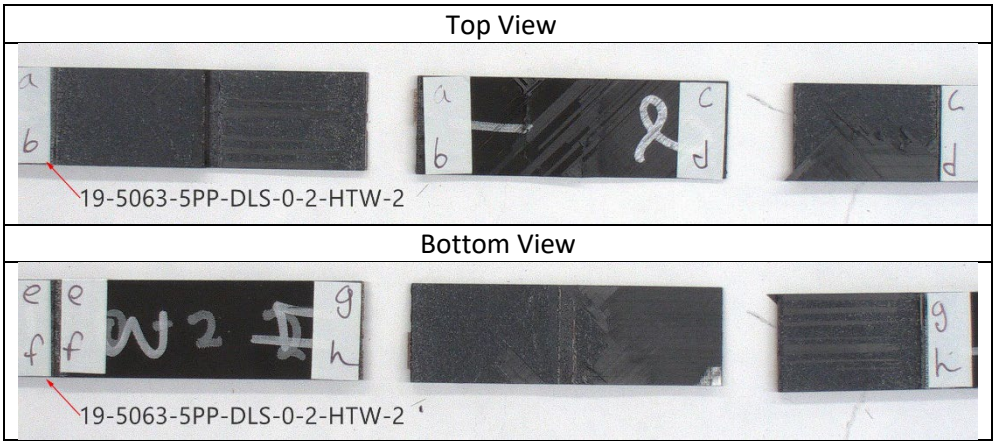

Figure 12. Example of a Failed IM7/5320-1/FM 309-1 DLS Specimen Tested at HTW

The average shear strength, bondline thicknesses, and failure mode percentages for these specimens are reported in Table 8 and Figure 13. The 90° surface ply orientation yielded the lowest average DLS strength.

Table 8. IM7/5320-1/FM 309-1 DLS Results Tested at HTW

Surface Ply Orientation/Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0°/PPS	4130	0.0054	92	8	0
0°/F100	3908	0.0083	79	0	21
45°/PPS	3881	0.0054	74	26	0
45°/F100	4034	0.0084	28	66	6
90°/PPS	3518	0.006	3	97	0
90°/F100	3667	0.0086	6	94	0

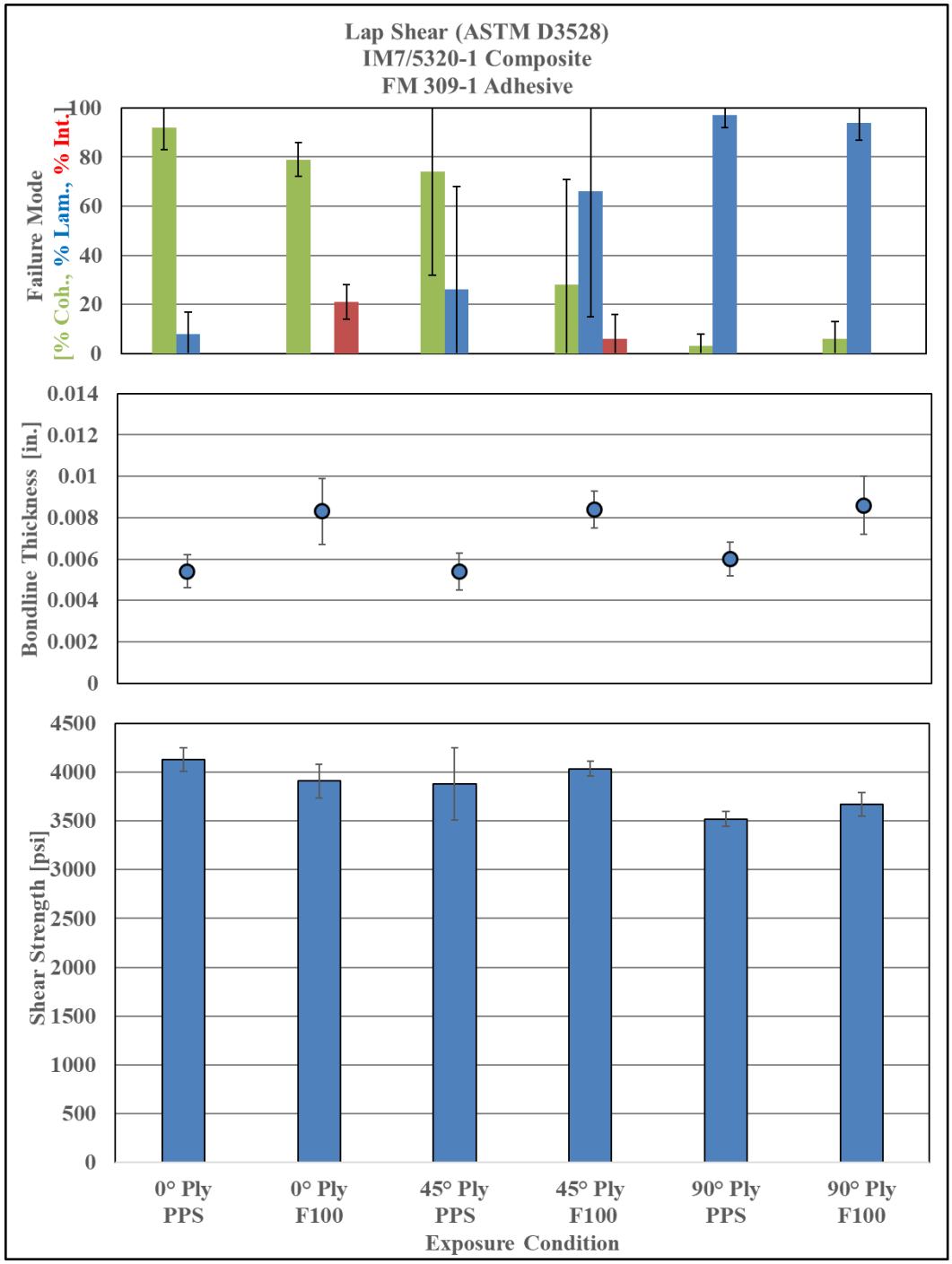

Figure 13. Graph of IM7/5320-1/FM 309-1 Results Tested at HTW

3.3.3. Cold Temperature Dry Double Lap Shear Tests

3.3.3.1. AS4/3501-6/FM 300

Predominantly laminate failure modes were observed for CTD specimens fabricated from AS4/3501-6 composite panels bonded using FM 300 adhesive. Some interfacial failure was observed for the 0° surface ply configuration when PPS was the surface preparation. Most tests resulted in Type 1 failures; however, there were a higher number of Type 4 and Type 2 failures for the CTD condition than for other temperature conditions. Type 3 and Type 4 failures were seen in two 0° surface ply PPS specimens with inconsistent failure modes between failed laps, so these have been excluded from the results summary. Three 45° and four 90° surface ply PPS specimens had Type 3 and Type 4 failures. One 0° surface ply F100 specimen failed in Type 2 and one 90° surface ply F100 specimen failed in Type 4. These specimens all showed laminate failure. Figure 14 shows an example of a Type 1 failure for one of these specimens.

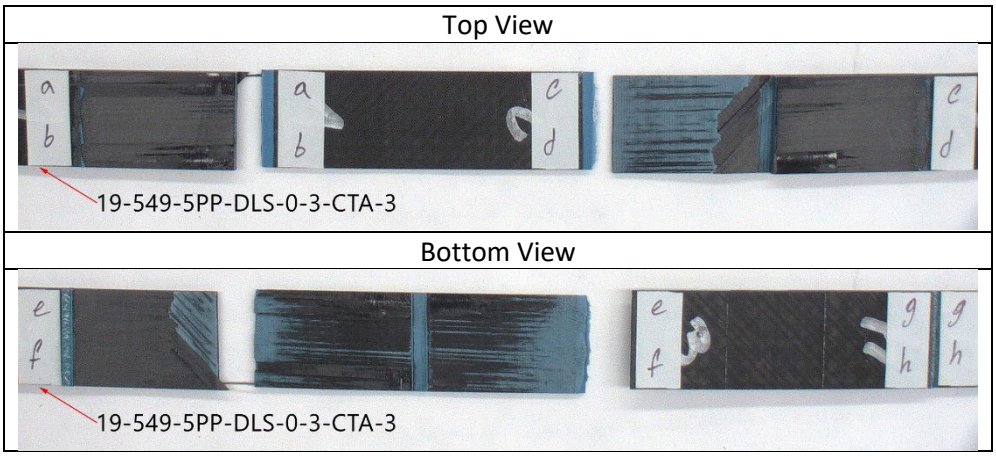

Figure 14. Example of a Failed AS4/3501-6/FM 300 DLS Specimen Tested at CTD

The average shear strength, bondline thicknesses, and failure mode percentages for these specimens are reported in Table 9 and Figure 15. The 90° surface ply orientation yielded the lowest average DLS strength. Average shear strength for the F100 specimens with 0° surface ply orientation was significantly higher than that of the 0° surface ply PPS baseline.

Table 9. AS4/3501-6/FM 300 Results Tested at CTD

Surface Ply Orientation/ Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0°/PPS	1539	0.0065	0	79	21
0°/F100	2184	0.0092	0	100	0
45°/PPS	1653	0.0058	0	100	0
45°/F100	1848	0.0077	0	100	0
90°/PPS	1261	0.0063	0	100	0
90°/F100	1377	0.0096	0	100	0

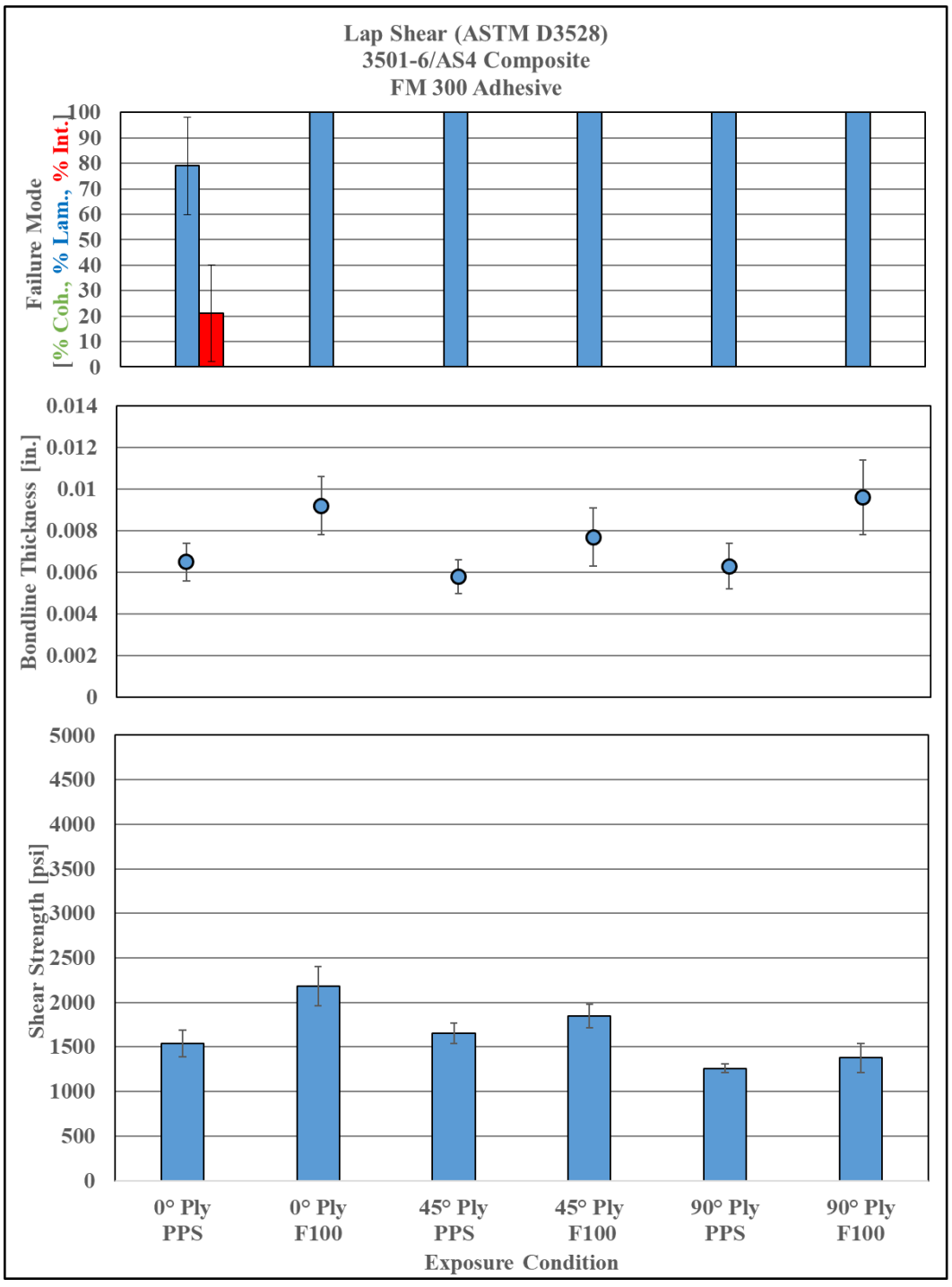

Figure 15. Graph of AS4/3501-6/FM 300 Results Tested at CTD

3.3.3.2. IM7/5320-1/FM 309-1

Testing at CTD for specimens fabricated from IM7/5320-1 composite bonded with FM 309-1 adhesive resulted in predominantly interfacial failure modes for the 0° surface ply orientation and nearly 100 percent laminate failures for the 45° and 90° surface ply specimens.

As was the case for AS4/3501-6/FM 300 specimens, a higher number of IM7/5320-1/FM 309-1 specimens failed in other ways than Type 1 for the cold testing condition. Three 0° surface ply F100 specimens exhibited Type 2 failures and had inconsistent failure modes between laps, so these were excluded from the failure mode results summary. One 90° surface ply F100 specimen also yielded a Type 2 failure, but resulted in laminate failure modes for both failed lap joints. One 90° surface ply PPS specimen had a Type 3 failure with laminate failure modes. Figure 15 provides an example of a Type 1 failure for a 0° surface ply F100 specimen.

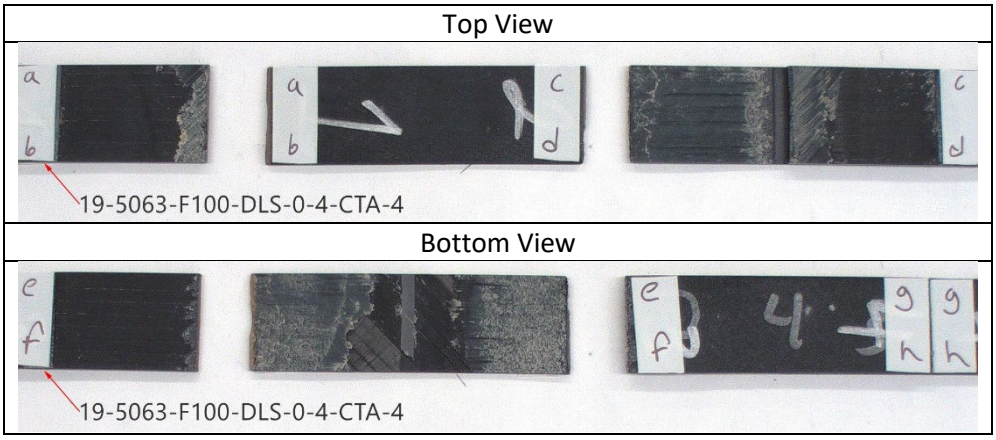

Figure 16. Example of a Failed IM7/5320-1/FM 309-1 DLS Specimen Tested at CTD

The average shear strength, bondline thicknesses, and failure mode percentages for these specimens are reported in Table 10 and Figure 17. The 90° surface ply orientation yielded the lowest average DLS strength. Average shear strength for the F100 specimens with 0° surface ply orientation was appreciably higher than that of the 0° surface ply PPS baseline, but significant scatter was seen for these F100 specimen DLS results.

Table 10. IM7/5320-1/FM 309-1 Results Tested at CTD

Surface Ply Orientation/Preparation	Average Strength [psi]	Average Bondline Thickness [in.]	Failure Mode		
			[% Coh]	[% Lam]	[% Int]
0° /PPS	1944	0.0052	5	0	95
0° /F100	2773	0.0078	15	0	85
45° /PPS	2155	0.0055	5	95	0
45° /F100	2163	0.0080	1	99	0
90° /PPS	1279	0.0056	0	100	0
90°/F100	1470	0.0090	0	100	0

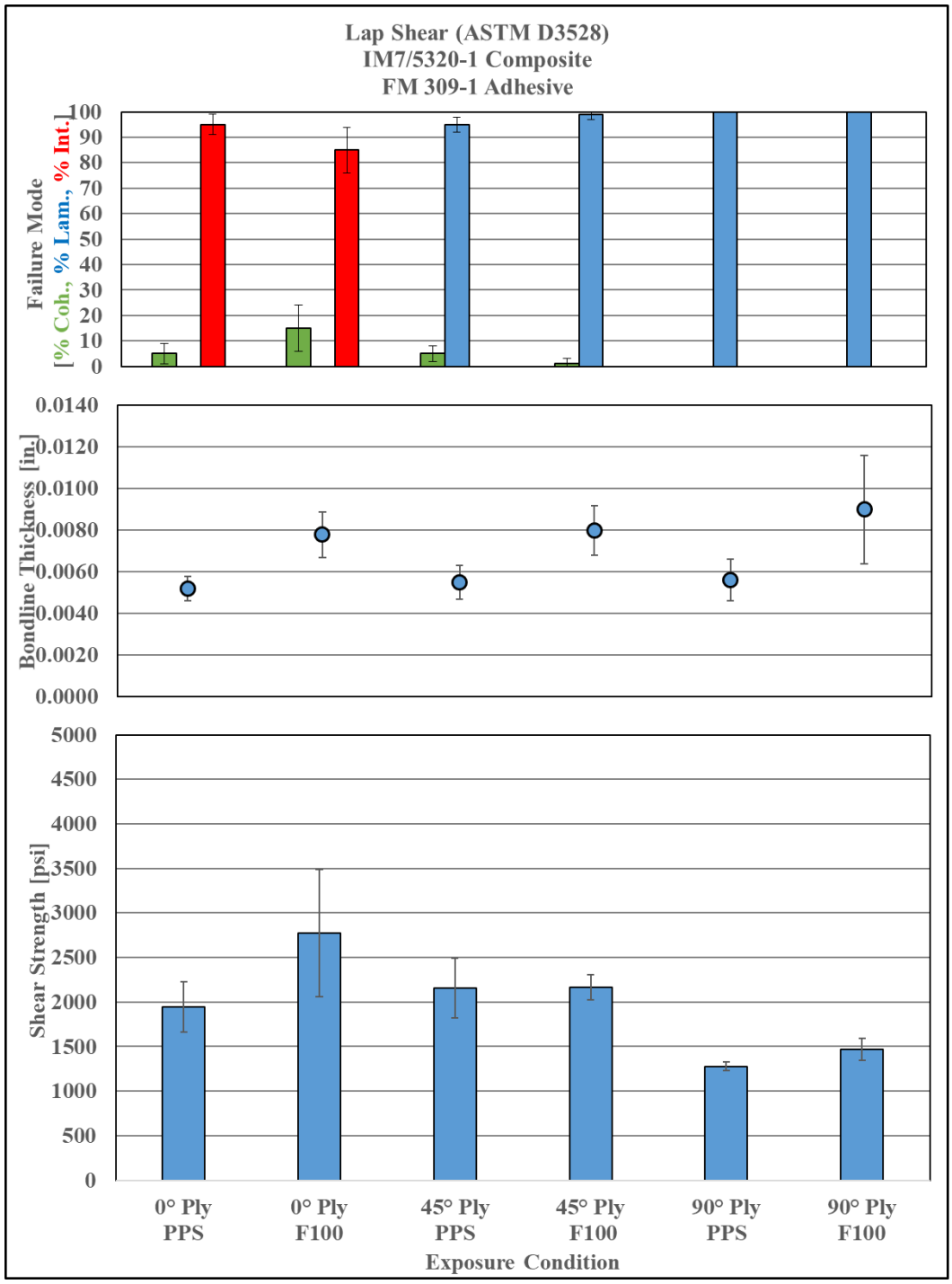

Figure 17. Graph of IM7/5320-1/FM 309-1 Results Tested at CTD

4.0 CONCLUSIONS

AFRL/RXSA tested 207 DLS specimens provided by Boeing. These included specimens with three different surface ply orientations (0°, 45°, and 90°) and two prebond surface preparations. The primary intent was to evaluate FusePly 100 resin-rich peel ply for surface preparation, which was compared to a baseline peel ply and sand approach. The results of this initial investigation indicate Solvay's FusePly technology could prove to be a robust composite surface preparation method. Shear strengths generated by F100 specimens were comparable to those from baseline specimens. For the most part, F100 specimens yielded more consistent failure modes, with fewer interfacial failures, when compared to the baseline PPS surface preparation. However, DLS testing did not clearly show the use of FusePly can eliminate airworthiness authority concerns about secondary bonding since some F100 specimens exhibited an appreciable amount of interfacial failure.

5.0 RECOMMENDATIONS

AFRL recommends further investigation of FusePly technology as a composite prebond surface preparation method. A closer examination of the interface created between a composite laminate with FusePly and the adhesive should be undertaken to better understand adhesion using this surface preparation approach. Though DLS or similar testing is usually required for design and structural analysis purposes, shear loading is generally not the most sensitive to interfaces or surface preparation variations. Other tests, such as double cantilever beam (DCB) with Mode I loading, should be conducted to better assess FusePly interfaces. These tests should include specimens with varying surface ply orientations, multiple test temperatures, and baseline surface preparation controls. An investigation of acceptable time limits between treatment and bonding would also be valuable.

Before FusePly or any new surface preparation can be implemented, application-specific testing must be conducted using the composite substrates and adhesive specified for the particular application processed as would occur for the application.

REFERENCES

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3. L. MacAdams and D. Kohli, “Development of a New Bonding Technology to Create Reliable Bonds. Fuseply™, Part 1,” Society for the Advancement of Material and Process Engineering (SAMPE) Conference Proceedings, Long Beach, CA, May 21-24, 2018.

4. T. Storage and G. Hahn, “Collaborative Development of Process Models for Aerospace Thermosets, Thermoplastics, and Bonding Interfaces,” USAF CRADA Number 17-307-RX-01.01, 05 February 2019.

5. ASTM D3548-96 (2016), “Standard Test Method for Strength Properties of Double Lap Shear Adhesive Joints by Tension Loading,” ASTM International, West Conshohocken, PA, 1996.

6. MIL-B-131, Military Specification: Barrier Materials, Watervaporproof, Greaseproof, Flexible, Heat-Sealable, Department of Defense, 1987.

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Systems Support Division
Materials and Manufacturing Directorate

APPENDIX A

Moisture Conditioning Datasheets

Project Number	3-036		**BOEING/AFRL CRADA**
Project Title	Boeing/AFRL CRADA - FusePly Eval.		**Moisture Conditioniong**
Test Engineer			
Ref. Document	USAF CRADA No. 17-307-RX-01		
Specimen Pedigree:	Adherend Type	AS4 / 3501-6 **(Base ID: 19-549)**	**Notes** Specimens weighed to nearest 0.0001g
	Adhesive	FM 300	Dryback started: 09/03/2020 @1249
			Conditioning Started: 09/09/2020 @0836
Test Conditions:	Dry Back	220 ± 5°F; 3 days (+4 hrs, -0)	Stage 2 conditioning Started: 11/23/2020 @1010
	Moist. Cond. (Stage 1)	160 ± 5°F / 95 ± 5 %RH	
	Moist. Cond. (Stage 2)	160 ± 5°F / 82 ± 5 %RH	
Measurement Device:	Balance (Model#):	Mettler Toledo XS205 (PMEL K054914)	
	Balance Accuracy:	±0.0001 g	

Specimen ID	W_{ar} [g]	W_b [g]	W_{MC1} [g]	W_{MC2} [g]
PPS-DLS-90-1-HTW-1	43.7231	43.6537	44.0552	44.0586
PPS-DLS-90-2-HTW-2	44.0409	43.9741	44.3851	44.3829
PPS-DLS-90-3-HTW-3	44.3409	44.2745	44.6730	44.6795
PPS-DLS-90-4-HTW-4	43.5763	43.5094	43.8972	43.9019
PPS-DLS-90-3-HTW-5	44.1243	44.0602	44.4551	44.4616
PPS-DLS-90-3-SP-3	42.3570	42.2982	42.6644	42.6681
PPS-DLS-0-1-HTW-1	44.8894	44.8169	45.2350	45.2339
PPS-DLS-0-2-HTW-2	44.1515	44.0817	44.4855	44.4882
PPS-DLS-0-3-HTW-3	44.6236	44.5466	44.9700	44.9695
PPS-DLS-0-4-HTW-4	43.5100	43.4440	43.8180	43.8220
PPS-DLS-0-3-HTW-5	44.7854	44.7085	45.1374	45.1421
PPS-DLS-0-3-SP-3	41.1830	41.1211	41.4795	41.4797
PPS-DLS-45-2-HTW-2	45.2944	45.2192	45.6650	45.6679
PPS-DLS-45-3-HTW-3	45.2707	45.1931	45.6397	45.6412
PPS-DLS-45-3-HTW-5	44.8351	44.7589	45.1921	45.11947
Average	44.0470	43.9773	44.3835	44.3811
Std. Dev	1.1032	1.0983	1.1232	1.1195
CoV [%]	2.5046	2.4973	2.5308	2.5226

Specimen ID	W_{ar} [g]	W_b [g]	W_{MC2} [g]	W_{MC2} [g]
F100-DLS-90-1-HTW-1	48.5028	48.3935	48.9329	48.9282
F100-DLS-90-2-HTW-2	48.2255	48.1199	48.6501	48.6481
F100-DLS-90-3-HTW-3	48.8850	48.7749	49.3258	49.3199
F100-DLS-90-4-HTW-4	47.7054	47.6017	48.1207	48.1183
F100-DLS-90-3-HTW-5	47.4555	47.3531	47.8654	47.8623
F100-DLS-90-3-SP-3	47.4262	47.3230	47.8399	47.8348
F100-DLS-0-1-HTW-1	48.4202	48.3109	48.8565	48.8370
F100-DLS-0-2-HTW-2	49.1386	49.0261	49.5850	49.5692
F100-DLS-0-3-HTW-3	48.4722	48.3641	48.9038	48.8848
F100-DLS-0-4-HTW-4	48.8262	48.7145	49.2638	49.2461
F100-DLS-0-3-HTW-5	47.8368	47.7315	48.2553	48.2482
F100-DLS-0-3-SP-3	47.8822	47.7806	48.2847	48.2745
F100-DLS-45-1-HTW-1	48.6935	48.5749	49.1303	49.1206
F100-DLS-45-2-HTW-2	49.0135	48.8957	49.4580	49.4534
F100-DLS-45-3-HTW-3	49.8346	49.7117	50.2895	50.2859
F100-DLS-45-4-HTW-4	48.9376	48.8136	49.3727	49.3659
F100-DLS-45-3-HTW-5	49.4763	49.3545	49.9262	49.9121
F100-DLS-45-3-SP-3	47.6837	47.5720	48.1015	48.0984
Average	48.4675	48.3565	48.8979	48.8893
Std. Dev	0.6994	0.6934	0.7135	0.7116
CoV [%]	1.4431	1.4339	1.4591	1.4555

W_{ar} = as-received specimen weight before drying [g]

W_b = Baseline specimen mass; mass of specimen after drying (exposure time = 0), [g]

W_i = Current mass of specimen after exposure to environment at exposure time i, [g]

ΔM= Mass change [%]

ΔM_{norm} =Normalized instantaneous mass change

W_{mc1} = Final weight of specimen after stage 1 moisture conditioning [g]

W_{mc2} = Final weight of specimen after stage 2 moisture conditioning [g]

$$\Delta M[\%] = \frac{(W_i - W_b)}{W_b} * 100$$

$$\Delta W_{norm}[\%] = \frac{|W_i - W_{i-1}|}{W_b}$$

Project Number	3-036	**BOEING/AFRL CRADA**	
Project Title	Boeing/AFRL CRADA - FusePly Eval.	**Moisture Conditioniong**	
Test Engineer			
Ref. Document			
Specimen Pedigree:	Adherend Type	IM7 / 5320-1	**Notes** Specimens weight to nearest 0.0001g
	Adhesive	FM 309-1	Dryback Started: 09/03/2020 @1300
Test Conditions:	Dry Back	220 ± 5°F; 3 days (+4 hrs, -0)	Conditioning Started: 09/09/2020 @0836
	Moist. Cond. (Stage 1)	160 ± 5°F / 95 ± 5 %RH for 30 days	
Measurement Device:	Balance (Model#):	Mettler Toledo XS205 (PMEL K054914)	
	Balance Accuracy:	±0.0001 g	

Specimen ID	W_{ar} [g]	W_b [g]	W_{mc1} [g]
5PP-DLS-90-1-HTW-1	44.9138	44.7855	45.1093
5PP-DLS-90-2-HTW-2	44.5157	44.3891	44.7077
5PP-DLS-90-3-HTW-3	44.9421	44.8102	45.1423
5PP-DLS-90-4-HTW-4	45.067	44.9404	45.2713
5PP-DLS-90-3-HTW-5	44.6426	44.5168	44.8444
5PP-DLS-90-3-SP-3	44.9587	44.8285	45.1659
5PP-DLS-0-1-HTW-1	44.4347	44.3144	44.6288
5PP-DLS-0-2-HTW-2	44.5008	44.3800	44.6926
5PP-DLS-0-3-HTW-3	44.6770	44.5488	44.8761
5PP-DLS-0-4-HTW-4	43.7610	43.6469	43.9479
5PP-DLS-0-3-HTW-5	44.2800	44.1602	44.4741
5PP-DLS-0-3-SP-3	43.7045	43.5916	43.8911
5PP-DLS-45-1-HTW-1	44.9248	44.7939	45.1310
5PP-DLS-45-2-HTW-2	44.6052	44.4735	44.8124
5PP-DLS-45-3-HTW-3	44.4558	44.3290	44.6531
5PP-DLS-45-4-HTW-4	44.6666	44.5358	44.8734
5PP-DLS-45-3-HTW-5	44.6101	44.4819	44.8073
5PP-DLS-45-3-SP-3	43.6185	43.4960	43.8148
Average	44.5155	44.3901	44.7135
Std. Dev	0.4331	0.4284	0.4377
CoV [%]	0.9728	0.9652	0.9789

Specimen ID	W_{ar} [g]	W_b [g]	W_{mc1} [g]
F100-DLS-90-1-	46.7054	46.5496	46.9273
F100-DLS-90-2-	46.9047	46.7518	47.1240
F100-DLS-90-3-	46.7211	46.5684	46.9413
F100-DLS-90-4-	46.7533	46.6006	46.9714
F100-DLS-90-3-	46.6550	46.5057	46.8728
F100-DLS-90-3-SP-	46.7232	46.5720	46.9413
F100-DLS-0-1-HTW-	46.7104	46.5674	46.9212
F100-DLS-0-2-HTW-	46.5779	46.4320	46.7929
F100-DLS-0-3-HTW-	46.5767	46.4315	46.7897
F100-DLS-0-4-HTW-	46.3834	46.2406	46.5942
F100-DLS-0-3-HTW-	46.7606	46.6136	46.9739
F100-DLS-0-3-SP-3	45.8514	45.7119	46.0581
F100-DLS-45-1-	46.6970	46.5550	46.9125
F100-DLS-45-2-	46.8196	46.6783	47.0340
F100-DLS-45-3-	46.6632	46.5216	46.8773
F100-DLS-45-4-	47.0319	46.8899	47.2491
F100-DLS-45-3-	46.6528	46.5116	46.8670
F100-DLS-45-3-SP-	46.5378	46.4012	46.7478
Average	46.6514	46.5057	46.8664
Std. Dev	0.2442	0.2423	0.2469
CoV [%]	0.5235	0.5209	0.5269

W_{ar} = as-received specimen mass, before drying [g]

W_b = Baseline specimen mass; mass of specimen after drying (exposure time = 0), [g]

W_i = Current mass of specimen after exposure to environment at exposure time i, [g]

ΔM= Mass change [%]

ΔM_{norm}=Normalized instantaneous mass change

W_{mc1} = Final mass of specimen after stage 1 moisture conditioning [g]

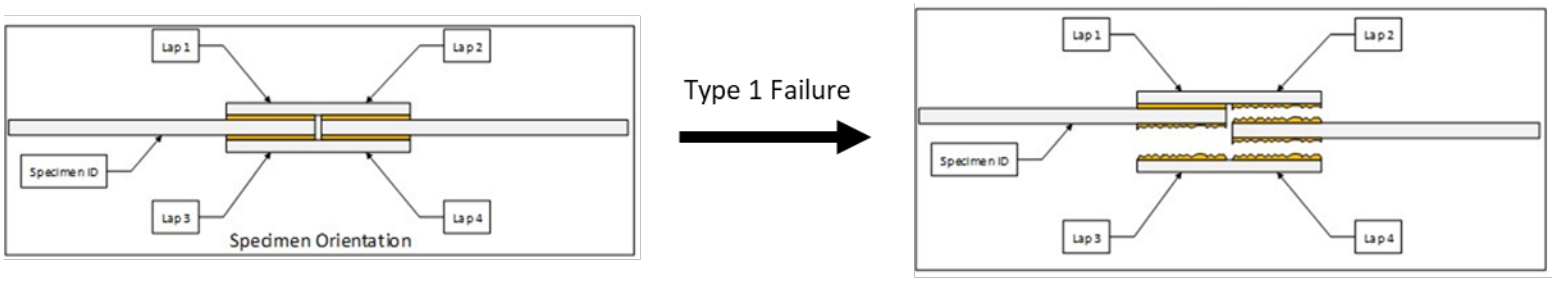
$$\Delta M[\%] = \frac{(W_i - W_b)}{W_b} * 100$$

$$\Delta W_{norm}[\%] = \frac{|W_i - W_{i-1}|}{W_b}$$

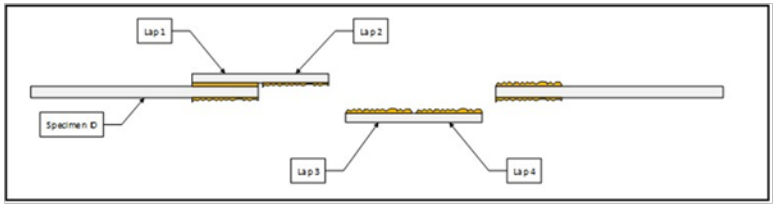
APPENDIX B

Failed Specimen Photo Documentation

Photo Documentation Orientation:

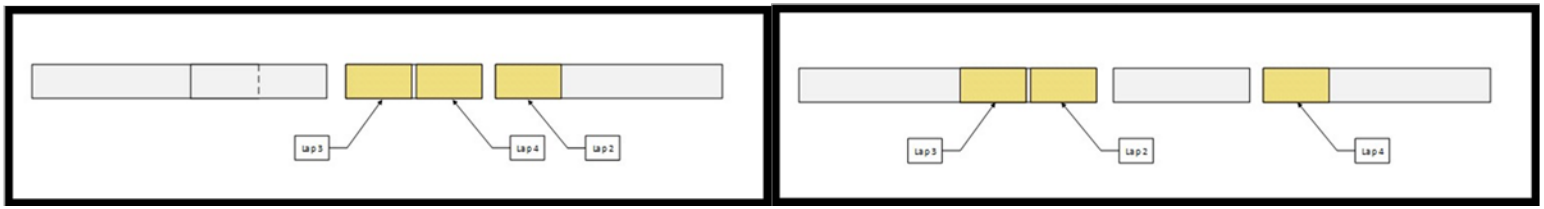


Disassembled

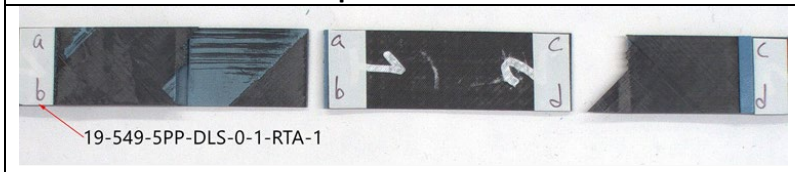
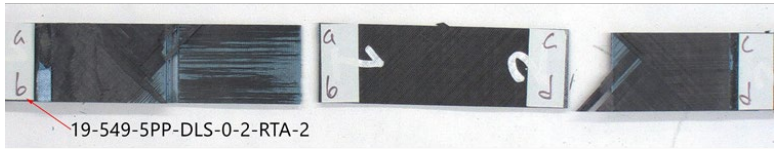
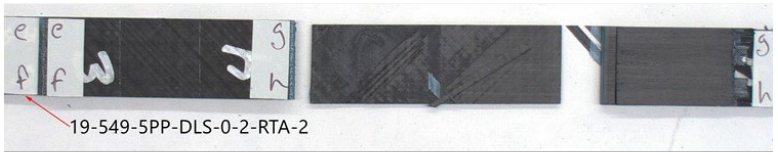
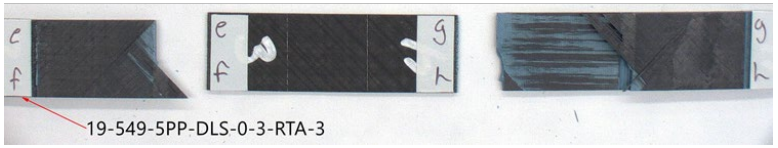
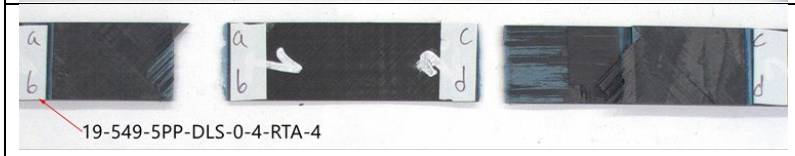
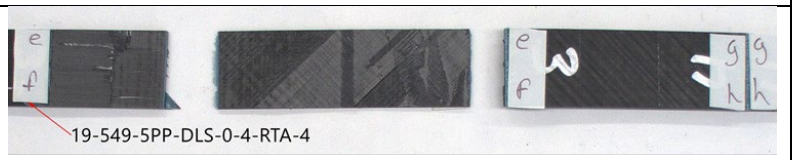
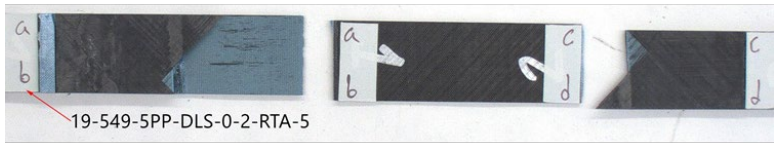
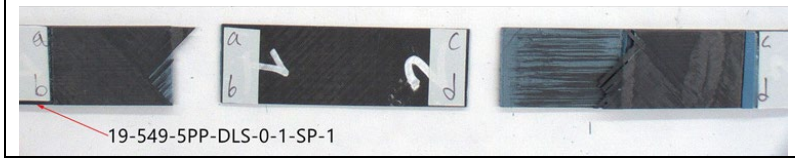
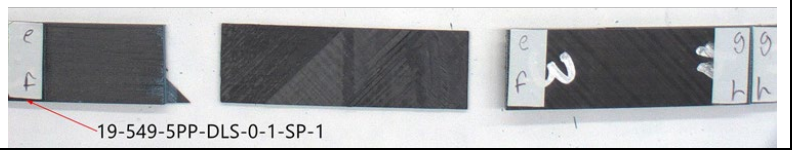


Picture # 1:
Top-down View

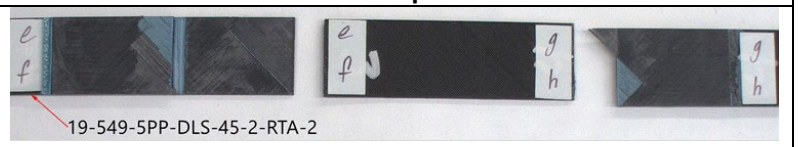
Picture #2:
Bottom-up View



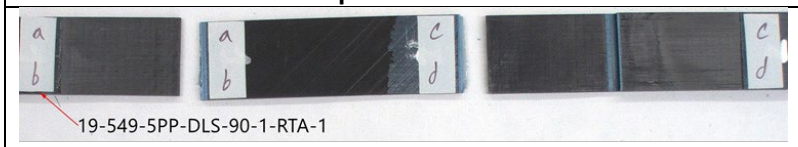
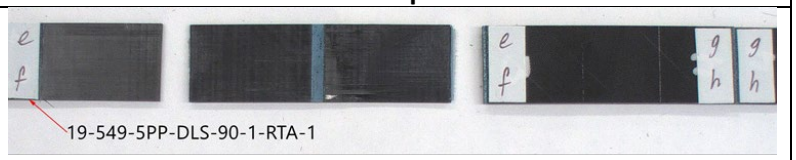
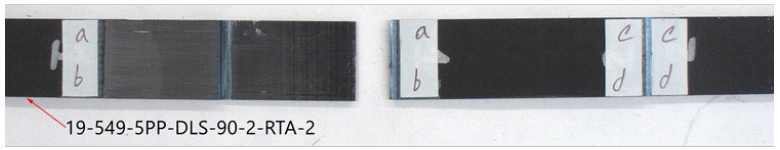
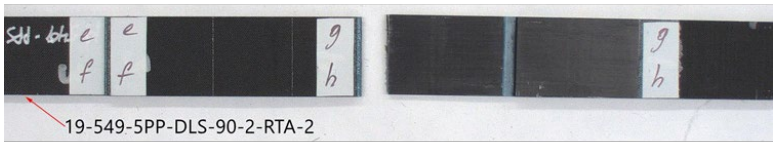
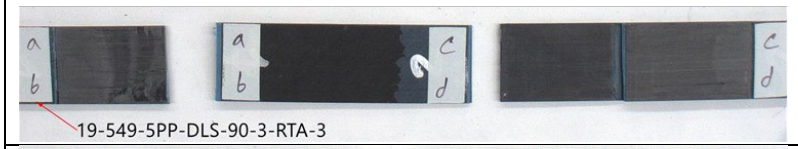
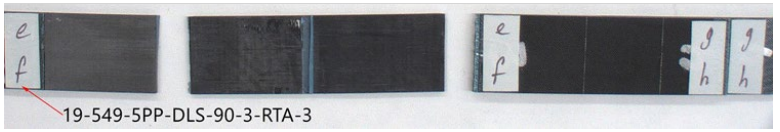
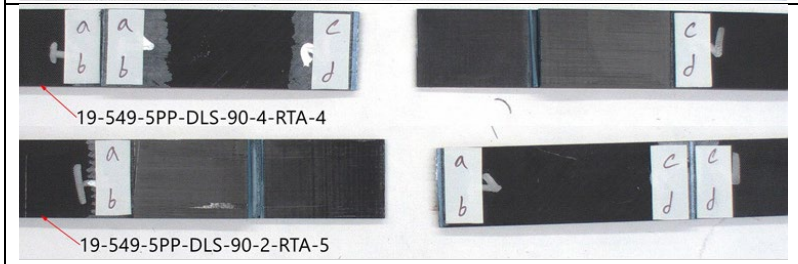
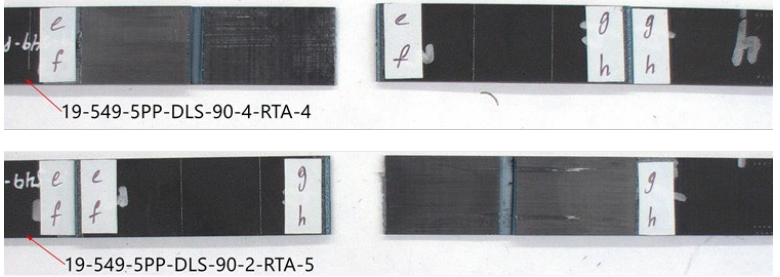
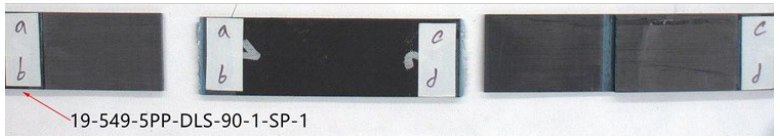
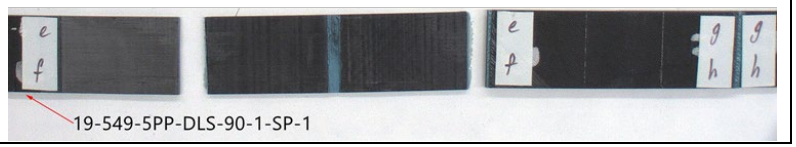
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 0° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

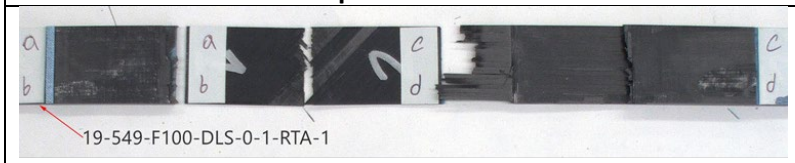
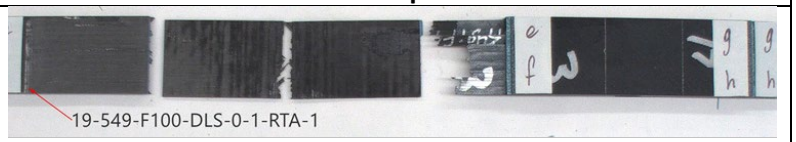
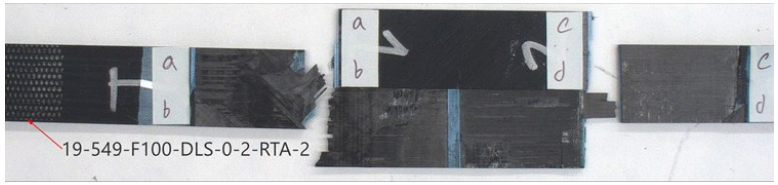
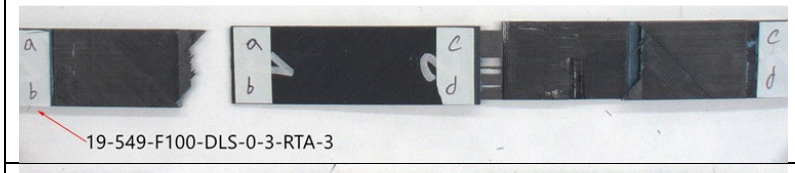
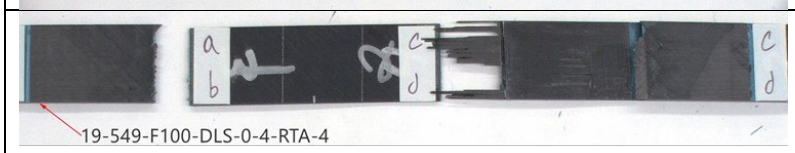
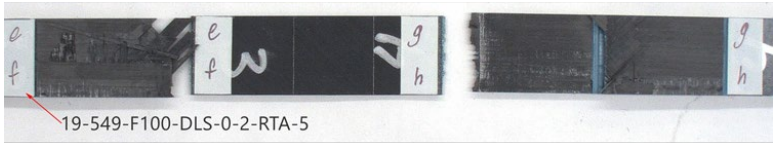
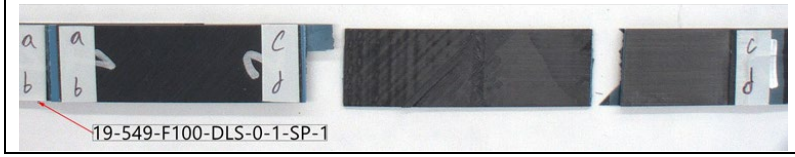
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 45° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	

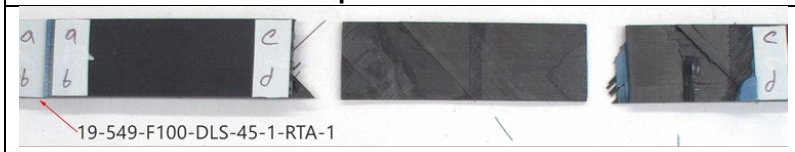
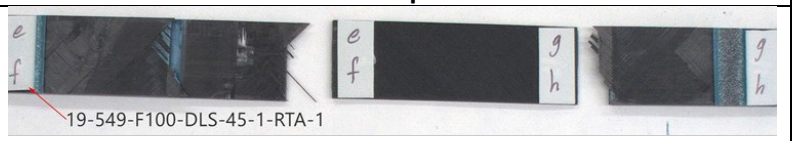
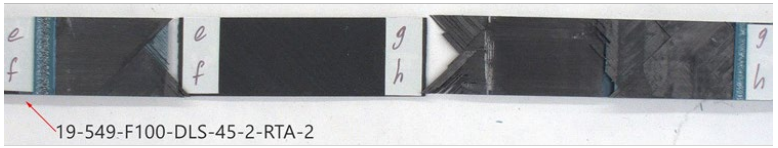
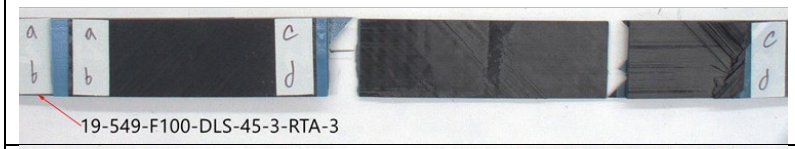
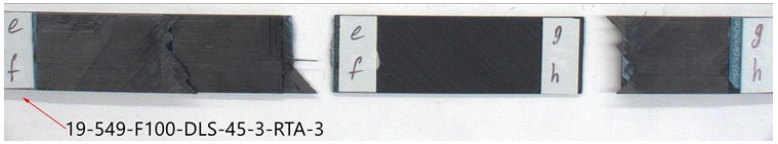
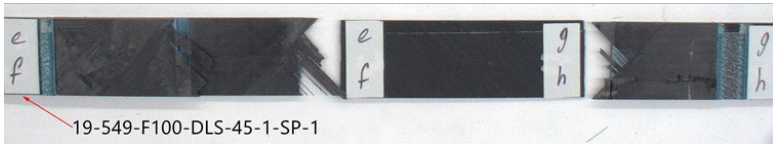
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 90° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	

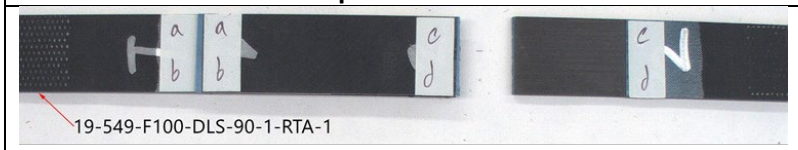
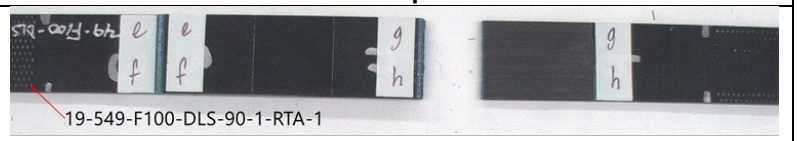
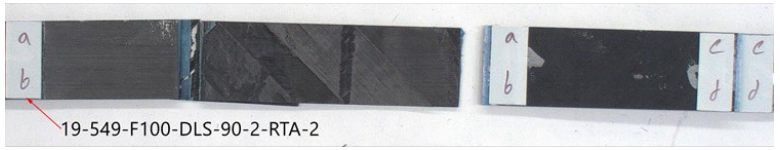
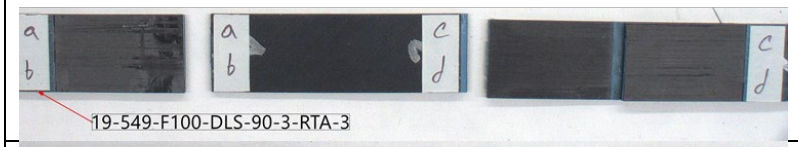
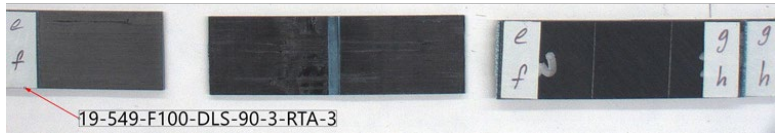
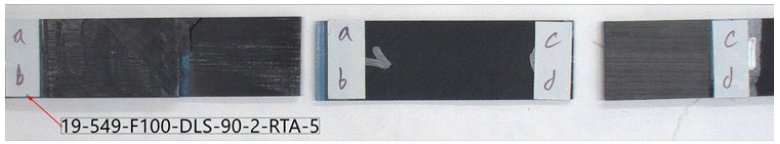
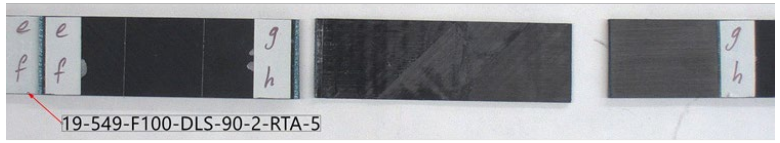
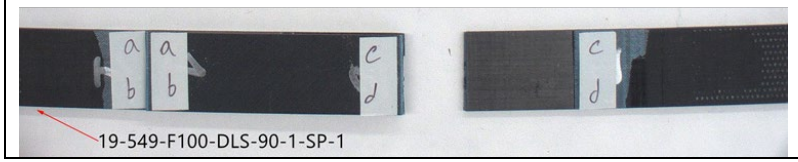
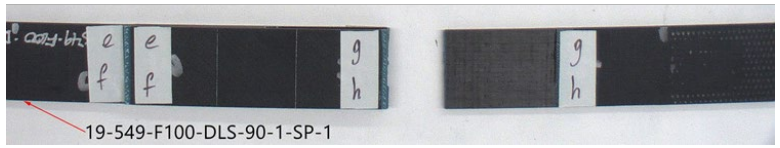
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 0° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

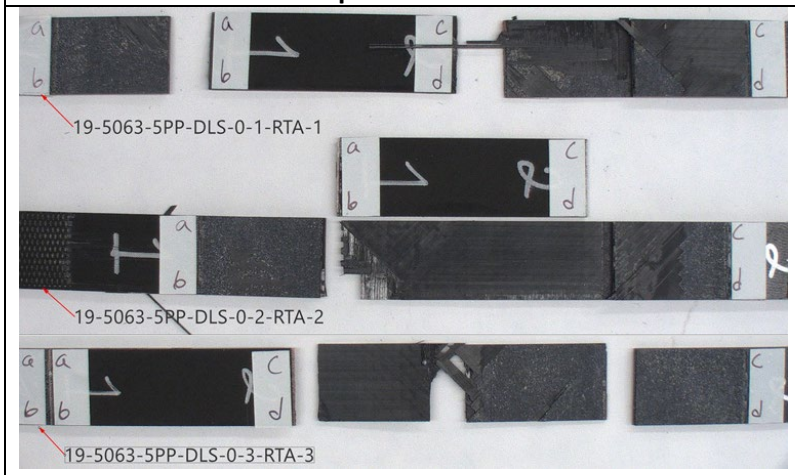
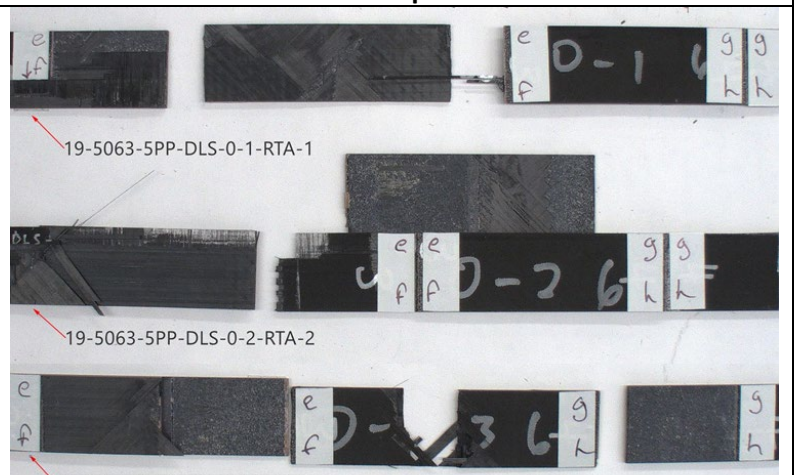
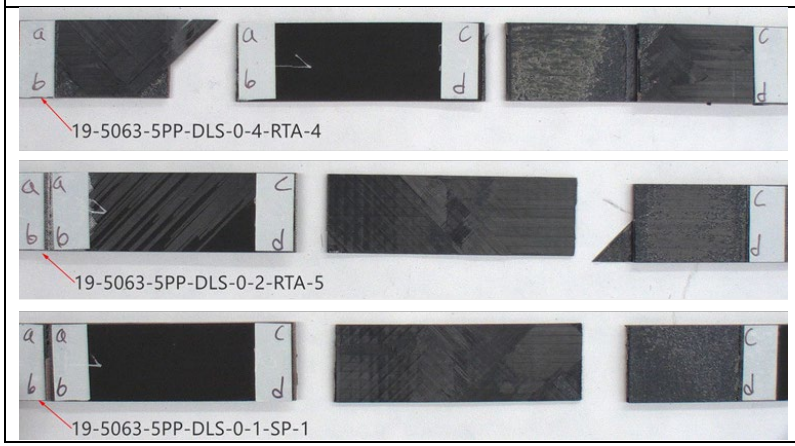
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 45° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

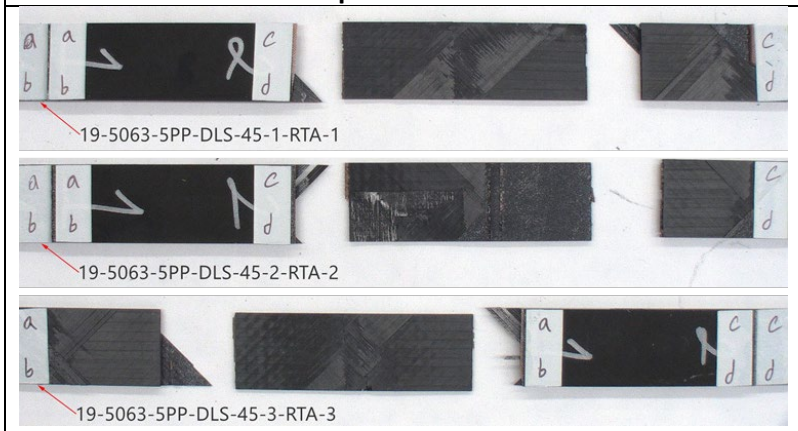
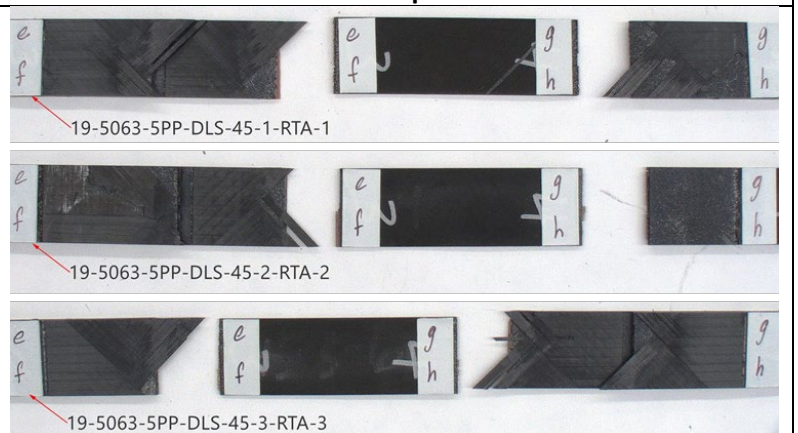
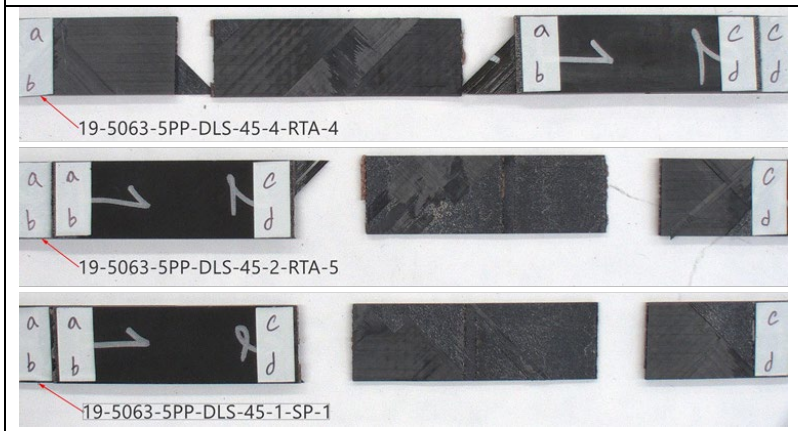
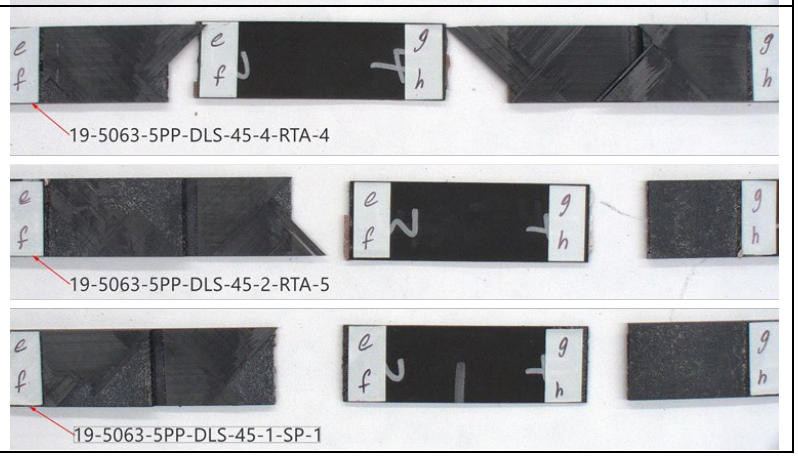
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 90° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

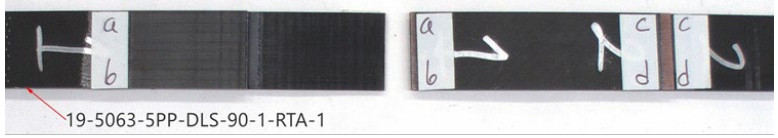
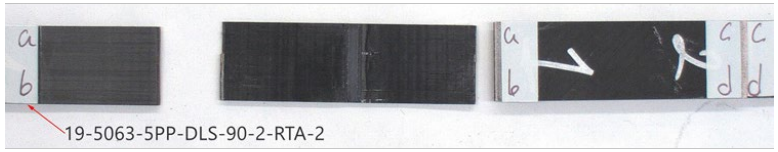
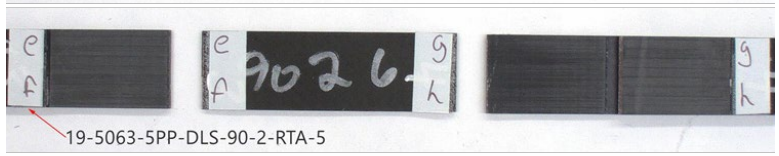
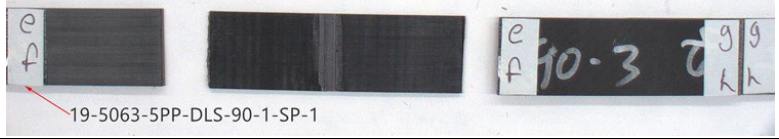
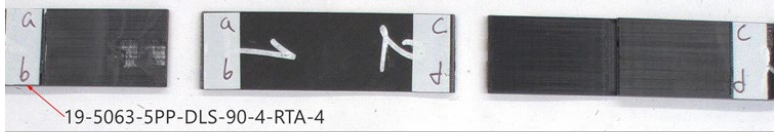
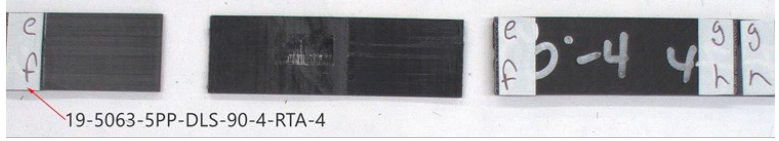
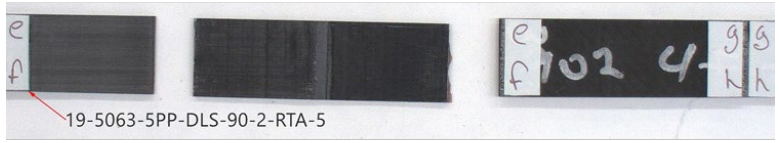
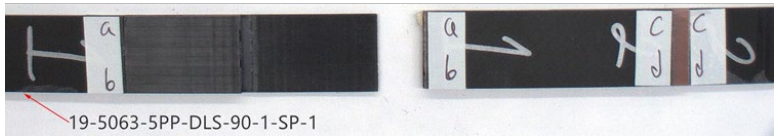
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 0° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	

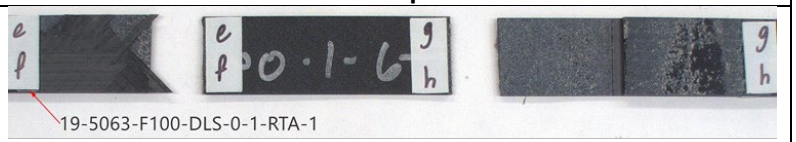
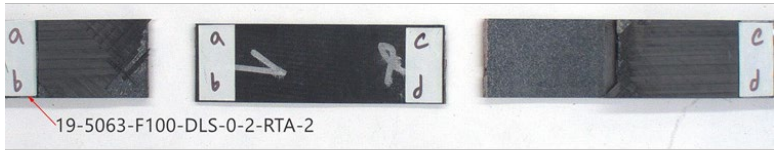
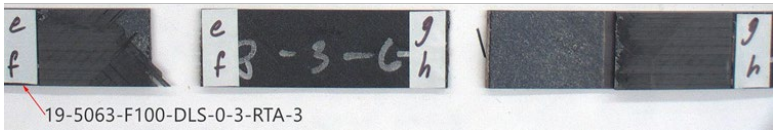
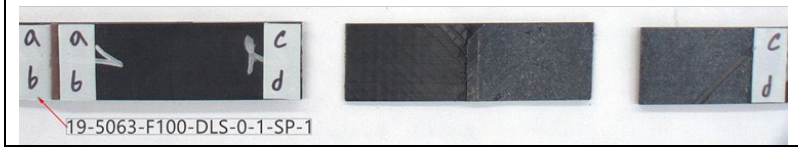
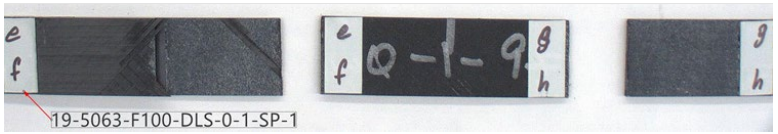
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 45° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	

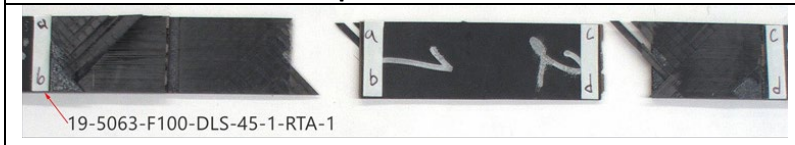
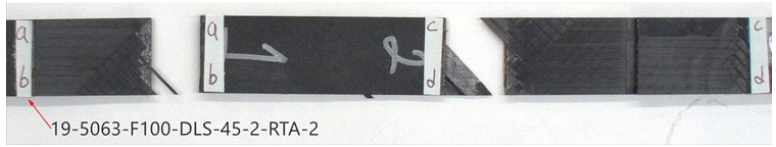
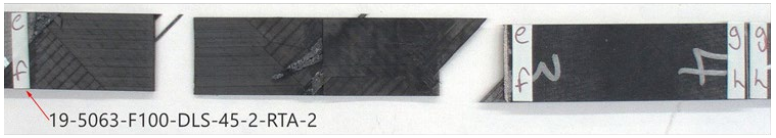
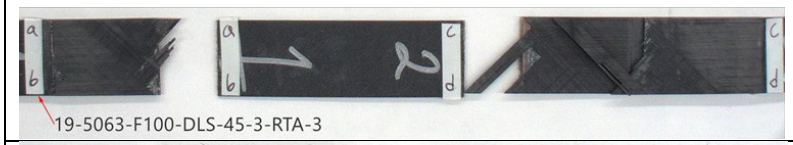
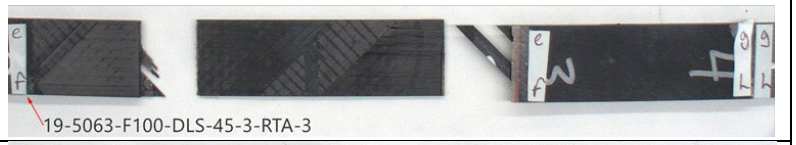
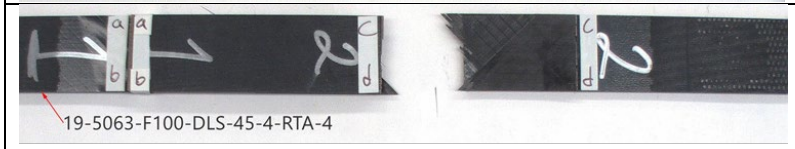
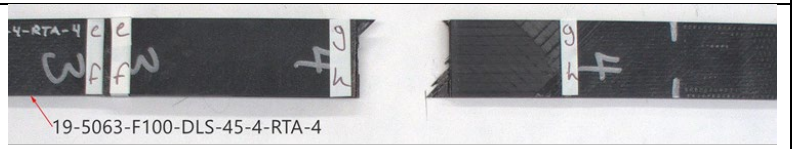
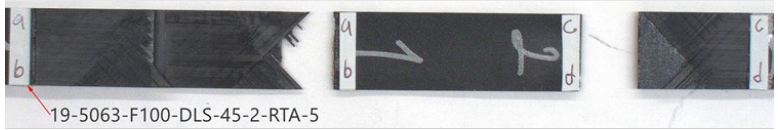
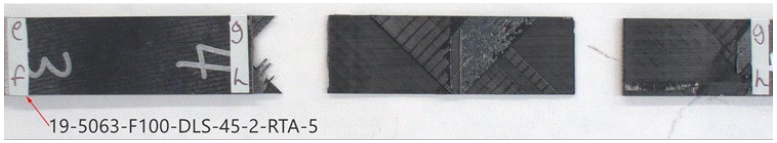
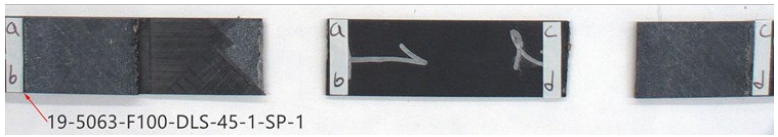
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 90° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

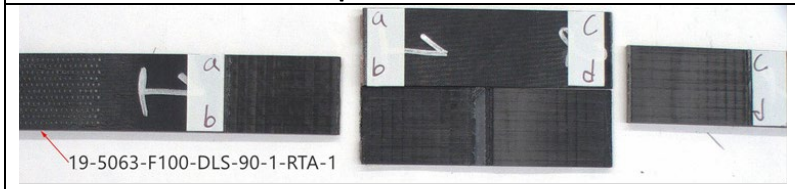
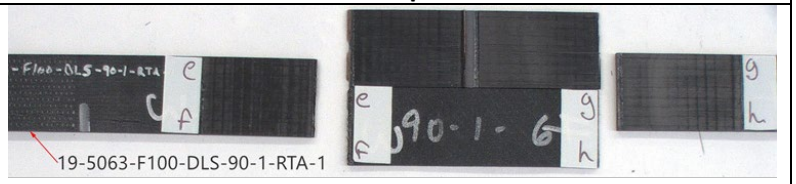
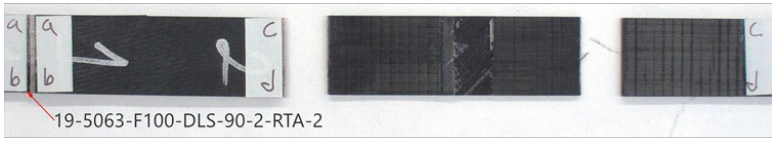
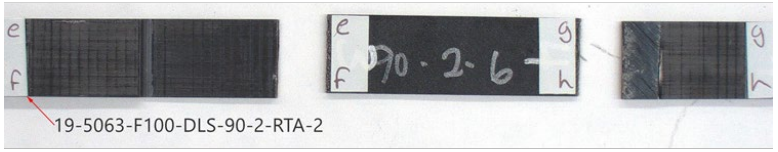
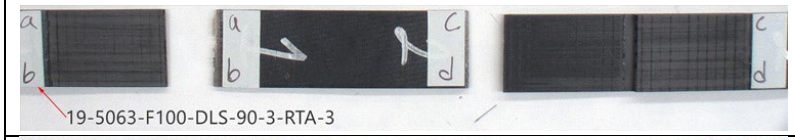
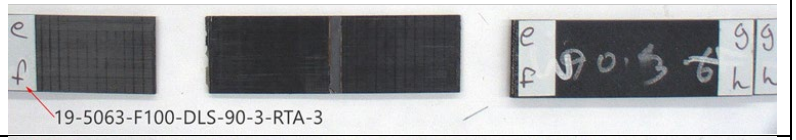
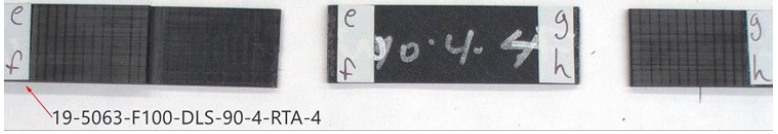
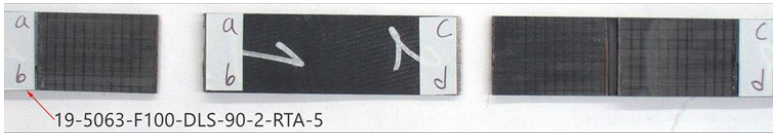
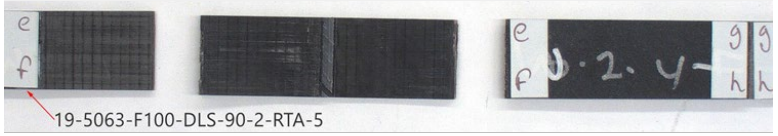
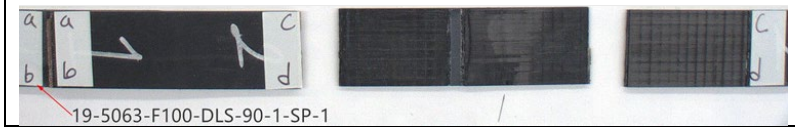
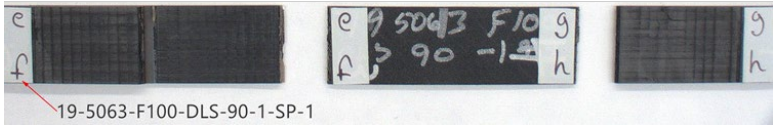
DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 0° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

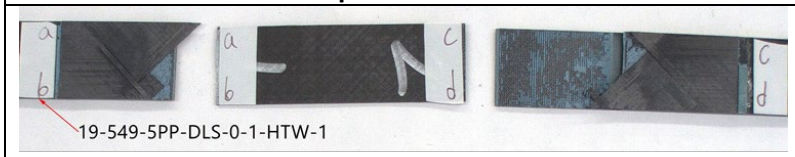
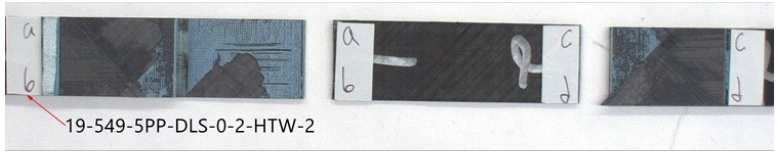
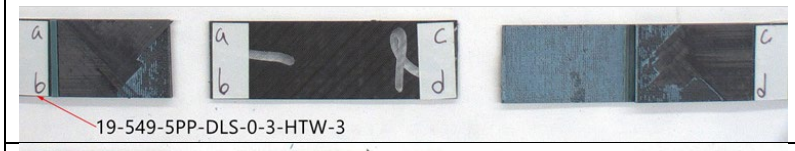
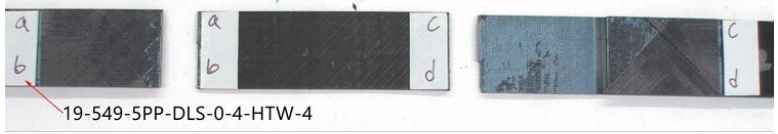
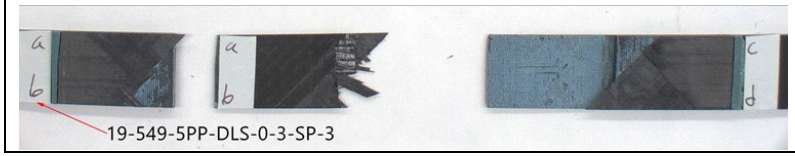
DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 45° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

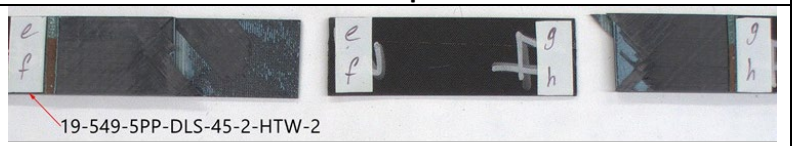
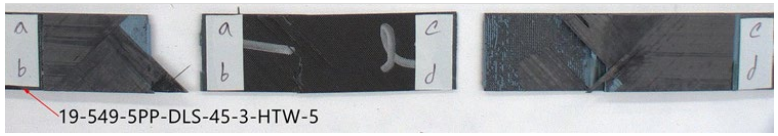
DLS Failures – IM7/5320/FM 309-2, FusePly Surface Preparation, 90° Surface Ply Orientation, RTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

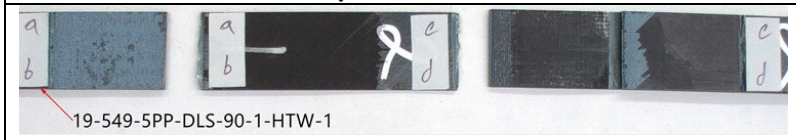
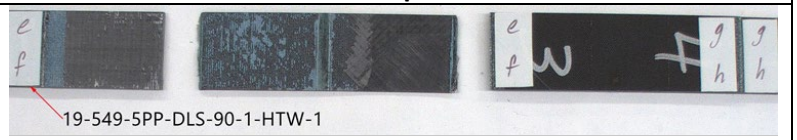
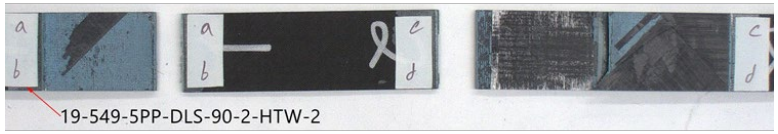
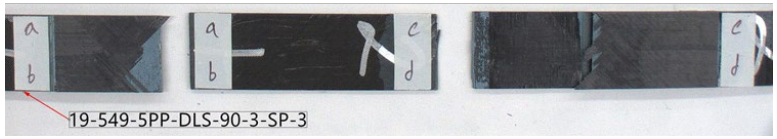
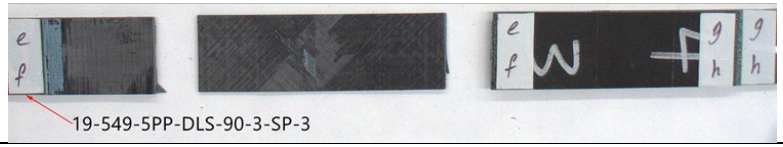
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 0° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

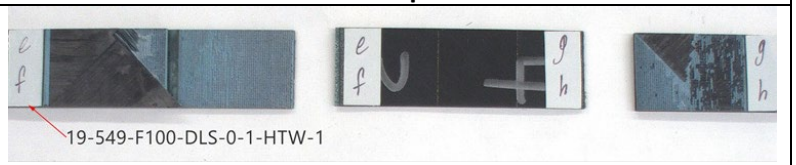
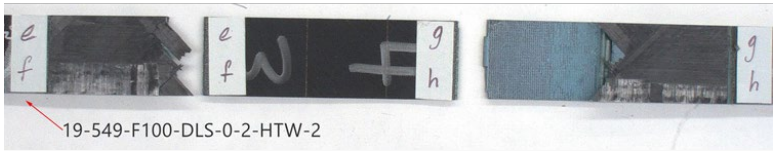
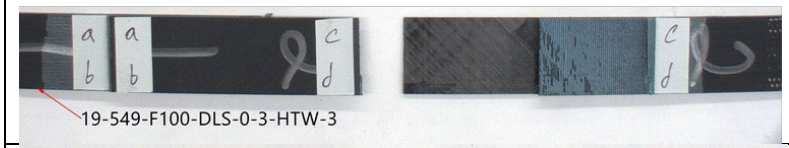
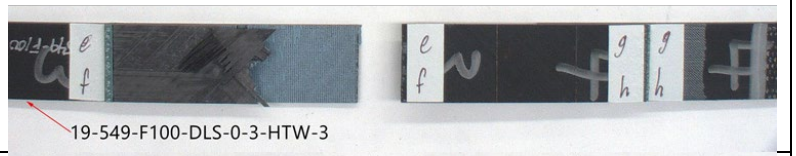
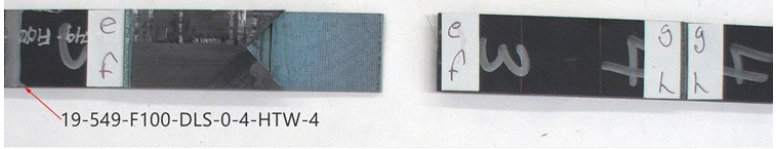
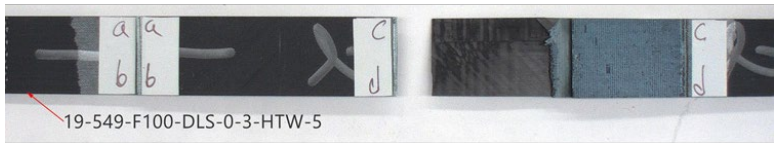
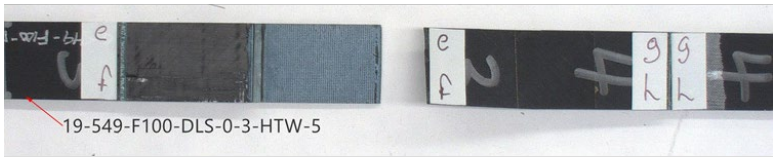
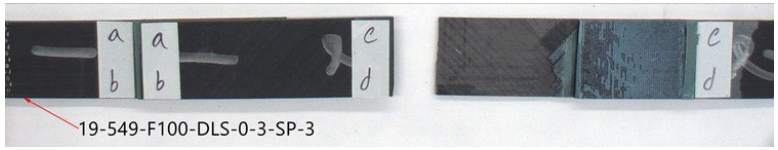
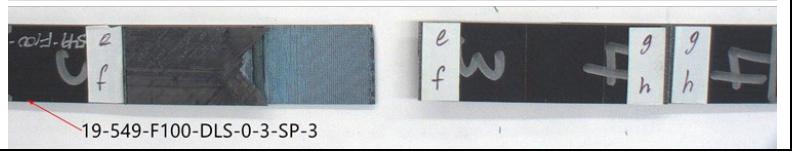
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 45° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	

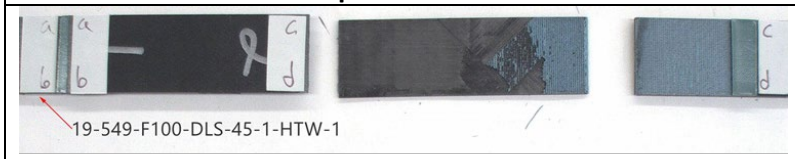
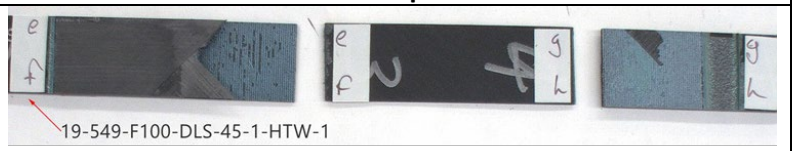
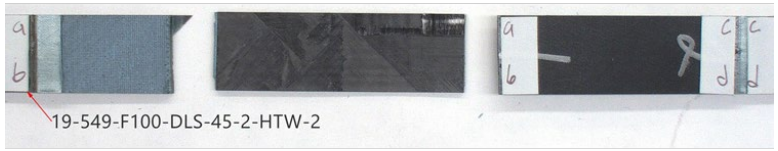
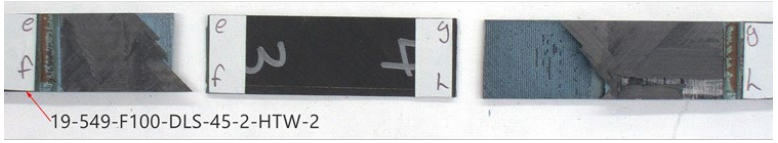
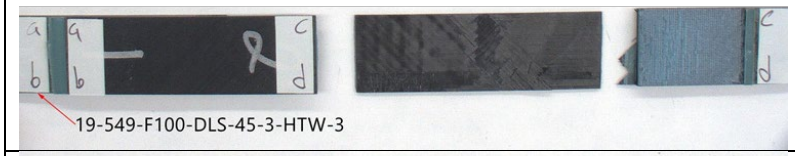
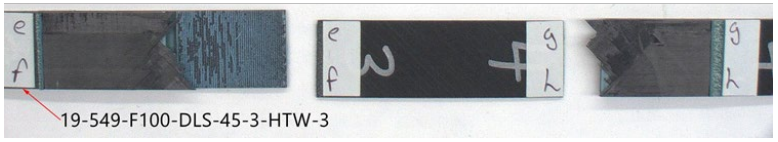
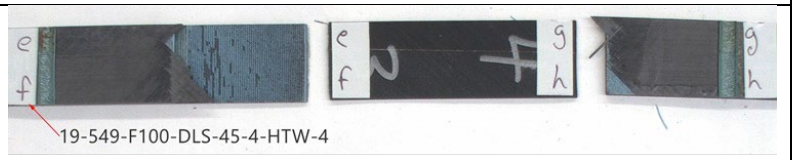
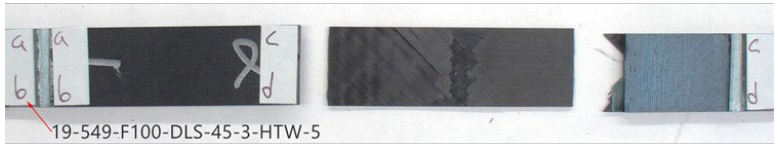
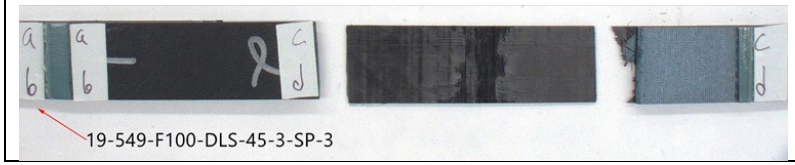
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 90° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

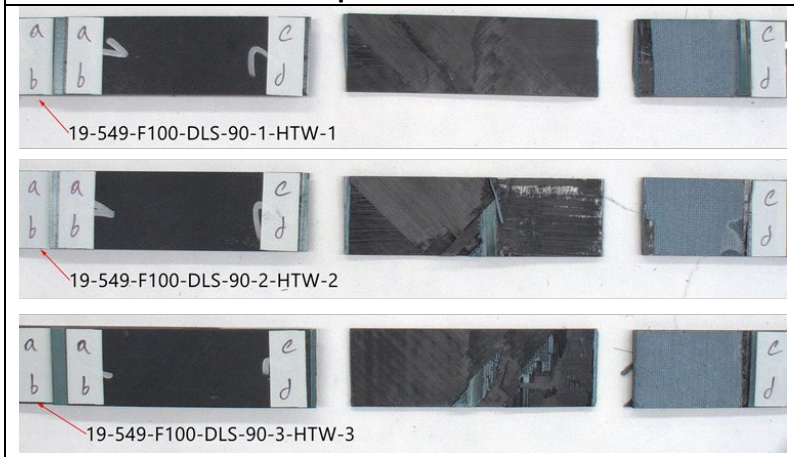
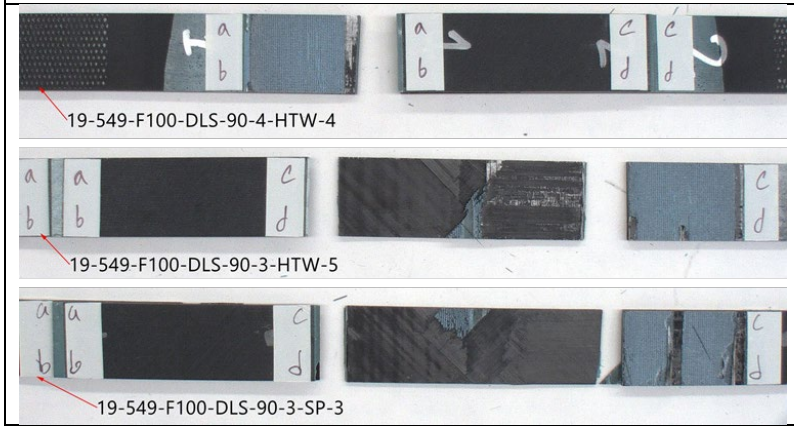
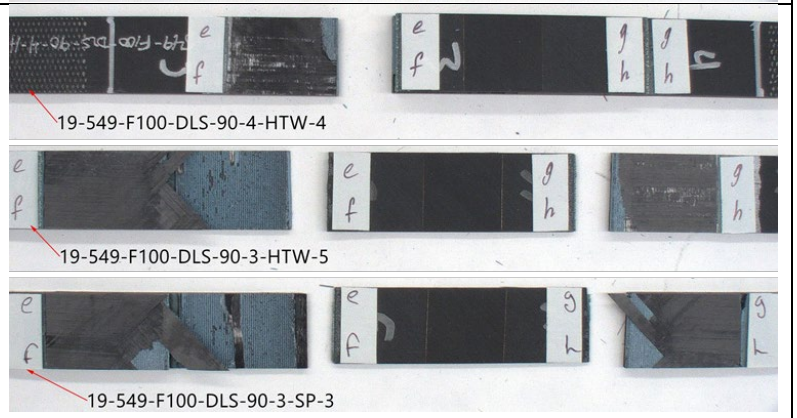
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 0° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

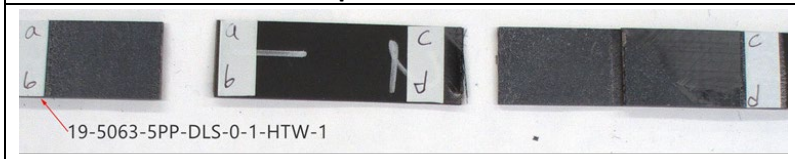
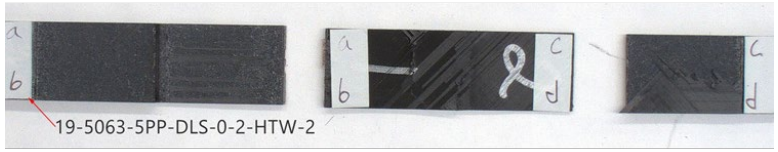
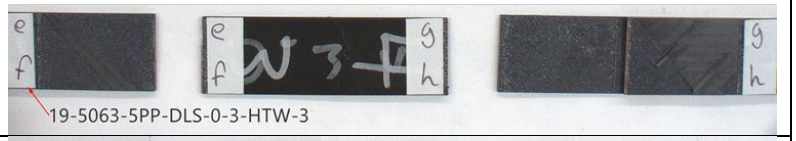
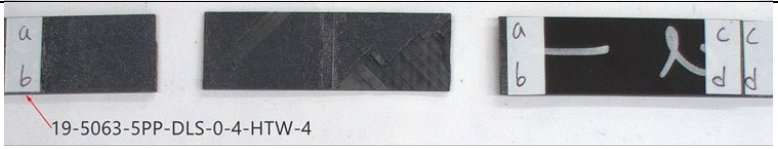
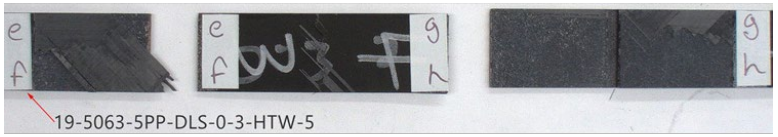
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 45° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

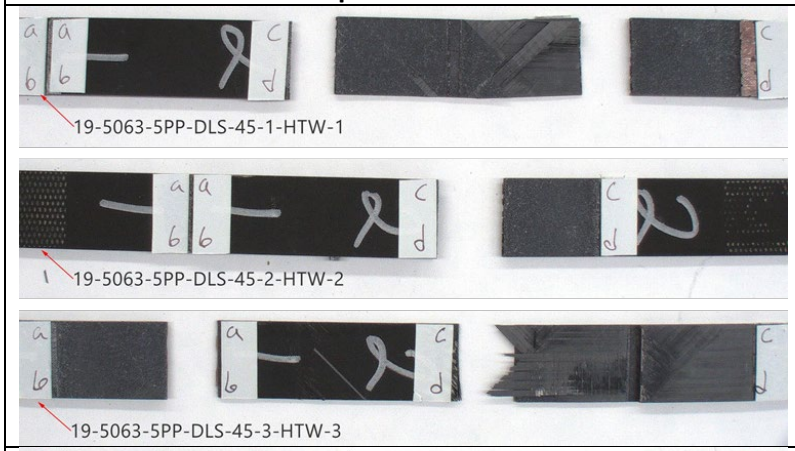
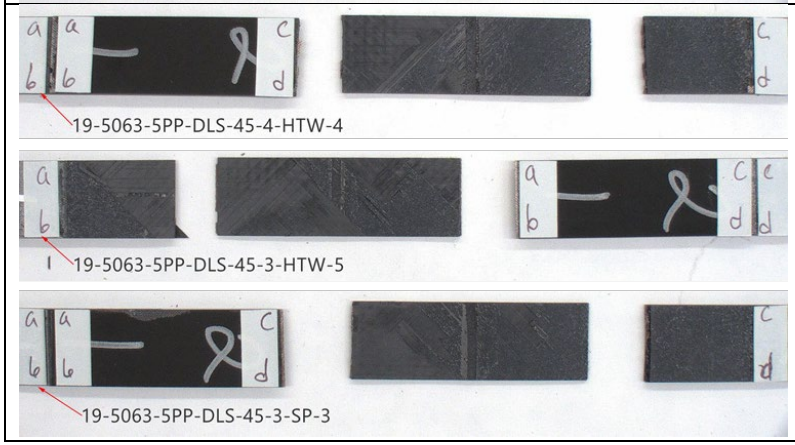
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 90° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	

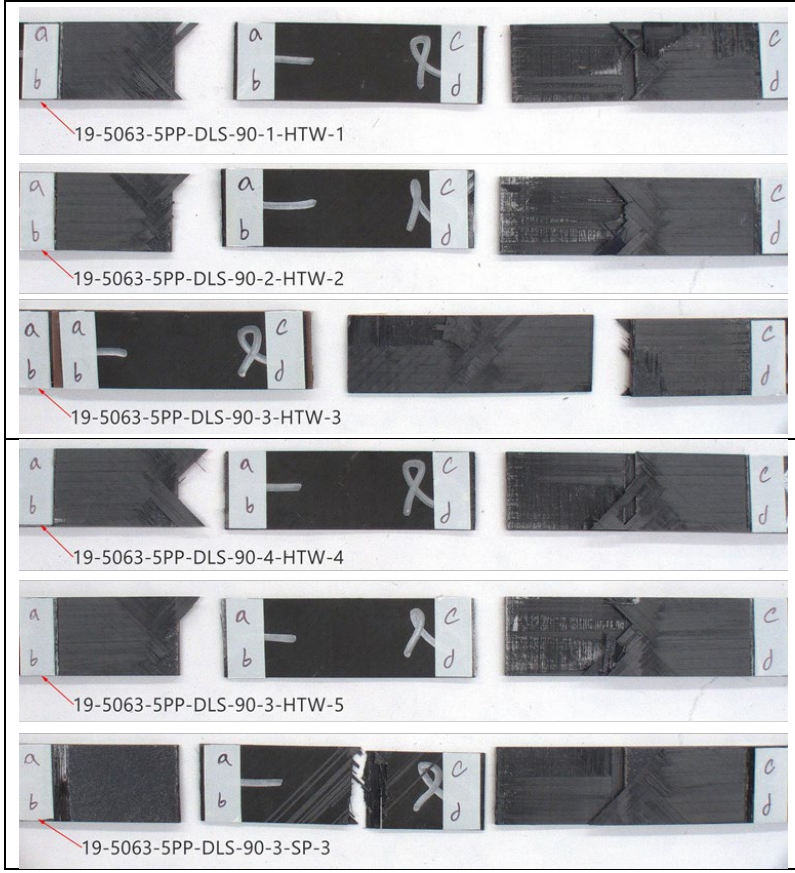
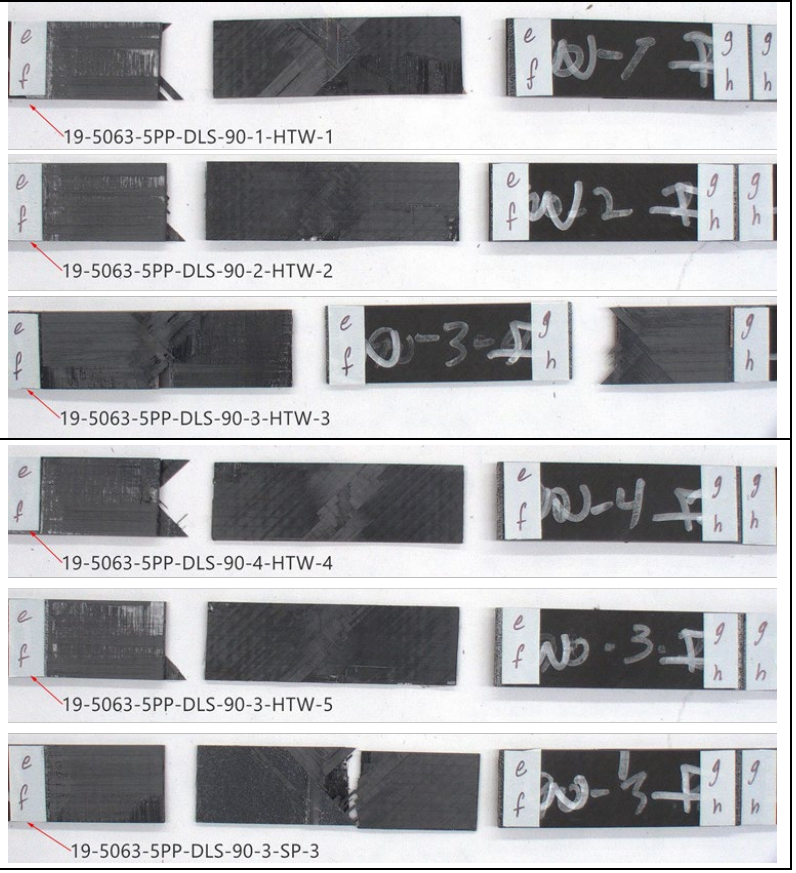
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 0° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

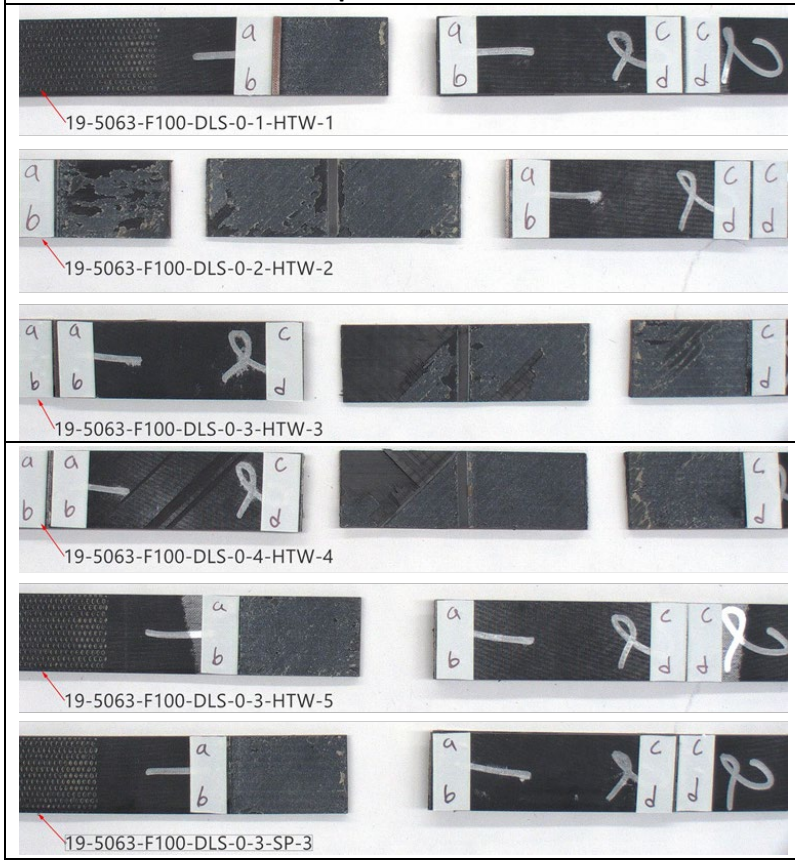
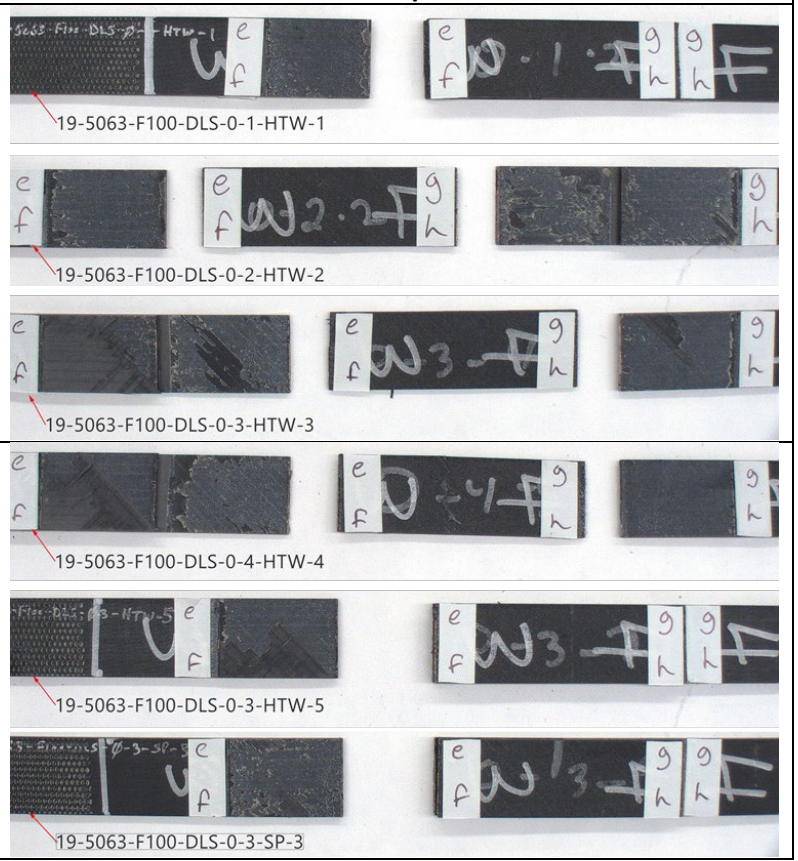
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 45° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	

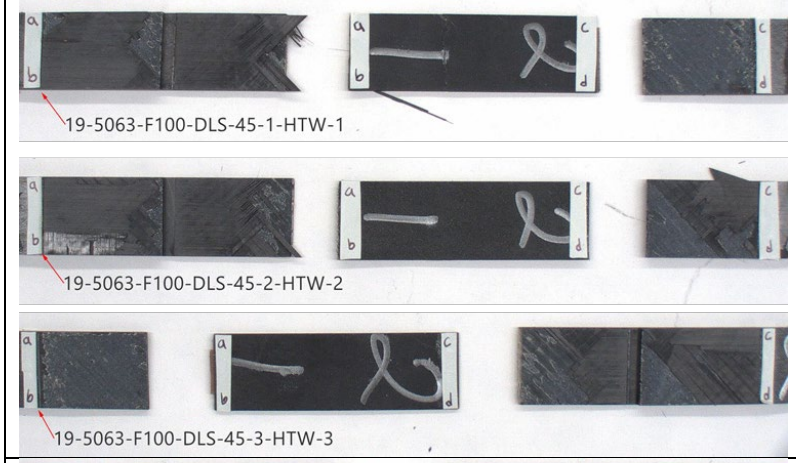
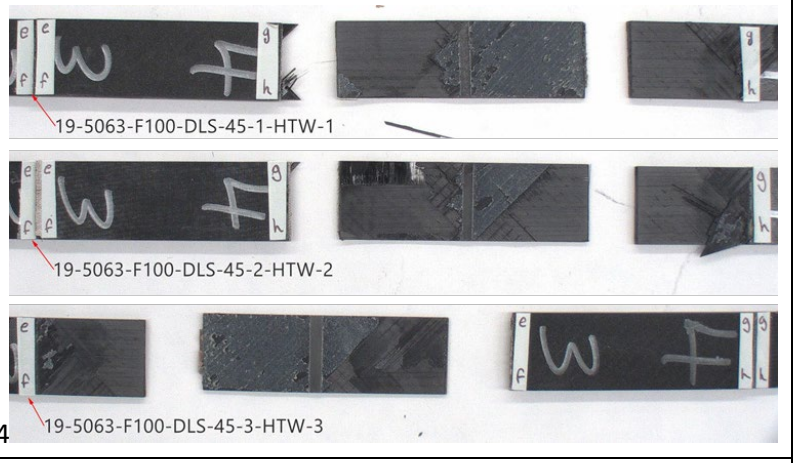
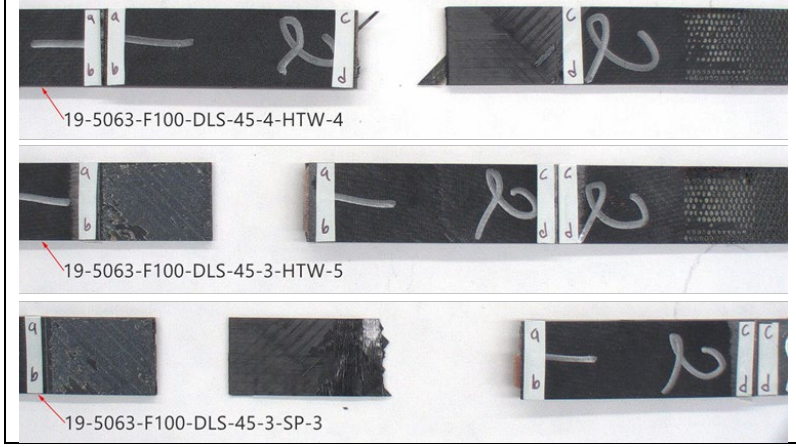
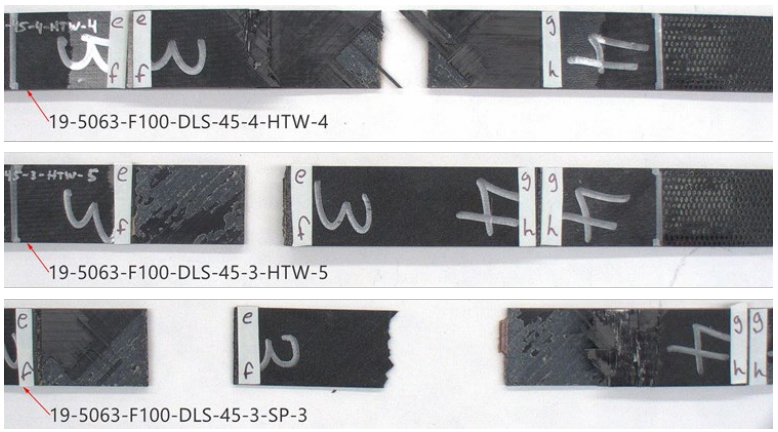
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 90° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	

DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 0° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	

DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 45° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	

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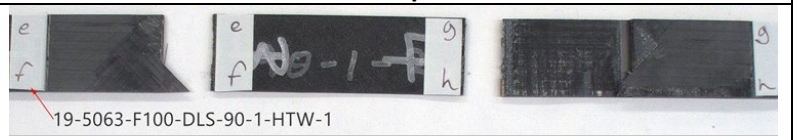
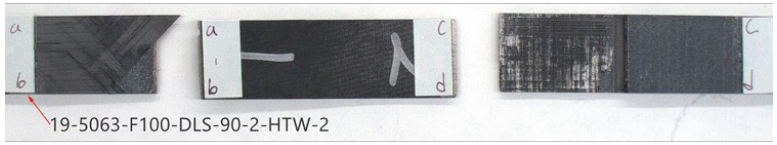
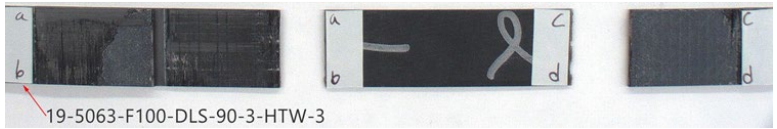
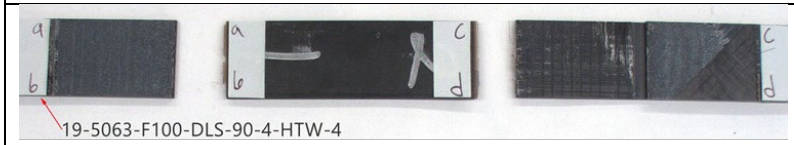
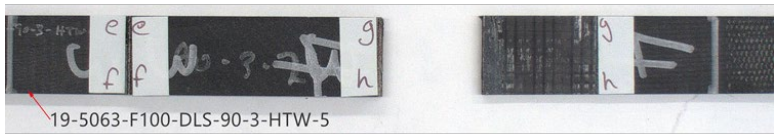
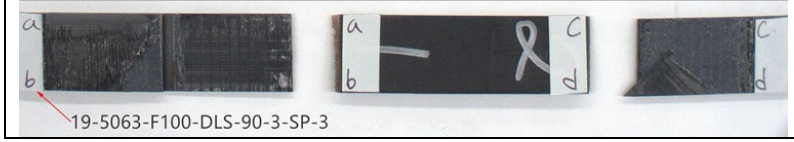
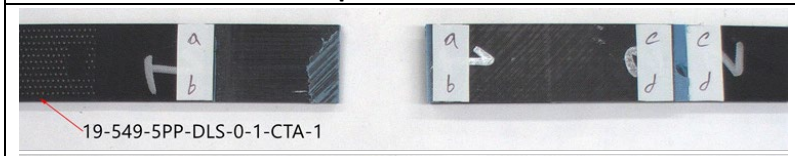
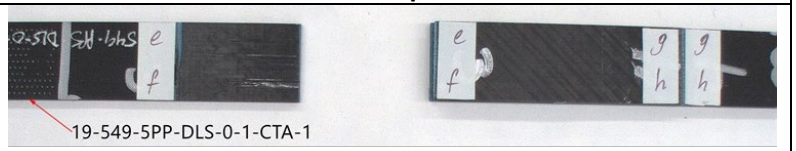
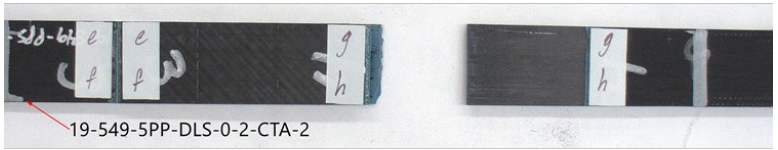
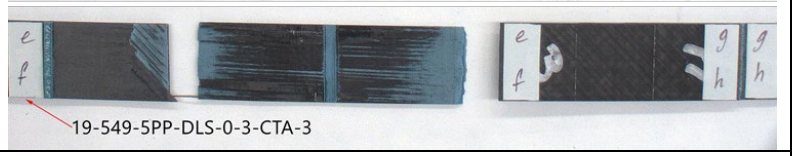
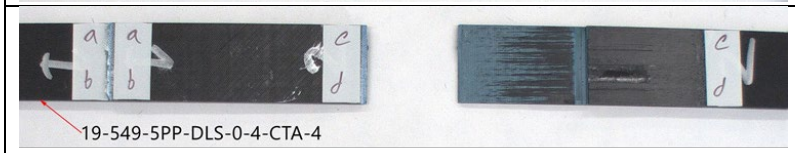
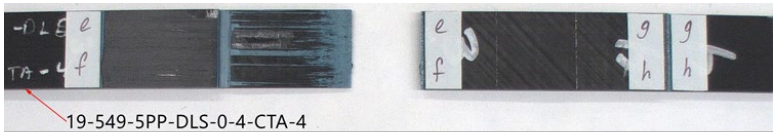
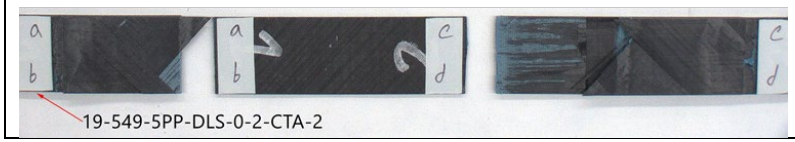
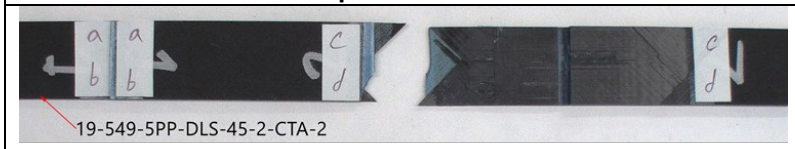
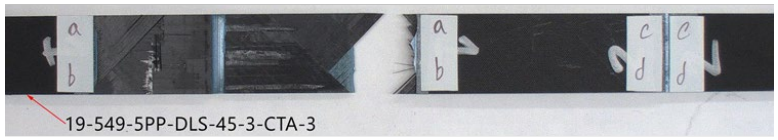
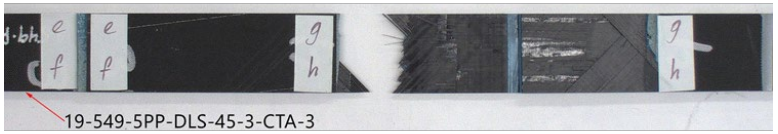
DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 90° Surface Ply Orientation, HTW Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

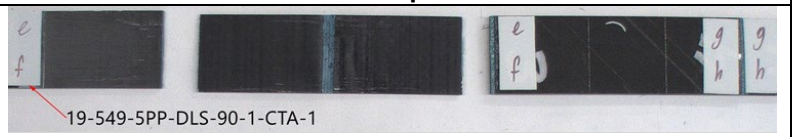
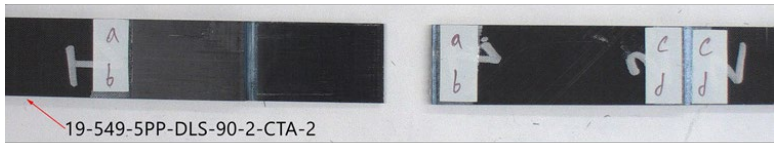
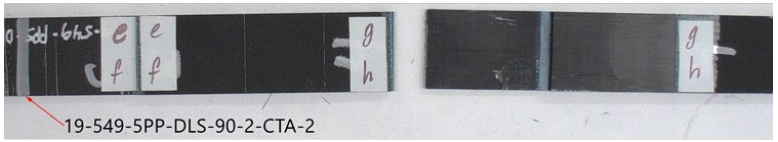
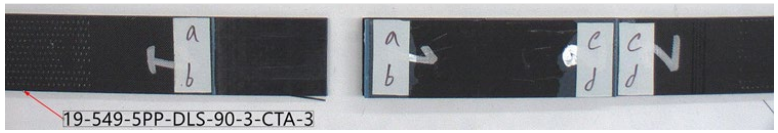
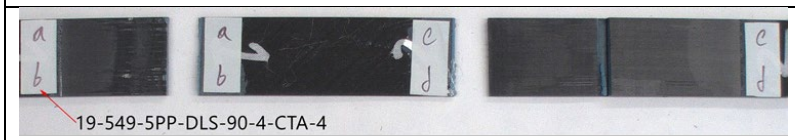
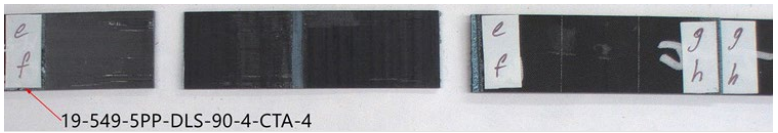
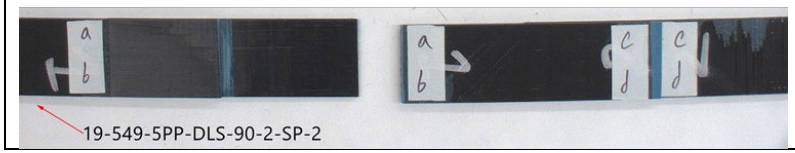
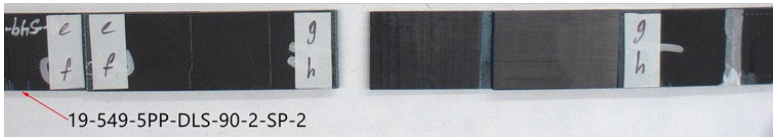
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 0° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

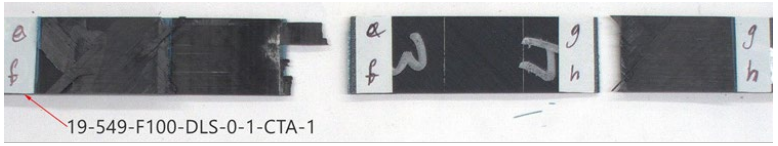
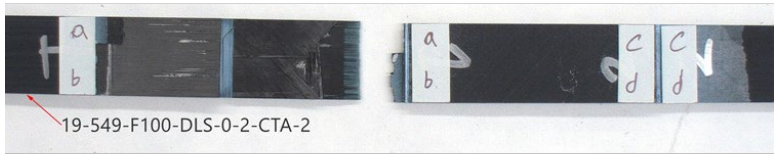
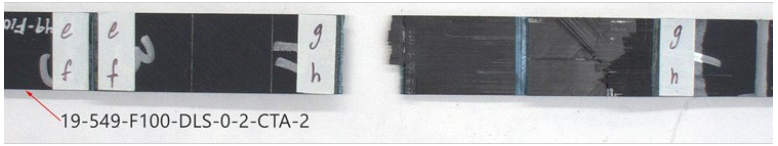
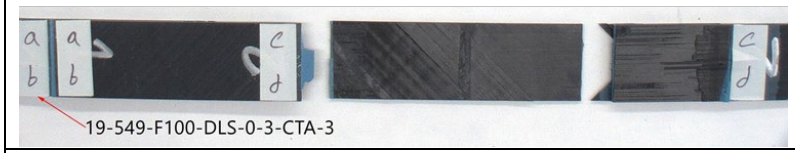
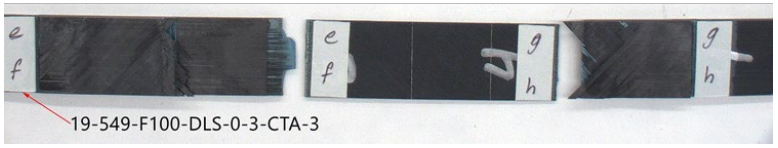
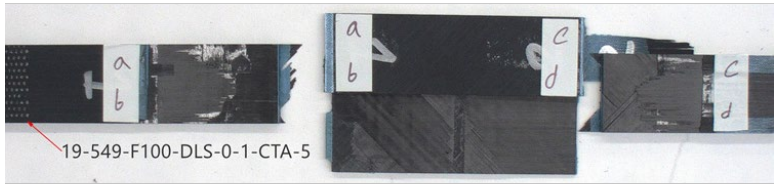
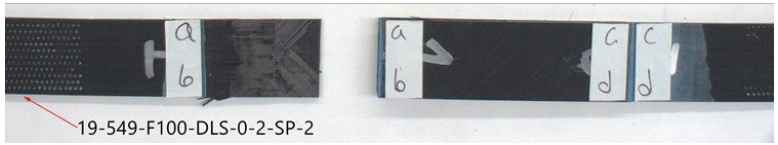
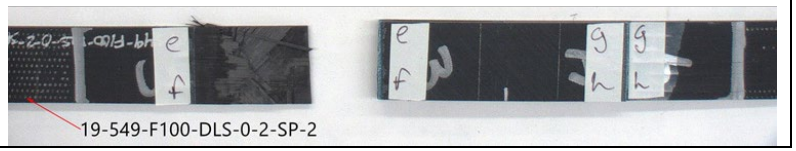
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 45° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	

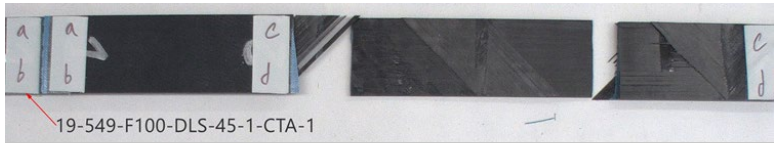
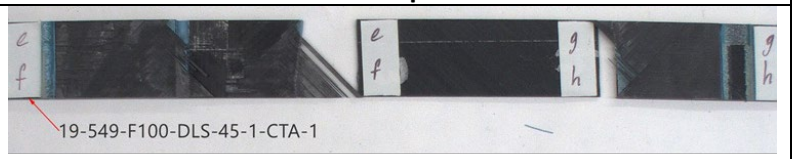
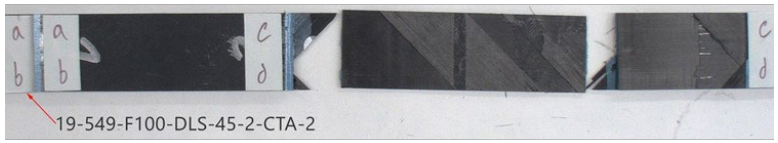
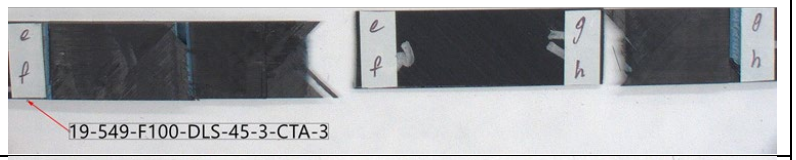
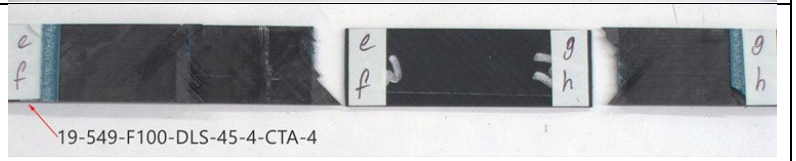
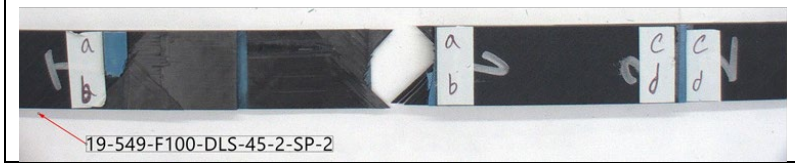
DLS Failures – AS4/3501-6/FM 300, PPS Surface Preparation, 90° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

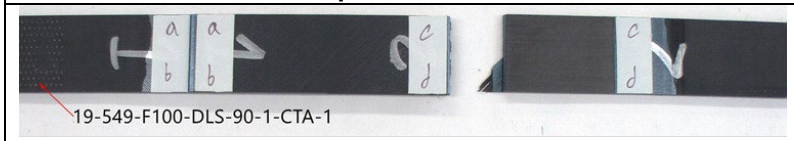
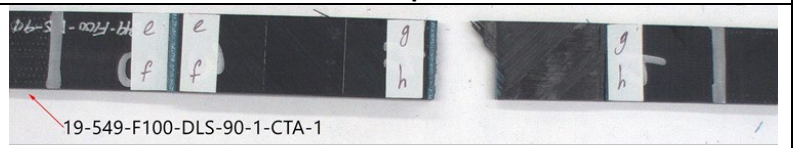
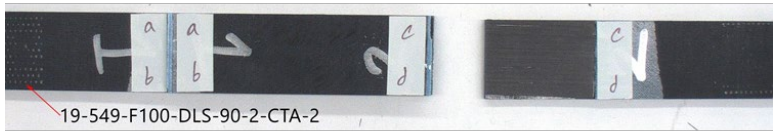
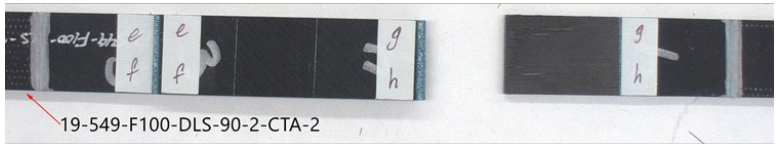
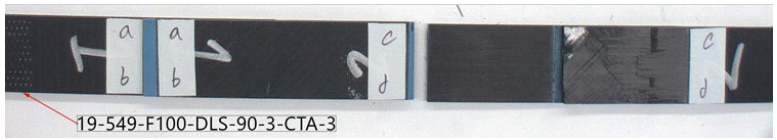
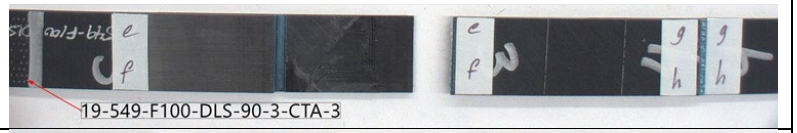
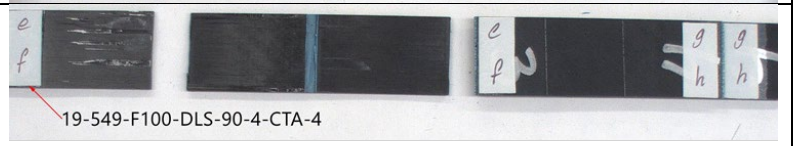
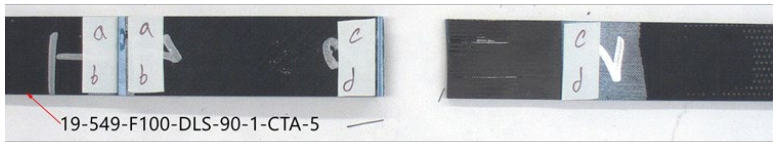
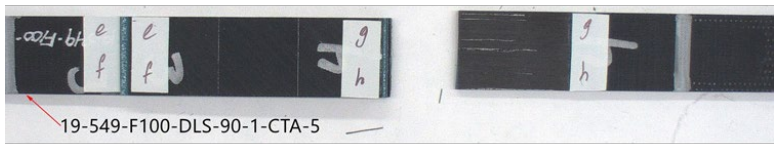
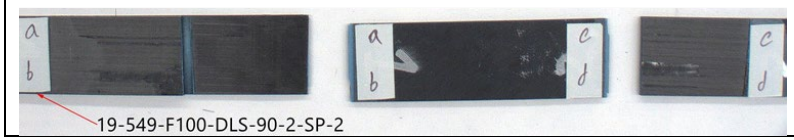
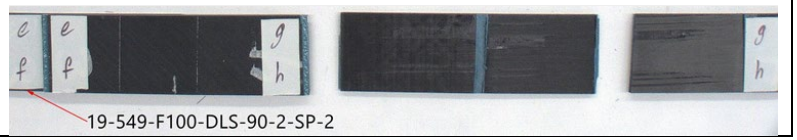
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 0° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

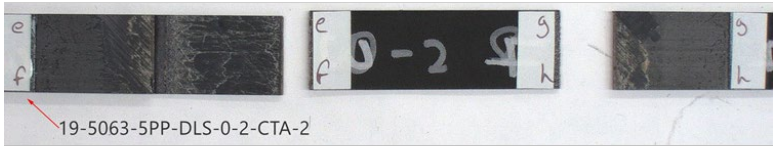
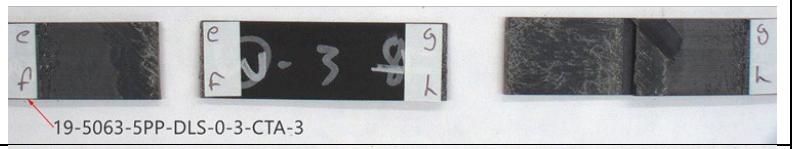
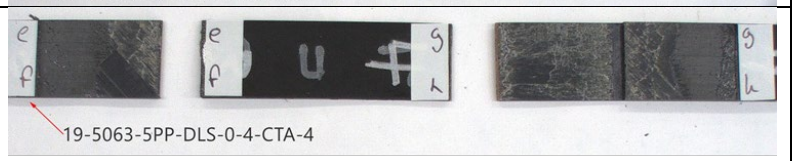
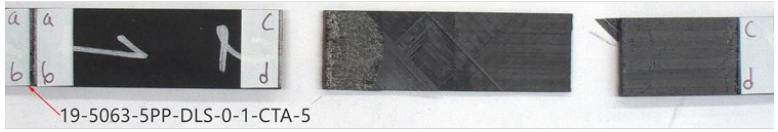
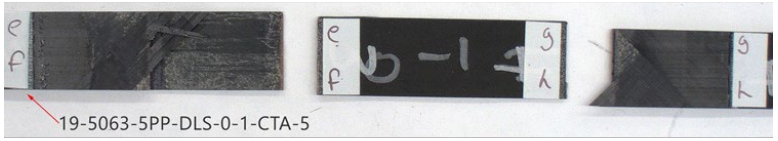
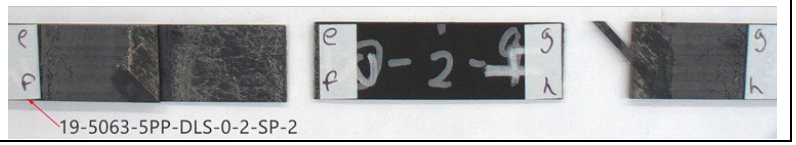
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 45° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

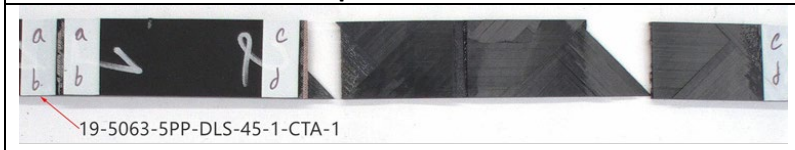
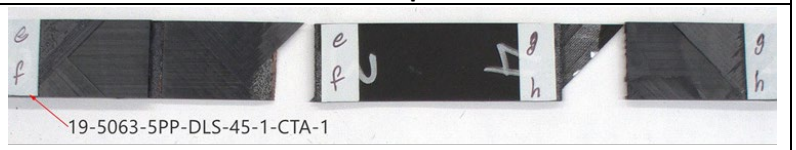
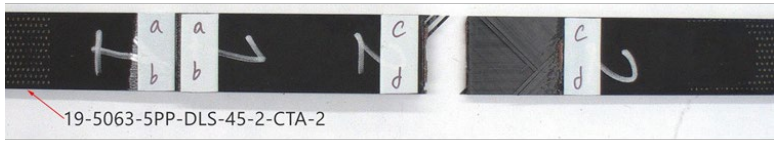
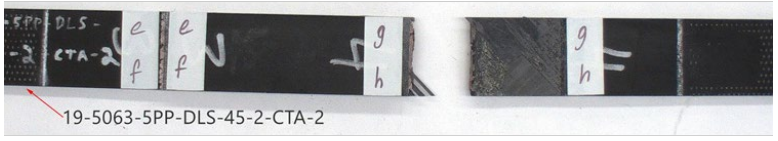
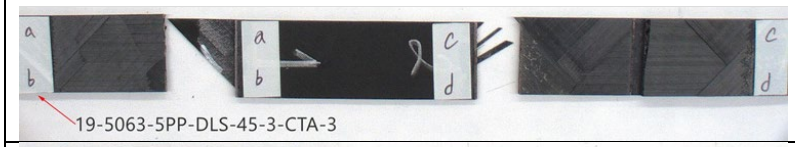
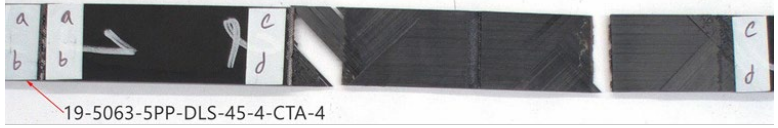
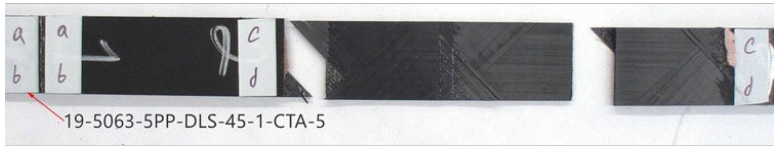
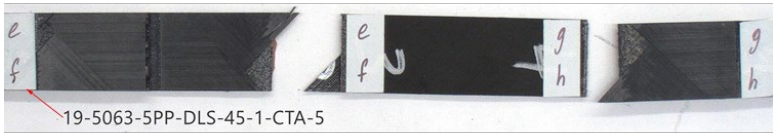
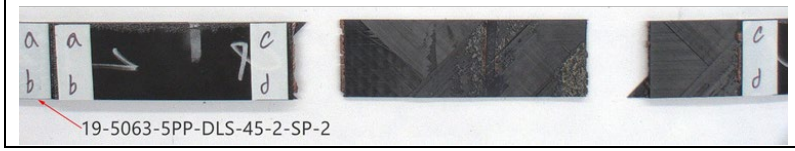
DLS Failures – AS4/3501-6/FM 300, FusePly Surface Preparation, 90° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

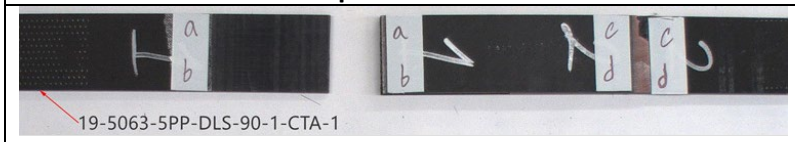
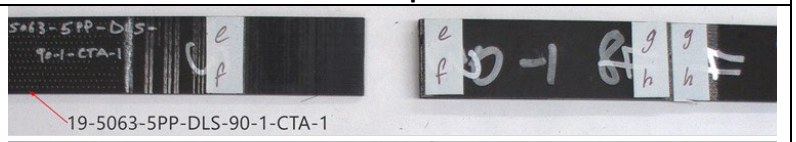
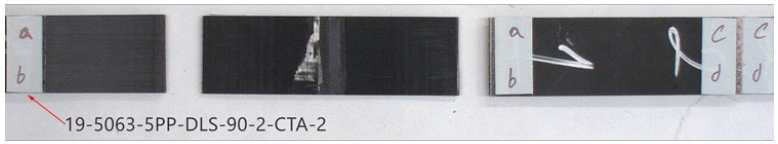
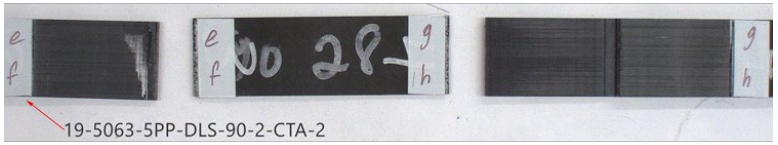
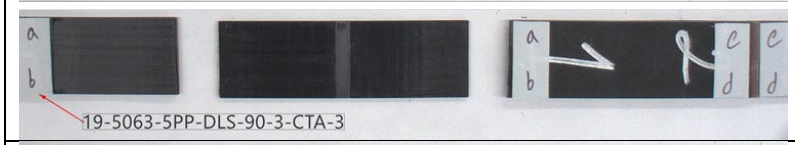
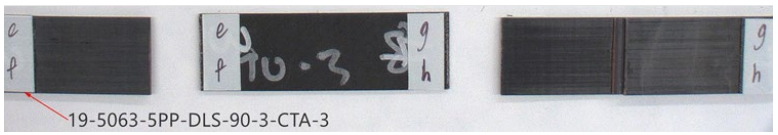
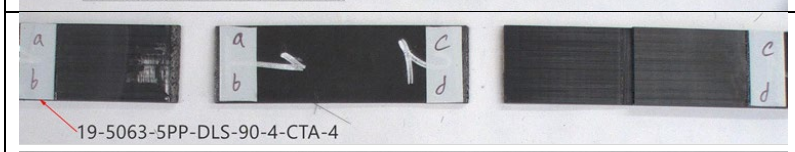
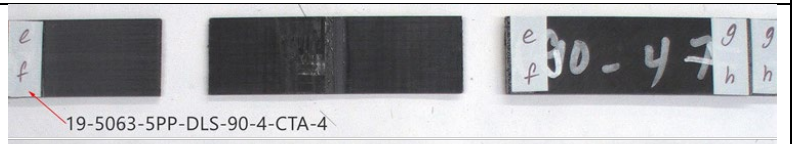
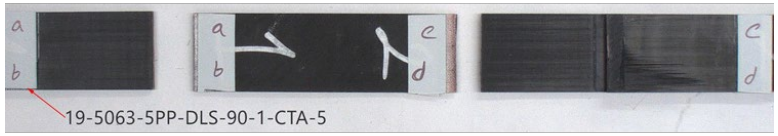
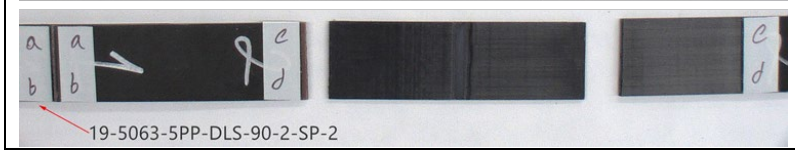
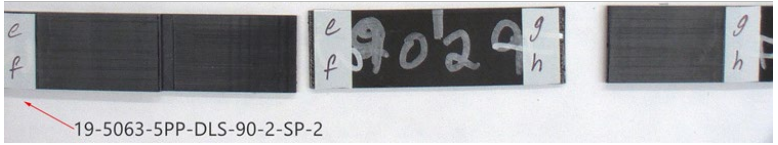
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 0° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

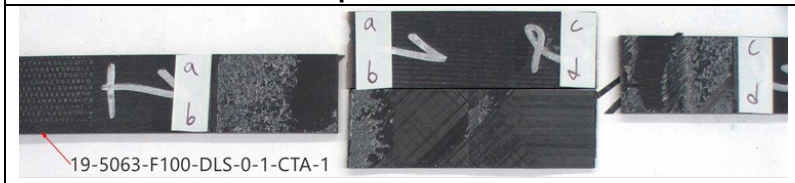
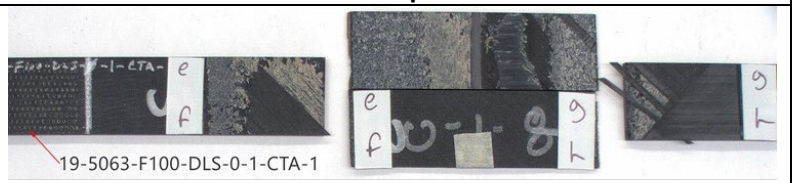
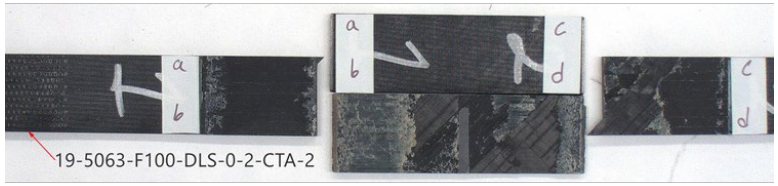
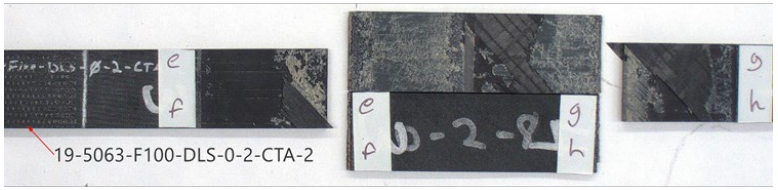
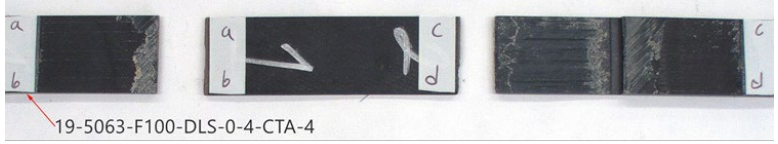
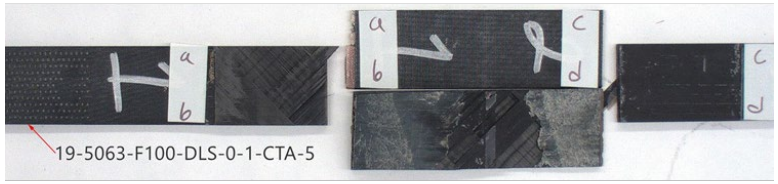
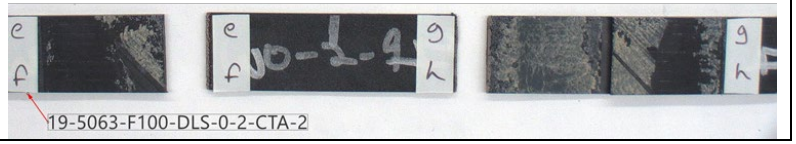
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 45° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

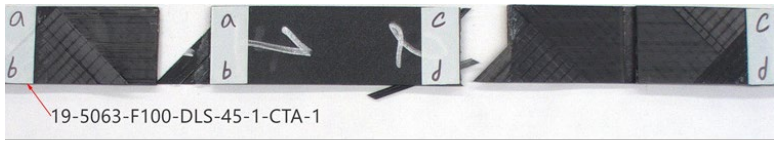
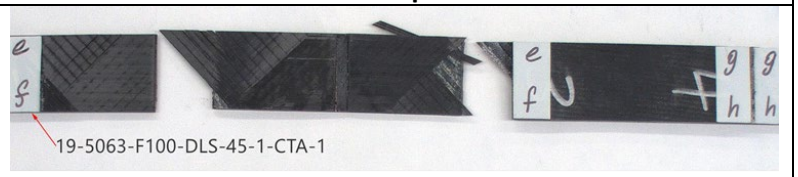
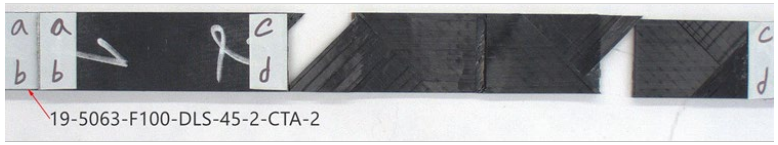
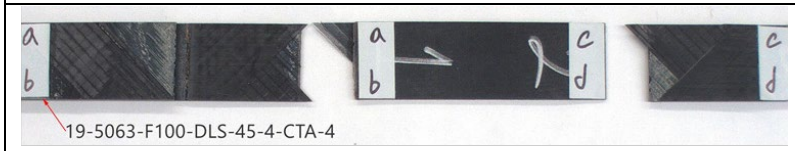
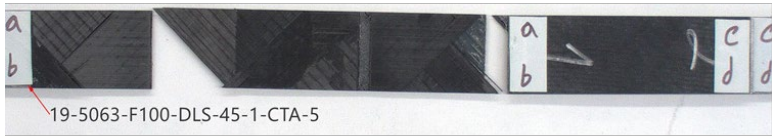
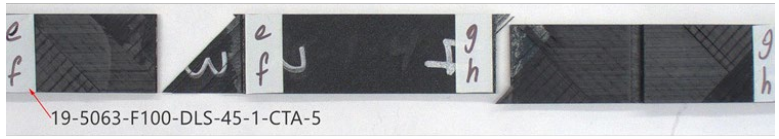
DLS Failures – IM7/5320/FM 309-1, PPS Surface Preparation, 90° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

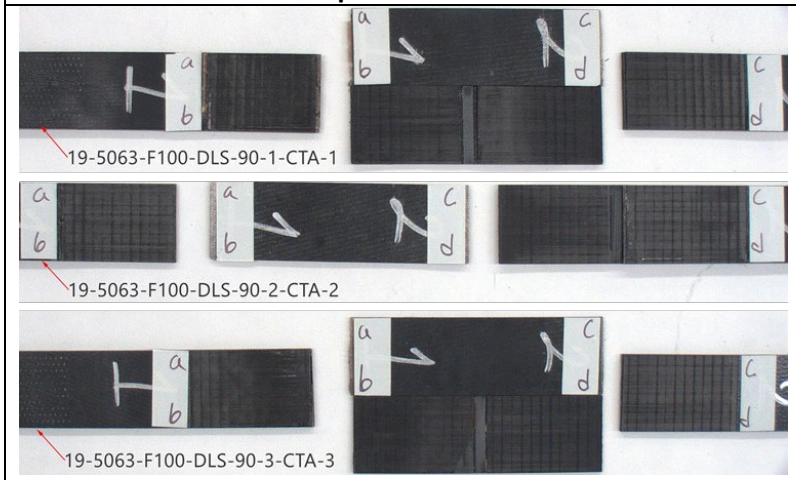
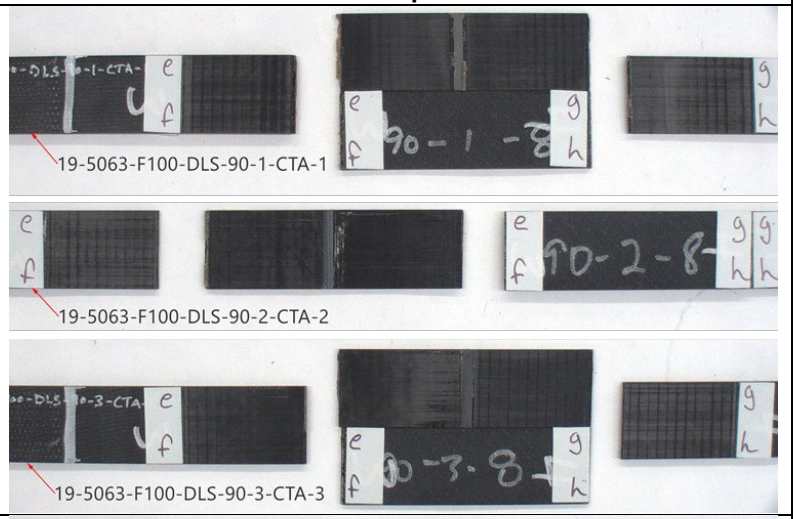
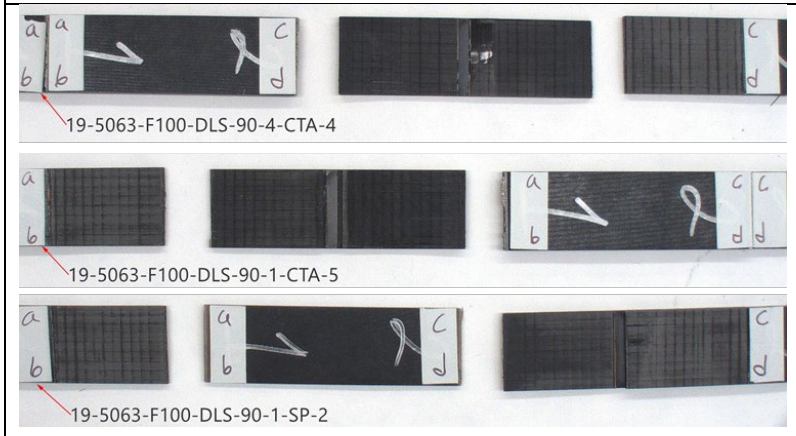
DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 0° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 45° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	
	
	
	
	

DLS Failures – IM7/5320/FM 309-1, FusePly Surface Preparation, 90° Surface Ply Orientation, CTD Tested

Top-down View	Bottom-up View
	
	

APPENDIX C

Double Lap Shear Test Datasheets

Support for Boeing-AFRL FusePly Evaluation, Double Lap Shear, RTD, ASTM D3528

AS4/3501-6

19-549-PPS-DLS-0-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE BOEING/AFRL CRADA - FUSEPLY EVAL. DATE 8-Dec-20

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 76 °F 13.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.] Lap 1	Lap 2	Lap 3	Lap 4	Average Bondline Thickness [in.] Lap 1	Lap 2	Lap 3	Lap 4	Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Failure Site	Shear Strength (F_{s1})	Strength (F_{s2}) [psi]	Failure Mode %Coh	%Lam	% Int.	Type	Failure Mode (2nd Lap) %Coh	%Lam	% Int.
1-RTA-1	1.004	1.51749	1.44135	1.48674	1.51682	0.00686	0.00742	0.00611	0.00664	12/8/2020	1000	76.0	5807.1	4	1955.3	1906.6	3.3	63.3	33.4	1	x	x	x
2-RTA-2	1.002	1.45339	1.52781	1.48844	1.48533	0.00598	0.00608	0.0063	0.00633	12/8/2020	1040	76.0	6919.9	4	2292.0	2324.8	0.0	100.0	0	1	x	x	x
3-RTA-3	1.004	1.48781	1.50978	1.52557	1.48603	0.00627	0.00677	0.00544	0.00559	12/8/2020	1100	75.7	6597.7	1	2181.8	2209.5	0.0	66.4	33.6	1	x	x	x
4-RTA-4	1.002	1.55447	1.47572	1.44438	1.50513	0.00686	0.00773	0.00652	0.00663	12/8/2020	1220	75.7	6465.6	3	2151.7	2233.7	0.0	10.0	90	1	x	x	x
2-RTA-5	1.004	1.44981	1.48635	1.50167	1.49942	0.00575	0.00681	0.00631	0.00637	12/8/2020	1320	75.7	5066.7	4	1691.0	1683.7	0.0	1.4	98.6	1	x	x	x
1-SP-1	1.011	1.5362	1.44568	1.5262	1.4819	0.00684	0.00699	0.00638	0.00608	12/8/2020	1255	75.7	5967.5	3	1927.4	1933.7	0.0	55.3	44.7	1	x	x	x
Avg:	1.004	1.500	1.481	1.4955	1.4958	0.0064	0.00697	0.00618	0.00627				6137.4		2033.2	2048.7							
												Std. Dev.	665.8		217.9	246.2							

Remarks:
Tested By:

19-549-PPS-DLS-45-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *9-Dec-20*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 75.7 °F 18.6 % R/H
Notes:

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
2-RTA-5	1.005	1.59356	1.38252	1.56994	1.46651	0.00601	0.0056	0.00606	0.00598	12/9/2020	0936	75.7	5863.3	2	2048.8	2111.0	0.0	100.0	0.0	1	x	x	x
2-RTA-2	1.005	1.32992	1.68755	1.39166	1.56856	0.0062	0.00635	0.00605	0.00625	12/9/2020	0900	75.7	5800.5	2	1773.4	1710.9	0.0	100.0	0.0	1	x	x	x
3-RTA-3	1.005	1.58742	1.38677	1.5488	1.46922	0.00564	0.00516	0.00646	0.00573	12/9/2020	0924	75.7	6862.1	1	2178.2	2151.7	0.0	100.0	0.0	1	x	x	x
Avg:	1.005	1.504	1.486	1.5035	1.5014	0.0060	0.0057	0.00619	0.00599				6175.3		2000.1	1991.2							
												Std. Dev.	595.6		206.7	243.6							

Remarks:
Tested By:

19-549-PPS-DLS-90-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *9-Dec-20*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s,
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 76.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-RTA-1	1.001	1.47528	1.55037	1.49907	1.55773	0.00606	0.00672	0.00568	0.00595	12/9/2020	1155	76.1	3499.2	3	1175.9	1166.5	0.0	100.0	0.0	1	x	x	x
2-RTA-2	1.005	1.42075	1.60679	1.5032	1.49808	0.00699	0.00639	0.00718	0.00677	12/9/2020	1210	76.1	3474.2	1 & 4	1184.9	*	0.0	100.0	0.0	4	0.0	100.0	0
3-RTA-3	1.005	1.39055	1.60904	1.41382	1.66806	0.00697	0.0068	0.00671	0.00561	12/9/2020	1214	76.1	4322	3	1534.3	1521.6	0.0	100.0	0.0	1	x	x	x
4-RTA-4	1.005	1.40146	1.61947	1.36819	1.64235	0.00848	0.00686	0.00668	0.00706	12/9/2020	1227	76.1	3954.2	2 & 3	1317.6	*	0.0	100.0	0.0	4	0.0	100.0	0
2-RTA-5	1.002	1.41284	1.56624	1.49702	1.46064	0.0067	0.00663	0.00647	0.00618	12/9/2020	1233	76.1	3701.3	1 & 4	1285.5	*	0.0	100.0	0.0	4	0.0	100.0	0
1-SP-1	1.005	1.48808	1.58561	1.46194	1.56667	0.00639	0.00643	0.00668	0.00627	12/9/2020	1240	76.1	3896.2	3	1314.8	1326.6	0.0	100.0	0.0	1	x	x	x
Avg:	1.003	1.431	1.590	1.4572	1.5656	0.0069	0.00664	0.00657	0.00631				3807.9		1302.2	1338.2							
												Std. Dev.	319.8		129.8	177.8							

Remarks: *Both straps stayed attached upon failure (Laminate failure)
Tested By:

19-549-F100-DLS-0-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *8-Dec-20 & 9-Dec-20*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/20
5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 76.7 & 75.7 °F 13.3 & 18.6 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

		Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
Specimen ID	Width [in.]	Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-RTA-1	1.003	1.56892	1.42863	1.53017	1.45355	0.00946	0.00981	0.00974	0.01037	12/8/2020	1340	76.7	9140.8	3	2942.2	2979.4	0.0	100.0	0.0	1	x	x	x
2-RTA-2	1.004	1.38992	1.62053	1.44024	1.55939	0.00887	0.01014	0.0101	0.00997	12/8/2020	1420	76.7	9595.7	*	*	*	0.0	100.0	0.0	2	0.0	100.0	0
3-RTA-3	1.004	1.64077	1.38658	1.57147	1.42107	0.00963	0.00981	0.00964	0.00913	12/8/2020	1447	76.7	7302.8	3	2264.4	2314.3	0.0	100.0	0.0	1	x	x	x
4-RTA-4	1.005	1.61699	1.6949	1.61695	1.38225	0.00927	0.00886	0.0095	0.00927	12/8/2020	1500	76.7	8422	3	2591.3	2591.3	0.0	100.0	0.0	1	x	x	x
2-RTA-5	1.004	1.3902	1.58396	1.46753	1.54872	0.01153	0.00853	0.00988	0.01022	12/9/2020	0800	75.7	9057.9	1	3157.0	3244.8	0.0	100.0	0.0	1	x	x	x
1-SP-1	0.995	1.58014	1.4126	1.56723	1.46698	0.01109	0.00988	0.01064	0.01013	12/9/2020	0830	75.7	7230.3	2	2523.5	2572.1	0.0	100.0	0.0	1	x	x	x
Avg:	1.002	1.531	1.521	1.5323	1.4720	0.0100	0.00951	0.00992	0.00985				8458.3		2695.7	2740.4							
												Std. Dev.	996.3		353.6	368.7							

Remarks: *Straps 1 & 2 broke away at failure. 1-RTA-1: Primary failure in thick adherend.
Tested By:

19-549-F100-DLS-45-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *9-Dec-20*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/20

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 75.7 °F 18.6 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-RTA-1	1.005	1.66286	1.33153	1.63097	1.3613	0.00916	0.00876	0.01057	0.00913	12/9/2020	0943	75.7	5540.8	2	2048.4	2071.3	0.0	100.0	0.0	1	x	x	x
2-RTA-2	1.005	1.40752	1.60321	1.43823	1.55832	0.00786	0.0103	0.00916	0.01029	12/9/2020	0955	75.7	7429.9	1	2599.2	2627.5	0.0	100.0	0.0	1	x	x	x
3-RTA-3	1.004	1.69523	1.38579	1.63672	1.41808	0.00892	0.0105	0.00956	0.00938	12/9/2020	1011	75.7	6660.9	2	2365.4	2393.0	0.0	100.0	0.0	1	x	x	x
4-RTA-4	1.005	1.47781	1.52513	1.53498	1.47804	0.00938	0.00932	0.00885	0.00913	12/9/2020	1022	75.7	5974.4	1	1973.1	2011.3	0.0	100.0	0.0	1	x	x	x
2-RTA-5	1.005	1.39823	1.59852	1.45855	1.56844	0.00888	0.01013	0.00957	0.01095	12/9/2020	1028	75.7	6306.5	2	1981.4	1962.8	0.0	100.0	0.0	1	x	x	x
1-SP-1	1.005	1.60896	1.35941	1.57502	1.37287	0.0088	0.00942	0.00962	0.00887	12/9/2020	1040	75.7	6532.8	2	2380.3	2392.0	0.0	100.0	0.0	1	x	x	x
Avg:	1.005	1.542	1.467	1.5457	1.4595	0.0088	0.00974	0.00956	0.00963				6407.6		2224.6	2243.0							
												Std. Dev.	644.1		259.9	266.2							

Remarks: *Primary failure in thick adherend for all specimens
Tested By:

19-549-F100-DLS-90-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *9-Dec-20*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0013 and 0014, Date Manufactured 6/8/2018

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 76.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Failure Site	Shear Strength (F_{s1})	Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
1-RTA-1	1.004	1.62703	1.38866	1.66794	1.34701	0.01005	0.01054	0.00987	0.0097	12/9/2020	1252	76.1	4475.4	2	1630.2	1605.8	0.0	100.0	0.0	1	x	x	x
2-RTA-2	1.004	1.67755	1.3524	1.71822	1.34878	0.01047	0.01011	0.00998	0.01006	12/9/2020	1311	76.1	6098.1	1	1788.6	1810.3	0.0	100.0	0.0	1	x	x	x
3-RTA-3	1.004	1.52411	1.51096	1.56947	1.45599	0.0103	0.00962	0.01028	0.01017	12/9/2020	1321	76.1	4977.1	3	1603.2	1580.1	0.0	100.0	0.0	1	x	x	x
4-RTA-4	1.004	1.41626	1.63132	1.39823	1.60116	0.00963	0.00975	0.00944	0.00955	12/9/2020	1347	76.1	6807.8	2	2097.7	2078.3	0.0	100.0	0.0	1	x	x	x
2-RTA-5	1.005	1.65892	1.35313	1.69212	1.35559	0.00674	0.00895	0.01016	0.00935	12/9/2020	1356	76.1	5460.8	4	2007.0	2005.2	0.0	100.0	0.0	1	x	x	x
1-SP-1*	1.013	1.66581	1.35437	1.6892	1.30846	0.00976	0.01052	0.00922	0.00982	12/9/2020	1408	76.1	4632.1	2	1717.2	1688.1	0.0	100.0	0.0	1	x	x	x
Avg:	1.005	1.595	1.432	1.6225	1.4028	0.0095	0.00991	0.00983	0.00978				5408.6		1807.3	1794.6							
												Std. Dev.	905.1		202.8	208.8							

Remarks: *1-SP-1: Machine stopped at 754.5lbs with no visible failure. Test was continued from same spot and reached the peak load listed in the table above. *1-RTA-1: Secondary strap did not fully break away.
Tested By:

IM7/5320-1

19-5063-5PP-DLS-0-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *24-Nov-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-RTA-1	1.001	1.48572	1.4847	1.47764	1.49899	0.00509	0.00544	0.00521	0.00506	11/24/2020	0900	75.1	13074	3	4407.5	4419.5	16.7	83.3	0.0	1	x	x	x
-2-RTA-2*	1.000	1.51521	1.4734	1.51052	1.48088	0.00526	0.00455	0.00514	0.00503	11/24/2020	0937	75.1	12632.5	1	4175.0	4168.6	86.0	4.0	10.0	1	x	x	x
-3-RTA-3	1.000	1.50182	1.45131	1.50686	1.43843	0.00522	0.00552	0.0056	0.00482	11/24/2020	1005	75.1	12191.2	2	4218.8	4200.1	99.0	0.0	1.0	1	x	x	x
-4-RTA-4	1.000	1.44154	1.50596	1.50328	1.43339	0.00564	0.0061	0.00552	0.00539	11/24/2020	1020	75.1	8845.5	3	3003.7	2942.1	24.0	0.0	76.0	1	x	x	x
-2-RTA-5	1.002	1.50218	1.47194	1.5069	1.45709	0.00533	0.00489	0.00568	0.00473	11/24/2020	1045	75.1	8932.9	2	3043.7	3028.3	28.0	0.0	72.0	1	x	x	x
-1-SP-1	1.002	1.52076	1.42544	1.49804	1.45737	0.00537	0.00462	0.00455	0.00534	11/24/2020	1100	75.1	12301.8	2	4258.8	4306.5	99.0	0.0	1.0	1	x	x	x
Avg:	1.001	1.495	1.469	1.5005	1.4610	0.0053	0.00519	0.00529	0.00506				11329.7		3851.3	3844.2							
												Std. Dev.	1915.4		645.9	671.7							

Remarks: *2-RTA-2: Failure in thick adherend for laps 1&3. Critical failure determined in lap 1-lap 3 still bonded. (Refer to photo documentation)

Tested By:

19-5063-5PP-DLS-45-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *24-Nov-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Failure Site	Shear Strength (F_{s1})	Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-RTA-1	1.000	1.56206	1.41489	1.38768	1.52179	0.00494	0.00522	0.00438	0.00543	11/24/2020	1517	75.1	9330.9	2	3177.4	3297.4	10.7	89.3	0.0	1	x	x	x
-2-RTA-2	0.999	1.72901	1.16231	1.74346	1.14912	0.00606	0.00522	0.00535	0.00522	11/24/2020	1530	75.1	9669.4	2	4187.5	4163.7	5.8	94.2	0.0	1	x	x	x
-3-RTA-3	0.999	1.42441	1.4621	1.41493	1.45895	0.00454	0.00484	0.00638	0.00593	11/24/2020	1542	75.1	10113.4	1	3565.4	3553.6	0.0	100.0	0.0	1	x	x	x
-4-RTA-4	0.999	1.56136	1.43808	1.60112	1.3841	0.00479	0.0047	0.0055	0.00552	11/24/2020	1552	75.1	7570.3	1	2397.4	2427.9	0.0	100.0	0.0	1	x	x	x
-2-RTA-5	0.998	1.71684	1.17939	1.70645	1.16199	0.00516	0.0064	0.0052	0.00494	11/24/2020	1610	75.1	8941.4	2	3826.5	3798.3	5.0	95.0	0.0	1	x	x	x
-1-SP-1	1.000	1.5651	1.3989	1.41701	1.55124	0.00583	0.00494	0.00445	0.00505	11/24/2020	1620	75.1	9657.6	2	3273.6	3451.9	25.7	74.3	0.0	1	x	x	x
Avg:	0.999	1.593	1.343	1.5451	1.3712	0.0052	0.00522	0.00521	0.00535				9213.8		3404.6	3448.8							
												Std. Dev.	894.7		616.5	584.7							

Remarks: *2-RTA-2, 3-RTA-3, 4-RTA-4, & 2-RTA-5: Primary laminate failure in thick adherend

Tested By:

19-5063-5PP-DLS-0-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *24-Nov-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-RTA-1	1.001	1.48572	1.4847	1.47764	1.49899	0.00509	0.00544	0.00521	0.00506	11/24/2020	0900	75.1	13074	3	4407.5	4419.5	16.7	83.3	0.0	1	x	x	x
-2-RTA-2*	1.000	1.51521	1.4734	1.51052	1.48088	0.00526	0.00455	0.00514	0.00503	11/24/2020	0937	75.1	12632.5	1	4175.0	4168.6	86.0	4.0	10.0	1	x	x	x
-3-RTA-3	1.000	1.50182	1.45131	1.50686	1.43843	0.00522	0.00552	0.0056	0.00482	11/24/2020	1005	75.1	12191.2	2	4218.8	4200.1	99.0	0.0	1.0	1	x	x	x
-4-RTA-4	1.000	1.44154	1.50596	1.50328	1.43339	0.00564	0.0061	0.00552	0.00539	11/24/2020	1020	75.1	8845.5	3	3003.7	2942.1	24.0	0.0	76.0	1	x	x	x
-2-RTA-5	1.002	1.50218	1.47194	1.5069	1.45709	0.00533	0.00489	0.00568	0.00473	11/24/2020	1045	75.1	8932.9	2	3043.7	3028.3	28.0	0.0	72.0	1	x	x	x
-1-SP-1	1.002	1.52076	1.42544	1.49804	1.45737	0.00537	0.00462	0.00455	0.00534	11/24/2020	1100	75.1	12301.8	2	4258.8	4306.5	99.0	0.0	1.0	1	x	x	x
Avg:	1.001	1.495	1.469	1.5005	1.4610	0.0053	0.00519	0.00529	0.00506				11329.7		3851.3	3844.2							
												Std. Dev.	1915.4		645.9	671.7							

Remarks: *2-RTA-2: Failure in thick adherend for laps 1&3. Critical failure determined in lap 1-lap 3 still bonded. (Refer to photo documentation)

Tested By:

19-5063-F100-DLS-0-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *24-Nov-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: , [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/20

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.1 °F 19.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-RTA-1	1.000	1.46977	1.50848	1.43627	1.53683	0.00855	0.00661	0.00798	0.00738	11/24/2020	1327	75.1	11375.8	1	3914.5	3869.9	100.0	0.0	0.0	1	x	x	x
-2-RTA-2	0.999	1.41016	1.59541	1.50785	1.47308	0.00837	0.00979	0.0093	0.00786	11/25/2020	1345	75.1	12123.1	3	3954.8	4024.0	100.0	0.0	0.0	1	x	x	x
-3-RTA-3	1.001	1.468	1.50505	1.44576	1.52852	0.00838	0.00929	0.00815	0.00796	11/26/2020	1359	75.1	11351.4	1	3891.9	3862.4	100.0	0.0	0.0	1	x	x	x
-4-RTA-4*	1.000	1.51316	1.5421	1.45233	1.49316	0.00699	0.00724	0.00715	0.00631	11/27/2020	1411	75.1	10906.9	2	3593.4	3536.4	100.0	0.0	0.0	1	x	x	x
-2-RTA-5	1.000	1.38614	1.5801	1.50986	1.49899	0.00917	0.00873	0.00839	0.00926	11/28/2020	1425	75.1	12270.5	1	4237.1	4426.1	100.0	0.0	0.0	1	x	x	x
-1-SP-1	0.999	1.53509	1.44709	1.54616	1.43893	0.00763	0.00785	0.00786	0.00767	11/29/2020	1438	75.1	10601	2	3678.7	3668.4	93.3	6.7	0.0	1	x	x	x
Avg:	1.000	1.464	1.530	1.4830	1.4949	0.0082	0.00825	0.00814	0.00774				11438.1		3878.4	3897.9							
												Std. Dev.	656.7		226.7	310.0							

Remarks: *4-RTA-4: Primary strap almost broke away

Tested By:

19-5063-F100-DLS-45-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *25-Nov-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/20

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.7 °F 31.7 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-RTA-1	1.002	1.48241	1.46048	1.5445	1.42705	0.00789	0.00892	0.00841	0.00842	11/25/2020	0930	75.7	7941.8	4	2746.3	2778.4	0.0	100.0	0.0	1	x	x	x
-2-RTA-2	0.998	1.5158	1.45048	1.53994	1.47525	0.00921	0.00993	0.00905	0.00756	11/25/2020	0940	75.7	8634.1	3	2957.0	2809.0	0.0	100.0	0.0	1	x	x	x
-3-RTA-3	1.000	1.37866	1.61687	1.34634	1.57037	0.00836	0.0099	0.00895	0.01003	11/25/2020	0950	75.7	7168.5	3	2630.6	2662.2	0.0	100.0	0.0	1	x	x	x
-4-RTA-4	1.001	1.55671	1.41075	1.59742	1.37457	0.00857	0.00843	0.00864	0.00924	11/25/2020	1000	75.7	7330.5	4*	2629.2	2663.8	0.0	100.0	0.0	1	x	x	x
-2-RTA-5	1.000	1.52911	1.43453	1.53683	1.46627	0.00883	0.00878	0.01047	0.00846	11/25/2020	1008	75.7	9161.1	4	3158.1	3123.9	0.0	100.0	0.0	1	x	x	x
-1-SP-1	1.000	1.47532	1.44891	1.53931	1.43686	0.00769	0.00754	0.00883	0.00798	11/25/2020	1012	75.7	9911.9	4	3434.8	3449.2	21.3	78.7	0.0	1	x	x	x
Avg:	1.000	1.490	1.470	1.5174	1.4584	0.0084	0.00892	0.00906	0.00862				8358.0		2926.0	2914.4							
												Std. Dev.	1075.1		322.9	311.7							

Remarks: *Secondary strap did not fully break away

Tested By:

19-5063-F100-DLS-90-RTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *04-Dec-20 & 08-Dec-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/20

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 76.2 & 76.0 18.6 & 13.5 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Failure	Shear	Strength	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	Strength (F_{s1})	(F_{s2}) [psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-RTA-1	1.000	1.39555	1.5484	1.37449	1.55734	0.00846	0.00904	0.00908	0.00938	12/4/2020	1418	76.2	5878.9	*	*	*	0.0	100.0	0.0	2	0.0	100.0	0.0
-2-RTA-2	0.999	1.43375	1.54946	1.40756	1.59415	0.0082	0.00799	0.00863	0.00876	12/4/2020	1443	76.2	4887.6	2	1556.3	1578.8	0.0	100.0	0.0	1	x	x	x
-3-RTA-3	1.000	1.49796	1.47462	1.50958	1.46402	0.0087	0.00841	0.00863	0.00908	12/8/2020	0910	76.0	5348.7	3	1778.4	1771.6	0.0	100.0	0.0	1	x	x	x
-4-RTA-4	1.000	1.52379	1.48808	1.50135	1.53364	0.00875	0.00849	0.01031	0.00838	12/8/2020	0830	76.0	5410.8	2	1790.6	1818.0	0.0	100.0	0.0	1	x	x	x
-2-RTA-5	1.000	1.48981	1.50265	1.42516	1.55821	0.00828	0.0097	0.00868	0.00899	12/8/2020	0920	76.0	6143.5	3	2107.6	2155.4	0.0	100.0	0.0	1	x	x	x
-1-SP-1	1.002	1.34752	1.57155	1.31728	1.58384	0.00937	0.00875	0.01522	0.01284	12/8/2020	0940	76.0	6300.5	2	1993.8	2001.5	0.0	100.0	0.0	1	x	x	x
Avg:	1.000	1.448	1.522	1.4226	1.5485	0.0086	0.00873	0.01009	0.00957				5661.7		1845.3	1865.1							
												Std. Dev.	538.1		213.2	221.3							

Remarks: *Both straps broke away upon failure

Tested By:

Support for Boeing-AFRL FusePly Evaluation, Double Lap Shear, HTW, ASTM D3528

AS4/3501-6

19-549-PPS-DLS-0-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE BOEING/AFRL CRADA - FUSEPLY EVAL. DATE 21-Jan-21

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 74.2 °F 18.3 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/21/2021 @0930

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp [°F]	Peak Load [lbs]	Critical Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-HTW-1	1.005	1.50521	1.50419	1.44056	1.54206	0.00667	0.00654	0.00586	0.00612	1/21/2021	1049	221.0	8917	3	3012.0	3079.6	25.3	0.0	74.7	1	x	x	x
-2-HTW-2	1.005	1.47442	1.47832	1.53789	1.43753	0.00597	0.0064	0.00559	0.00535	1/21/2021	1123	221.0	8830.6	4	3013.4	3056.2	14.3	29.3	56.4	1	x	x	x
-3-HTW-3	1.004	1.47844	1.52403	1.55029	1.49722	0.00632	0.00669	0.00614	0.006	1/21/2021	1151	221.0	9012.1	3	2963.7	2895.0	30.7	0.0	69.3	1	x	x	x
-4-HTW-4	1.002	1.55065	1.47808	1.44969	1.5875	0.00712	0.00782	0.00614	0.00608	1/21/2021	1300	222.1	8720.8	3	2900.8	3001.8	30.7	0.7	68.6	1	x	x	x
-3-HTW-5	1.004	1.47981	1.49009	1.58329	1.4556	0.00617	0.00629	0.00552	0.00611	1/21/2021	1328	222.9	8709.1	4	2944.8	2979.7	22.1	40.0	37.9	1	x	x	x
-3-SP-3	0.957	1.52312	1.5471	1.46745	1.52186	0.00639	0.00666	0.00596	0.00589	1/21/2021	1610	222.0	8064.1	3	2817.7	2871.1	14.2	0.7	85.1	1	x	x	x
Avg:	0.996	1.502	1.504	1.5049	1.5070	0.0064	0.00673	0.00587	0.00592				8709.0		2942.1	2980.6							
												Std. Dev.	336.4		74.3	84.0							

Remarks:

Tested By:

19-549-PPS-DLS-45-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *25-Jan-21*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 75 °F 24.9 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/26/2021 @0855

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp [°F]	Peak Load [lbs]	Critical Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-2-HTW-2	1.005	1.53986	1.43965	1.50151	1.48285	0.0056	0.00555	0.00593	0.00571	1/26/2021	0954	221.3	8651.5	2	2945.6	2989.8	7.9	30.7	61.4	1	x	x	x
-3-HTW-3	1.005	1.35535	1.66857	1.39469	1.56994	0.00569	0.00673	0.00579	0.00627	1/26/2021	1021	221.1	8828.5	1	3195.9	3242.3	10.0	28.5	61.5	1	x	x	x
-3-HTW-5	1.005	1.3552	1.67948	1.36878	1.57573	0.00609	0.00688	0.00562	0.00702	1/26/2021	1055	221.1	8824.9	3	3223.6	3207.6	14.3	26.4	59.3	1	x	x	x
Avg:	1.005	1.417	1.596	1.4217	1.5428	0.0058	0.00638	0.00578	0.00633				8768.3		3121.7	3146.6							
												Std. Dev.	101.2		153.2	136.9							

Remarks: *Large fillets present on all specimens.

Tested By:

19-549-PPS-DLS-90-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *28-Jan-21*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s,
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 73.9 °F 11 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/28/2021 @0845

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.003	1.46206	1.55246	1.51678	1.52958	0.00634	0.00636	0.00632	0.00517	1/28/2021	0942	221.0	9048.8	3	3028.6	2974.0	3.3	90.0	6.7	1	x	x	x
-2-HTW-2	1.005	1.43469	1.53289	1.48509	1.44485	0.00665	0.00698	0.00573	0.00662	1/28/2021	1009	221.1	9306.3	3	3171.5	3117.7	6.0	86.7	7.3	1	x	x	x
-3-HTW-3	1.005	1.43532	1.58214	1.45682	1.64723	0.00765	0.0069	0.00686	0.0066	1/28/2021	1043	221.1	8399.5	3	2889.8	2868.5	2.9	89.3	7.8	1	x	x	x
-4-HTW-4	1.005	1.38776	1.56955	1.35315	1.6066	0.00599	0.00698	0.00642	0.00657	1/28/2021	1113	221.1	8423.6	3	3059.5	3098.6	3.8	90.0	6.2	1	x	x	x
-3-HTW-5	1.005	1.48233	1.54068	1.49324	1.64947	0.0066	0.00638	0.0067	0.00611	1/28/2021	1259	221.2	8370.5	3	2800.5	2790.2	2.7	86.7	10.6	1	x	x	x
-3-SP-3	0.984	1.37622	1.64786	1.38402	1.6729	0.00606	0.00706	0.00695	0.00623	1/28/2021	1335	221.3	8424.4	3	3102.3	3093.6	2.9	85.7	11.4	1	x	x	x
Avg:	1.001	1.430	1.571	1.4482	1.5918	0.0065	0.00678	0.0065	0.00622				8662.2		3008.7	2990.4							
												Std. Dev.	407.9		138.4	136.9							

Remarks:

Tested By:

19-549-F100-DLS-0-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *25-Jan-21*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018
5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 74.6 °F 17.7 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/25/2021 @0850

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.005	1.52186	1.44166	1.51801	1.43512	0.00917	0.00955	0.00934	0.00919	1/25/2021	0959	221.1	7050.4	2	2438.6	2433.1	75.7	0.0	24.3	1	x	x	x
-2-HTW-2	1.005	1.41107	1.55899	1.50241	1.53431	0.00866	0.00816	0.0092	0.00905	1/25/2021	1027	221.2	7107.6	1	2427.4	2506.0	77.1	0.0	22.9	1	x	x	x
-3-HTW-3	1.005	1.66136	1.41304	1.58982	1.40311	0.00888	0.00975	0.00868	0.00869	1/25/2021	1105	221.2	6995.5	2	2471.7	2463.0	95.0	0.0	5.0	1	x	x	x
-4-HTW-4	1.005	1.61447	1.37142	1.63416	1.38154	0.01023	0.00916	0.01015	0.00834	1/25/2021	1133	221.1	6389.2	2	2309.3	2317.8	78.5	0.0	21.5	1	x	x	x
-3-HTW-5	1.005	1.60971	1.41839	1.60723	1.40504	0.01014	0.0091	0.00967	0.00921	1/25/2021	1314	220.5	7643.7	2	2693.8	2681.1	95.3	0.0	4.7	1	x	x	x
-3-SP-3	1.011	1.67168	1.35902	1.61605	1.40784	0.00874	0.00914	0.0086	0.00802	1/25/2021	1404	221.7	6966.5	2 & 3	2316.1	*	76.0	0.0	23.1	4	5.3	94.7	0
Avg:	1.006	1.582	1.427	1.5779	1.4278	0.0093	0.00914	0.00927	0.00875				7025.5		2442.8	2480.2							
												Std. Dev.	399.7		140.0	132.2							

Remarks: *1-HTW-1, 3-HTW-3, 3-HTW-5: Secondary strap did not fully break away. 4-HTW-4: Secndary strap fractured in laminate; critical site of lap 2 determined. *3-SP-3: Failed in 2 sites.

Tested By:

19-549-F100-DLS-45-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *27-Jan-21*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 74.6 °F 16.2 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/27/2021 @0845

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.004	1.25916	1.70342	1.33275	1.70227	0.00851	0.00862	0.00872	0.00946	1/27/2021	0940	221.4	7445.6	2	2177.5	2176.8	95.0	0.0	5.0	1	x	x	x
-2-HTW-2	1.005	1.58937	1.40989	1.55695	1.43879	0.00859	0.00819	0.01059	0.00981	1/27/2021	1010	221.2	7313.1	1	2312.8	2289.2	97.1	0.0	2.9	1	x	x	x
-3-HTW-3	1.005	1.65286	1.39181	1.57447	1.40351	0.00816	0.00778	0.00833	0.01006	1/27/2021	1043	221.1	6870.8	2	2445.7	2456.0	77.7	0.0	22.3	1	x	x	x
-4-HTW-4	1.005	1.4445	1.51041	1.5284	1.491	0.00865	0.00812	0.0082	0.00879	1/27/2021	1116	221.2	7324.5	2	2428.2	2412.6	92.7	0.0	7.3	1	x	x	x
-3-HTW-5	1.005	1.67408	1.3715	1.58946	1.395	0.00819	0.00894	0.00859	0.00971	1/27/2021	1315	221.2	6744.2	2	2426.9	2447.7	85.7	0.0	14.3	1	x	x	x
-3-SP-3	1.000	1.66325	1.32334	1.62825	1.3259	0.00811	0.00761	0.00905	0.00852	1/27/2021	1410	221.3	6453.6	2	2437.2	2439.6	95.8	0.0	4.2	1	x	x	x
Avg:	1.004	1.547	1.452	1.5350	1.4594	0.0084	0.00821	0.00891	0.00939				7025.3		2371.4	2370.3							
												Std. Dev.	394.6		107.0	113.1							

Remarks: *4-HTW-4 reached 226°F for ~2min before being brought back within soak tolerance. *Large Fillets present in all specimens.

Tested By:

19-549-F100-DLS-90-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *29-Jan-21*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0013 and 0014, Date Manufactured 6/8/2018

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 160 ± 5°F / 95 ± 5 %RH
160 ± 5°F / 82 ± 5 %RH

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 75 °F 10.7 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 12/18/2020
Pulled from freezer and thawed on 01/29/2021 @0845

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.004	1.59498	1.35339	1.65467	1.3813	0.00907	0.00869	0.00888	0.0087	1/29/2021	0929	220.5	7064.4	2	2573.0	2599.5	84.6	15.4	0.0	1	x	x	x
-2-HTW-2	1.005	1.69078	1.30125	1.72003	1.34205	0.00929	0.00983	0.00842	0.00911	1/29/2021	0956	220.5	6693.3	2	2519.6	2559.1	81.5	11.4	7.1	1	x	x	x
-3-HTW-3	1.004	1.51033	1.49367	1.52289	1.43571	0.00972	0.00838	0.00909	0.00907	1/29/2021	1022	220.5	7745.3	2	2633.5	2582.4	90.6	6.7	2.7	1	x	x	x
-4-HTW-4	1.004	1.63585	1.38705	1.62262	1.37217	0.00902	0.0097	0.00871	0.00904	1/29/2021	1051	220.5	6388.7	1	1953.8	1945.9	79.3	14.3	6.4	1	x	x	x
-3-HTW-5	1.005	1.56742	1.40142	1.56647	1.38575	0.00942	0.00893	0.00894	0.00933	1/29/2021	1220	221.3	7172.7	2	2560.7	2546.4	95.0	3.6	1.4	1	x	x	x
-3-SP-3	0.979	1.52836	1.561	1.58573	1.48174	0.01002	0.00816	0.0091	0.00959	1/29/2021	1255	220.9	8318.6	2	2794.0	2723.1	76.8	21.3	1.9	1	x	x	x
Avg:	1.000	1.588	1.416	1.6121	1.3998	0.0094	0.00895	0.00886	0.00914				7230.5		2505.7	2492.7							
												Std. Dev.	703.9		287.0	275.2							

Remarks: *4-HTW-4: Secondary strap did not fully break away upon failure.

Tested By:

IM7/5320-1

19-5063-5PP-DLS-0-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE BOEING/AFRL CRADA - FUSEPLY EVAL. DATE 1-Feb-21

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 73.9 °F 15.1 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp [°F]	Peak Load [lbs]	Critical Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-HTW-1	1.000	1.44796	1.52769	1.45225	1.5134	0.00543	0.00542	0.00605	0.00568	2/1/2021	1040	221.1	12787.9	4	4235.9	4272.8	100	0	0	1	x	x	x
-2-HTW-2	1.002	1.50107	1.50619	1.51619	1.4804	0.00551	0.00514	0.00493	0.00522	2/1/2021	1111	221.1	12676.3	1	3993.3	3993.5	75.3	24.7	0.0	1	x	x	x
-3-HTW-3	1.001	1.49481	1.46965	1.49501	1.4629	0.00539	0.00455	0.00586	0.00564	2/1/2021	1256	221.3	11945.1	1	4218.0	4298.1	94.0	6.0	0.0	1	x	x	x
-4-HTW-4	1.001	1.4415	1.5271	1.49627	1.45524	0.00521	0.00589	0.00492	0.00545	2/1/2021	1328	221.4	12403.8	1	4007.4	4027.7	94.3	5.7	0.0	1	x	x	x
-3-HTW-5	1.001	1.47529	1.46993	1.49025	1.48355	0.00447	0.00491	0.00619	0.00496	2/1/2020	1420	221.2	11895.9	4	4197.3	4235.7	94.7	5.3	0.0	1	x	x	x
-3-SP-3	1.002	1.49005	1.43922	1.49509	1.41339	0.00558	0.00599	0.00538	0.00589	2/1/2021	1450	221.0	11997.3		4130.4	4165.6	99.0	1.0	0.0	1	x	x	x
Avg:	1.001	1.47511	1.48996	1.49084	1.46815	0.00527	0.00532	0.00556	0.00547				12284.38333										
												Std. Dev.	392.4		119.6	143.7							

Remarks: *Primary lamiante failure in thick adherend for all specimens

Tested By:

19-5063-5PP-DLS-45-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *3-Feb-21*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 74.8 °F 12.2 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020
Pulled from freezer and thawed on 02/03/2021 @0900

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.001	1.5160	1.4320	1.4167	1.5145	0.0057	0.0050	0.0053	0.0055	2/3/2021	0953	221.0	9932.6	2	3367.6	3464.7	100.0	0.0	0.0	1	x	x	x
-2-HTW-2*	1.001	1.7024	1.2129	1.6841	1.1926	0.0055	0.0062	0.0040	0.0059	2/3/2021	1027	221.2	8797.9	4	3653.8	3684.9	100.0	0.0	0.0	1	x	x	x
-3-HTW-3	1.000	1.4154	1.4861	1.4175	1.4594	0.0059	0.0056	0.0059	0.0060	2/3/2021	1101	221.1	12449.0	3	4394.6	4391.3	0.0	100.0	0.0	1	x	x	x
-4-HTW-4	1.001	1.6618	1.3265	1.5788	1.4252	0.0058	0.0051	0.0046	0.0041	2/3/2021	1136	221.1	10370.2	2	3764.8	3905.0	100.0	0.0	0.0	1	x	x	x
-3-HTW-5	1.001	1.4073	1.5206	1.4223	1.4806	0.0062	0.0054	0.0057	0.0057	2/3/2021	1310	221.2	11801.1	1	4166.6	4188.8	46.4	53.6	0.0	1	x	x	x
-3-SP-3	1.000	1.4504	1.3319	1.4209	1.4233	0.0053	0.0049	0.0057	0.0057	2/3/2021	1340	221.6	10851.6	2	3938.6	4073.8	100.0	0.0	0.0	1	x	x	x
Avg:	1.001	1.5255	1.3850	1.4900	1.4159	0.0057	0.0054	0.0052	0.0055				10700.4		3881.0	3951.4							
												Std. Dev.	1312.3		368.1	339.1							

Remarks: *2-HTW-2: secondary strap hardly broke.

Tested By:

19-5063-5PP-DLS-90-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *8-Feb-21*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [90,0,90,0,45,-45]2s,
Strap

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

BONDING CYCLE: 1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

Lab Conditions: 74.3 °F 7.4 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020
Pulled from freezer and thawed on 02/08/2021 @0900

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	1.002	1.4421	1.5627	1.4069	1.6005	0.0053	0.0054	0.0066	0.0058	2/8/2021	1001	221.1	10222.7	3	3581.1	3625.9	0.0	100.0	0	1	x	x	x
-2-HTW-2	1.000	1.4871	1.5490	1.4757	1.4425	0.0065	0.0057	0.0052	0.0051	2/8/2021	1028	221.2	10415.3	3	3515.4	3529.0	0.0	100.0	0	1	x	x	x
-3-HTW-3	1.001	1.4992	1.5124	1.4893	1.4773	0.0061	0.0057	0.0059	0.0064	2/8/2021	1104	221.2	10515.9	2	3513.9	3473.1	10.7	89.3	0	1	x	x	x
-4-HTW-4	1.003	1.5900	1.4401	1.5891	1.4808	0.0073	0.0072	0.0066	0.0063	2/8/2021	1132	221.2	10881.2	3	3412.5	3413.4	10.0	90.0	0	1	x	x	x
-3-HTW-5	1.002	1.5453	1.4835	1.5170	1.4972	0.0067	0.0057	0.0056	0.0062	2/8/2021	1308	221.4	10621.4	3	3461.5	3493.8	0.0	100.0	0	1	x	x	x
-3-SP-3	1.003	1.4271	1.6049	1.4852	1.4753	0.0054	0.0054	0.0058	0.0059	2/8/2021	1340	221.5	10581.2	3	3622.4	3551.6	0.0	100.0	0	1	x	x	x
Avg:	1.002	1.4985	1.5254	1.4938	1.4956	0.0062	0.0058	0.0059	0.0060				10539.6		3517.8	3514.5							
												Std. Dev.	219.8		76.5	72.6							

Remarks:

Tested By:

19-5063-F100-DLS-0-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT **3-036** TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE ***2-Feb-21***

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: , [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M; Source; Weight 0.080 psf; Carrier; Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 74.4 °F 10.8 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020
Pulled from freezer and thawed on 02/02/2021 @0845

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-HTW-1	0.999	1.35646	1.64392	1.30031	1.71377	0.00763	0.007	0.00908	0.00966	2/2/2021	0944	221.1	10418.7	1 & 3	3925.5	*	92.3	0.0	7.7	3	90.7	0.0	9.3
-2-HTW-2	1.000	1.39839	1.59144	1.52564	1.59132	0.00904	0.00803	0.00735	0.00764	2/2/2021	1036	221.2	12378.5	1	4233.4	4426.0	74.3	0.0	25.7	1	x	x	x
-3-HTW-3	1.002	1.46178	1.5093	1.44729	1.51115	0.00862	0.00832	0.00748	0.00737	2/2/2021	1109	221.1	11445.1	2	3783.5	3785.8	75.3	0.0	24.7	1	x	x	x
-4-HTW-4	1.000	1.56458	1.4621	1.47666	1.44615	0.00825	0.00842	0.00822	0.0066	2/2/2021	1137	221.1	11018.7	2	3790.7	3770.0	86.7	0.0	13.3	1	x	x	x
-3-HTW-5	1.002	1.49836	1.51556	1.48588	1.51371	0.00893	0.00842	0.00895	0.00868	2/2/2021	1310	221.2	11267.8	1 & 3	3770.1	*	98.0	2.0	0.0	3.0	0.0	36.0	64.0
-3-SP-3	1.001	1.4632	1.49541	1.4205	1.52596	0.00878	0.00813	0.00739	0.01026	2/2/2021	1345	221.3	11379	1 & 3	3942.0	*	96.0	3.3	0.0	3.0	89.0	10.7	0.0
Avg:	1.000	1.457	1.536	1.4427	1.5503	0.0085	0.00806	0.00808	0.00837				11318.0		3907.5	3993.9							
												Std. Dev.	639.6		176.4	374.2							

Remarks: *1-HTW-1, 3-HTW-5, and 3-SP-3 failed at 2 critical sites.

Tested By:

19-5063-F100-DLS-45-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *4-Feb-21*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 73.9 °F 14.3 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020
Pulled from freezer and thawed on 02/04/2021 @0950

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-HTW-1	0.999	1.56175	1.45099	1.56746	1.41776	0.00729	0.00812	0.00851	0.0083	2/4/2021	1044	221.1	11674.7	4	4075.7	4123.5	0.0	100.0	0.0	1	x	x	x
-2-HTW-2	1.002	1.55647	1.47729	1.53765	1.48206	0.00909	0.00854	0.00901	0.0074	2/4/2021	1111	221.1	11542.8	4	3894.6	3888.3	0.0	100.0	0.0	1	x	x	x
-3-HTW-3	1.001	1.37181	1.57222	1.37721	1.60963	0.00874	0.00958	0.00816	0.0081	2/4/2021	1145	221.1	11151.7	3	4052.6	4044.6	3.6	96.4	0.0	1	x	x	x
-4-HTW-4*	1.002	1.60309	1.37173	1.57474	1.41146	0.00876	0.0087	0.00849	0.00811	2/4/2021	1306	221.4	11160.6	2	4002.0	4060.0	0.0	100.0	0.0	1	x	x	x
-3-HTW-5*	1.001	1.39721	1.56309	1.40457	1.6003	0.0082	0.00865	0.00798	0.00845	2/4/2021	1340	221.2	11379.5	3	4057.5	4046.8	74.3	0.0	25.7	1	x	x	x
-3-SP-3*	1.002	1.34134	1.56179	1.37343	1.62994	0.0084	0.00933	0.00838	0.0085	2/4/2021	1405	221.5	11198.3	1	4118.8	4168.0	91.5	0.0	8.5	1	x	x	x
Avg:	1.001	1.472	1.500	1.4725	1.5252	0.0084	0.00882	0.00842	0.00814				11351.3		4033.5	4055.2							
												Std. Dev.	219.9		77.8	95.3							

Remarks: *Instron fixture grips recently greased before testing. *4-HTW-4, 3-HTW-5, 3-SP-3: Secondary strap fractured and still attached.

Tested By:

19-5063-F100-DLS-90-HTW
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *10-Feb-21*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE: 220 ± 5°F; 3 days (+4 hrs, -0)
MOISTURE COND: 220 ± 5°F; 3 days (+4 hrs, -0)

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 74.4 °F 9.6 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Packaged for freezer on 10/09/2020
Pulled from freezer and thawed on 02/10/2021 @0850

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp [°F]	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-HTW-1	1.001	1.48084	1.52714	1.45461	1.53624	0.0087	0.00916	0.01032	0.01084	2/10/2021	0947	221.0	11078	1	3772.0	3738.6	6.4	93.6	0.0	1	x	x	x
-2-HTW-2	1.000	1.50974	1.46347	1.42949	1.57384	0.00858	0.00885	0.00907	0.00894	2/10/2021	1019	221.2	10462.9	3	3559.7	3659.7	4.3	95.7	0.0	1	x	x	x
-3-HTW-3	1.002	1.5082	1.45434	1.53509	1.44079	0.00845	0.00792	0.00869	0.00887	2/10/2021	1049	221.1	10852.5	4	3741.1	3758.6	0.0	100.0	0.0	1	x	x	x
-4-HTW-4	1.001	1.53761	1.45737	1.52072	1.51525	0.00786	0.00771	0.00875	0.00908	2/10/2021	1120	221.2	10637.2	3	3474.6	3493.9	0.0	100.0	0.0	1	x	x	x
-3-HTW-5	1.001	1.48718	1.52088	1.55261	1.41776	0.00794	0.00795	0.00828	0.00791	2/10/2021	1258	221.2	10882.3	4	3701.3	3835.9	17.7	82.3	0.0	1	x	x	x
-3-SP-3	1.002	1.50667	1.49737	1.4971	1.48635	0.00836	0.00834	0.00749	0.009	2/10/2021	1325	221.4	11221.4	4	3753.4	3767.3	6.7	93.3	0.0	1	x	x	x
Avg:	1.001	1.505	1.487	1.4983	1.4950	0.0083	0.00832	0.00877	0.00911				10855.7		3667.0	3709.0							
												Std. Dev.	277.8		121.4	119.6							

Remarks: *3-HTW-5: Small crack in lap 1; secondary failure assumed.

Tested By: _____

Support for Boeing-AFRL FusePly Evaluation, Double Lap Shear, CTD, ASTM D3528

AS4/3501-6

19-549-PPS-DLS-0-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT **3-036** TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE ***01/05/2021 & 01/06/2021***

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

DRY CYCLE:
MOISTURE COND:

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

Lab Conditions: 72.8 °F 23.1 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-CTA-1	1.001	1.51927	1.43465	1.49178	1.4882	0.00743	0.00671	0.00613	0.00643	1/5/2021	1500	-65.0	4350.5	3	1444.1	1457.4	0.0	58.0	42.0	1	x	x	x
-2-CTA-2*	1.024	1.4906	1.48473	1.48477	1.44477	0.00584	0.00633	0.00606	0.0063	1/6/2021	0952	-65.0	4980.8	2 & 4	1661.2	*	0.0	100.0	0.0	3	14.0	46.7	39.3
-3-CTA-3	1.005	1.47655	1.54167	1.48233	1.51194	0.0065	0.00668	0.00587	0.00623	1/6/2021	1054	-65.0	4102.5	3	1380.3	1377.6	0.0	100.0	0.0	1	x	x	x
-4-CTA-4	1.004	1.55293	1.46792	1.46213	1.51115	0.0071	0.00787	0.00656	0.00617	1/6/2021	1153	-65.0	4111.9	2 & 3	1397.8	*	0.0	72.0	28.0	4	0.0	45.3	54.7
-1-CTA-5	1.005	1.50982	1.48662	1.46489	1.52198	0.00698	0.00699	0.00588	0.00612	1/6/2021	1406	-65.0	5010.4	1	1676.8	1651.8	0.0	88.7	11.3	1	x	x	x
-2-SP-2	0.996	1.51765	1.48977	1.48788	1.44009	0.006	0.00682	0.00613	0.00589	1/6/2021	1516	-65.0	5005	3	1672.8	1689.5	0.0	70.0	30.0	1	x	x	x
Avg:	1.005	1.511	1.484	1.4790	1.4864	0.0066	0.0069	0.0061	0.00619				4593.5		1538.8	1544.1	0.0	79.2	20.8				
												Std. Dev.	452.8		145.6	150.5							

Remarks: 2-CTA-2*: Specimen soaked @ -65°F for ~5min and liquid nitrogen supply was depleted. Speciment heated to ~80°F and removed. *3-CTA-3: Primary strap almost broke away upon failure.

Tested By:

19-549-PPS-DLS-45-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *01/11/2021 & 01/12/2021*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 73.7 °F 14 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Critical Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-2-CTA-2	1.004	1.14888	1.65022	1.45418	1.59644	0.00557	0.00582	0.00565	0.00522	1/11/2021	1039	-65.0	4946.7	2 & 3	1587.9	*	0.0	100.0	0.0	4	0.0	100.0	0
-3-CTA-3	1.001	1.70605	1.70605	1.57612	1.43642	0.00599	0.00592	0.00524	0.0067	1/12/2021	0939	-65.0	4996.8	1 & 4	1588.5	*	0.0	100.0	0.0	4	0.0	94.0	6
-2-SP-2	1.010	1.33705	1.33705	1.57612	1.59242	0.00608	0.00588	0.00584	0.00603	1/12/2021	1038	-65.0	5240.1	2 & 3	1781.8	*	0.0	100.0	0.0	4	0.0	90.7	9.3
Avg:	1.005	1.397	1.564	1.5355	1.5418	0.0059	0.00587	0.00558	0.00599				5061.2		1652.7	#DIV/0!							
												Std. Dev.	156.9		111.8	#DIV/0!							

Remarks: *All specimens failed in 2 critical sites. *3-CTA-3: underwent 8 minutes of soak and nitrogen supply depleted and speciment was heated to ~130°F and pulled from oven.

Tested By:

19-549-PPS-DLS-90-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *01/13/2021 - 01/15/2021*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s,
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: PFG 60001 Polyester PeelPly
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 75.2 °F 20 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-CTA-1	1.004	1.46269	1.56758	1.47048	1.55671	0.00619	0.00601	0.00525	0.00564	1/13/2021	0951	-65.0	3756.1	3	1275.5	1272.1	0.0	100.0	0.0	1	x	x	x
-2-CTA-2	1.003	1.37992	1.63392	1.48974	1.54513	0.00702	0.00664	0.00705	0.00563	1/13/2021	1044	-65.0	3624.8	1 & 4	1236.1	*	0.0	100.0	0.0	4	0.0	100.0	0
-3-CTA-3	1.003	1.35886	1.65514	1.38232	1.69105	0.00693	0.00615	0.00593	0.00639	1/14/2021	0933	-65.0	3639.7	1 & 3	1323.8	*	0.0	100.0	0.0	3	0.0	100.0	0
-4-CTA-4	1.003	1.36213	1.67617	1.33114	1.67991	0.00595	0.00665	0.00619	0.00652	1/14/2021	1030	-65.0	3492	3	1292.7	1307.7	0.0	100.0	0.0	1	x	x	x
-1-CTA-5	1.003	1.47737	1.53789	1.51324	1.55069	0.00644	0.00606	0.00655	0.00569	1/15/2021	0931	-65.0	3643.4	2 & 3	1190.5	*	0.0	100.0	0.0	4	0.0	100.0	0
-2-SP-2	1.003	1.38095	1.62565	1.46143	1.56502	0.00693	0.00632	0.00819	0.00538	1/15/2021	1029	-65.0	3681.7	1 & 4	1246.0	*	0.0	100.0	0.0	4	0.0	100.0	0
Avg:	1.003	1.404	1.616	1.4414	1.5981	0.0066	0.00631	0.00653	0.00588				3639.6		1260.8	1289.9							
												Std. Dev.	86.4		46.8	25.2							

Remarks: *Specimen failed in 2 critical sites.

Tested By:

19-549-F100-DLS-0-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE ***01/07/02021 & 01/08/2021***

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018
5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 72.6 °F 21.8 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-CTA-1	0.993	1.55919	1.42115	1.52706	1.47076	0.00922	0.01005	0.00963	0.00968	1/7/2021	0941	-65.0	6531.8	2	2274.6	2314.3	0.0	100.0	0.0	1	x	x	x
-2-CTA-2	1.001	1.38587	1.6301	1.42229	1.57461	0.00996	0.0085	0.00976	0.01034	1/7/2021	1050	-65.0	6561.1	1	2334.1	2364.8	0.0	100.0	0.0	1	x	x	x
-3-CTA-3	1.002	1.6492	1.36248	1.58927	1.42107	0.00885	0.00884	0.00888	0.00857	1/7/2021	1151	-65.0	5715	2	2050.1	2094.1	0.0	100.0	0.0	1	x	x	x
-4-CTA-4	0.976	1.60691	1.42	1.5788	1.4076	0.0082	0.00845	0.00922	0.00849	1/7/2021	1503	-65.0	5134.4	2	1860.5	1852.3	0.0	100.0	0.0	1	x	x	x
-1-CTA-5	1.004	1.54679	1.42737	1.52253	1.44012	0.00895	0.00938	0.01008	0.01011	1/8/2021	0944	-65.0	6711.8	*	*	*	0.0	100.0	0.0	2	0.0	100.0	0
-2-SP-2	1.005	1.40705	1.61108	1.41607	1.55258	0.00833	0.00783	0.00915	0.00996	1/8/2021	1055	-65.0	6807.7	1	2399.4	2407.1	0.0	100.0	0.0	1	x	x	x
Avg:	0.997	1.526	1.479	1.5093	1.4778	0.0089	0.00884	0.00945	0.00952				6243.6		2183.7	2206.5							
												Std. Dev.	668.0		223.5	231.8							

Remarks: *1-CTA-5: Both straps broke away upon failure. *2-CTA-2: Secondary strap did not fully break away upon failure. Primary failure found in thick adherend.

Tested By:

19-549-F100-DLS-45-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *01/11/2021 - 01/19/2021*

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 73.9 °F 19.9 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
-1-CTA-1	1.004	1.62274	1.35453	1.56899	1.36685	0.0085	0.00836	0.00854	0.00795	1/11/2021	1339	-65.0	5151.7	2	1885.5	1894.1	0.0	100.0	0.0	1	x	x	x
-2-CTA-2	0.992	1.38351	1.60345	1.42249	1.55513	0.00718	0.00743	0.00842	0.00934	1/12/2021	1336	-65.0	5497.9	2	1755.5	1729.1	0.0	100.0	0.0	1	x	x	x
-3-CTA-3	0.996	1.66617	1.36465	1.62542	1.38154	0.00685	0.00652	0.0074	0.0077	1/12/2021	1523	-65.0	5381.4	2	1967.3	1979.4	0.0	100.0	0.0	1	x	x	x
-4-CTA-4	1.003	1.45438	1.52895	1.51564	1.47682	0.00766	0.00612	0.00723	0.00766	1/13/2021	1350	-65.0	5372	2	1781.9	1751.5	0.0	100.0	0.0	1	x	x	x
-1-CTA-5	1.005	1.68026	1.2749	1.6744	1.33984	0.00816	0.00678	0.0069	0.00756	1/19/2021	1327	-65.0	5653.4	1	1677.7	1674.8	0.0	100.0	0.0	1	x	x	x
-2-SP-2	1.018	1.38673	1.62183	1.41937	1.56238	0.00711	0.00743	0.00839	0.00857	1/19/2021	1440	-65.0	5765.4	1	2018.3	2042.0	0.0	100.0	0.0	1	x	x	x
Avg:	1.003	1.532	1.458	1.5377	1.4471	0.0076	0.00711	0.00781	0.00813				5470.3		1847.7	1845.1							
												Std. Dev.	219.3		131.6	148.6							

Remarks: *2-SP-2: Critical failure determined to be lap #1 due to laminate fracture along the strap connecting laps 3 & 4. 1-CTA-5: Secondary strap did not fully break away. Primary laminate failure in thick adherend (all).

Tested By:

19-549-F100-DLS-90-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE ***01/19/2021 - 01/21/2021***

ADHEREND: HYE 3501-6/AS4 12K 145/31
Batch 301914981, Rolls 37 and 38, Date Manufactured 11/13/2019
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s
1. Autoclave cured at 240±10 °F for 65 min. pressure at 85±5 (psig).
2. Pressure to 100±5 (psig) at a max. 2.5 psig/min. ventat 1-5 Inch of Hg/min.
3) temp. to 350±10 °F. Hold at temp. for a 375 ±15 min.

SURFACE PREP: Fuseply®100
Batch 101, Rolls 0013 and 0014, Date Manufactured 6/8/2018

ADHESIVE: Name FM300
Source
Weight 0.100+\-0.010 psf
Carrier polyester tricot knit carrier
Batch # Batch 1368, Roll 1, Date Manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE: 1) Maintain 9±3 (In. of Hg) vacuum until venting.
2) Autoclave pressure was set to 50±5 (psig) and venting vacuum at 10
3) Autoclave was set to 350±10 °F for 80±20 min.

Lab Conditions: 74.4 °F 13.2 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
-1-CTA-1	0.998	1.64546	1.3778	1.66727	1.31862	0.00914	0.00946	0.00802	0.00773	1/19/2021	0937	-65.0	2816.4	2	1046.6	1024.1	0.0	100.0	0.0	1	x	x	x
-2-CTA-2	1.004	1.669	1.37276	1.71058	1.33929	0.01013	0.00897	0.01137	0.00921	1/19/2021	1030	-65.0	3920.2	4	1439.7	1457.7	0.0	100.0	0.0	1	x	x	x
-3-CTA-3	0.994	1.52053	1.53986	1.5897	1.43264	0.01	0.00795	0.00955	0.00977	1/20/2021	0939	-65.0	4525.6	2 & 3	1454.8	*	0.0	100.0	0.0	4	0.0	100.0	0
-4-CTA-4	1.004	1.43257	1.62809	1.4065	1.62349	0.01055	0.00998	0.00973	0.00978	1/20/2021	1035	-65.0	4004.9	3	1405.7	1418.7	0.0	100.0	0.0	1	x	x	x
-1-CTA-5	1.005	1.6177	1.36579	1.66239	1.33937	0.00882	0.00959	0.00959	0.00934	1/21/2021	1319	-65.0	3856.7	2	1419.3	1405.6	0.0	100.0	0.0	1	x	x	x
-2-SP-2	1.020	1.68314	1.37949	1.73161	1.37784	0.01043	0.01152	0.0103	0.00888	1/21/2021	1449	-65.0	4214.4	4	1498.5	1470.2	0.0	100.0	0.0	1	x	x	x
Avg:	1.004	1.595	1.444	1.6280	1.4052	0.0098	0.00958	0.00976	0.00912				3889.7		1377.4	1355.3							
												Std. Dev.	579.1		165.2	187.0							

Remarks: *1-CTA-1: secondary strap did not fully breakaway. *3-CTA-3: Failed in 2 critcal sites. Slight fracture along strap between lap 1 and lap 2. *4-CTA-4: Secondary strap almost broke fully away.

Tested By:

IM7/5320-1

19-5063-5PP-DLS-0-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *15-Dec-20 & 16-Dec-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 76.2 & 76.0 °F 12.3 & 15.2 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date Tested	Time Tested	Test Temp	Peak Load [lbs]	Critical Failure Site	Shear Strength (F_{s1}) [psi]	Shear Strength (F_{s2}) [psi]	Failure Mode			Type	Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4								%Coh	%Lam	% Int.		%Coh	%Lam	% Int.
1-CTA-1	1.002	1.5145	1.4556	1.4908	1.4806	0.0049	0.0050	0.0052	0.0051	12/15/2020	1015	-65.0	6603.4	2	2244.4	2263.7	12.0	0.0	88	1	x	x	x
2-CTA-2	1.002	1.5187	1.4680	1.5004	1.4854	0.0057	0.0049	0.0059	0.0056	12/15/2020	1150	-65.0	4915.0	2	1660.9	1670.8	1.4	0.0	98.6	1	x	x	x
3-CTA-3	1.002	1.4978	1.4427	1.5015	1.4214	0.0050	0.0047	0.0053	0.0050	12/15/2020	1426	-65.4	5023.4	1	1671.5	1673.6	0.0	0.0	100	1	x	x	x
4-CTA-4	1.002	1.4779	1.4895	1.5625	1.4409	0.0049	0.0060	0.0054	0.0049	12/16/2020	0937	-65.2	6505.4	1	2135.4	2196.5	7.3	0.0	92.7	1	x	x	x
1-CTA-5	1.001	1.4620	1.5109	1.4598	1.5030	0.0054	0.0050	0.0054	0.0052	12/16/2020	1108	-65.3	6697.1	2	2219.8	2214.0	3.3	0.0	96.7	1	x	x	x
2-SP-2	1.003	1.5138	1.4632	1.4914	1.4824	0.0049	0.0055	0.0050	0.0046	12/16/2020	1407	-65.3	5116.7	2	1731.8	1743.2	6.7	0.0	93.3	1	x	x	x
Avg:	1.002	1.4975	1.4717	1.5011	1.4690	0.0051	0.0052	0.0054	0.0051				5810.2		1944.0	1960.3							
												Std. Dev.	871.8		283.7	291.7							

Remarks:

Tested By:

19-5063-5PP-DLS-45-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *18-Dec-20 & 21-Dec-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6)
Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm
Batch 301914409, Roll 7B
Hand sand: 120- to 240-grit abrasive paper.
Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.2 & 75.4 °F 18.8 & 22.4 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-CTA-1	0.997	1.55836	1.40311	1.41441	1.40363	0.00521	0.00605	0.00503	0.00571	12/18/2020	1513	-65.0	5573.5	2	1991.7	1992.1	6.4	93.6	0.0	1	x	x	x
2-CTA-2	1.000	1.75196	1.14242	1.76468	1.12923	0.00574	0.00551	0.00512	0.00467	12/18/2020	1612	-65.0	5723.2	2*	2519.4	2504.9	8.2	91.8	0.0	1	x	x	x
3-CTA-3	1.000	1.44264	1.42245	1.41327	1.44245	0.00526	0.00572	0.00642	0.00569	12/21/2020	1000	-65.0	5389.6	3	1887.2	1906.8	0.0	100.0	0.0	1	x	x	x
4-CTA-4	0.999	1.61522	1.39193	1.57132	1.40977	0.0055	0.00551	0.00525	0.0051	12/21/2020	1111	-65.0	5073	2	1812.5	1824.1	2.1	97.9	0.0	1	x	x	x
1-CTA-5	0.997	1.52297	1.4252	1.4039	1.53049	0.0052	0.00505	0.00505	0.00559	12/21/2020	1218	-65.0	6200	2	2105.0	2182.8	5.0	95.0	0.0	1	x	x	x
2-SP-2	0.999	1.7474	1.13317	1.76964	1.12522	0.00594	0.00722	0.00516	0.00551	12/21/2020	1426	-65.0	5899.6	2	2616.2	2607.1	5.5	94.5	0.0	1	x	x	x
Avg:	0.999	1.606	1.320	1.5562	1.3401	0.0055	0.00584	0.00534	0.00538				5643.2		2155.3	2169.6							
												Std. Dev.	394.1		335.8	323.7							

Remarks: *2-CTA-2: Secondary failure strap did not fully break away upon failure.

Tested By:

19-5063-5PP-DLS-90-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *12/23/2020 & 01/04/2021*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018; Parent Panel: [90,0,90,0,45,-45]2s, Strap

SURFACE PREP: 5320-1 impregnated peel ply (Cycom 5320-1/Diatex 1500EV6); Resin content: 46+/-3% by weight, Fabric areal weight: 99+/-3 gsm; Batch 301914409, Roll 7B; Hand sand: 120- to 240-grit abrasive paper.; Wiped with clean wipers (cheesecloth)/ vacuumed

ADHESIVE: Name FM309-1M; Source; Weight 0.080 psf; Carrier; Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE: MOISTURE COND:

BONDING CYCLE: 1) Autoclave cured, full vacuum; 2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min; 3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum; 4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .; 5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 74.8 & 73.0 °F 15.5 & 19.5 % R/H

Notes: ASTM D3528, Type B specimen configuration with modification to overlap length; Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak	Critical Failure	Shear Strength (F_{s1})	Shear Strength (F_{s2}) [psi]	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Site	[psi]		%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-CTA-1*	1.000	1.44201	1.56218	1.453	1.56817	0.00506	0.00517	0.0057	0.00583	12/23/2020	1051	-65.0	3701.2	1 & 3	1278.5	*	0.0	100.0	0.0	3	0.0	100.0	0
2-CTA-2	0.999	1.486	1.50552	1.55832	1.47021	0.00542	0.00472	0.00514	0.00557	12/23/2020	1153	-65.0	3860	1	1269.2	1300.1	0.0	100.0	0.0	1	x	x	x
3-CTA-3	1.000	1.43493	1.58809	1.48336	1.4714	0.00563	0.00508	0.00534	0.00551	12/23/2020	1254	-65.0	3906	1	1338.5	1361.0	0.0	100.0	0.0	1	x	x	x
4-CTA-4	1.000	1.5584	1.47017	1.4945	1.53785	0.0058	0.00603	0.00647	0.00701	1/4/2021	1101	-65.0	3900.4	3	1277.6	1304.9	0.0	100.0	0.0	1	x	x	x
1-CTA-5	1.000	1.44083	1.55832	1.42083	1.58356	0.00484	0.00593	0.00728	0.00472	1/4/2021	1200	-65.0	3771	3	1317.8	1327.0	0.0	100.0	0.0	1	x	x	x
2-SP-2	1.000	1.47068	1.51344	1.55143	1.49615	0.00584	0.00472	0.00575	0.00483	1/4/2021	1401	-65.0	3581.8	2	1190.1	1183.3	0.0	100.0	0.0	1	x	x	x
Avg:	1.000	1.472	1.533	1.4936	1.5212	0.0054	0.00528	0.00595	0.00558				3786.7		1278.6	1295.3							
												Std. Dev.	128.1		51.1	67.0							

Remarks: *1-CTA-1: Laps 1 & 3 complete interfacial failure; laps 2 & 4 did not fail. Primary Laminate failure in thick adherend for all specimens.

Tested By:

19-5063-F100-DLS-0-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *16-Dec-20 to 18-Dec-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: , [0,90,0,90,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.7 °F 17.7 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-CTA-1	1.002	1.52497	1.4604	1.52135	1.4654	0.00838	0.00705	0.00786	0.00701	12/16/2020	1532	-65.0	10451.2	*	*	*	*	*	*	2	*	*	*
2-CTA-2	1.002	1.41902	1.60187	1.52931	1.43953	0.00766	0.00664	0.008	0.00875	12/17/2020	1043	-65.0	9160.2	*	*	*	*	*	*	2	*	*	*
3-CTA-3	1.002	1.46647	1.49647	1.43764	1.51899	0.00867	0.00808	0.00695	0.0075	12/17/2020	1412	-65.0	9599.6	1	3300.6	3268.1	24.0	0.0	76.0	1	x	x	x
4-CTA-4	1.003	1.46674	1.49352	1.45666	1.46202	0.00773	0.00813	0.00765	0.00708	12/17/2020	1509	-65.0	5743.5	3	1959.8	1966.5	6.7	0.0	93.3	1	x	x	x
1-CTA-5	1.001	1.40142	1.5774	1.35201	1.62002	0.00796	0.00736	0.0092	0.0084	12/18/2020	1403	-65.0	6440.6	*	*	*	*	*	*	2	*	*	*
2-SP-2	0.998	1.41934	1.60396	1.53175	1.43154	0.00705	0.00762	0.00829	0.00802	12/17/2020	1600	-65.0	9007.5	1	3058.4	3179.5	15.3	0.0	84.7	1	x	x	x
Avg:	1.001	1.450	1.539	1.4715	1.4896	0.0079	0.00748	0.00799	0.00779				8400.4		2772.9	2804.7							
												Std. Dev.	1870.3		714.5	727.2							

Remarks: *Both straps broke away upon failure.

Tested By:

19-5063-F100-DLS-45-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *21-Dec-20 to 23-Dec-20*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [+45,-45,0,90,0,90]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 75.8 °F 17.7 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-CTA-1	0.998	1.53856	1.43855	1.47336	1.44705	0.00808	0.00754	0.0074	0.00704	12/21/2020	1532	-65.0	6308.7	3	2098.8	2145.2	0.0	100.0	0.0	1	x	x	x
2-CTA-2	0.996	1.54974	1.46765	1.5149	1.4495	0.00891	0.00748	0.0085	0.00891	12/22/2020	1015	-65.0	6308	2	2171.1	2157.6	0.0	100.0	0.0	1	x	x	x
3-CTA-3	0.996	1.37248	1.62935	1.34082	1.56301	0.00812	0.00865	0.008	0.00923	12/22/2020	1116	-65.0	5931.3	3	2194.8	2220.7	0.0	100.0	0.0	1	x	x	x
4-CTA-4	0.999	1.56643	1.41973	1.58526	1.3928	0.00769	0.00737	0.00795	0.00802	12/22/2020	1215	-65.0	6505.4	4	2316.5	2338.9	0.0	100.0	0.0	1	x	x	x
1-CTA-5	1.001	1.54017	1.46446	1.5697	1.43619	0.00843	0.00761	0.00918	0.00783	12/22/2020	1500	-65.0	5985.3	1	1922.7	1941.1	0.0	100.0	0.0	1	x	x	x
2-SP-2	1.001	1.56923	1.45713	1.52765	1.44552	0.00785	0.0068	0.00708	0.00769	12/23/2020	0939	-65.0	6607.7	2	2274.2	2265.1	4.3	95.7	0.0	1	x	x	x
Avg:	0.998	1.523	1.479	1.5019	1.4557	0.0082	0.00758	0.00802	0.00812				6274.4		2163.0	2178.1							
												Std. Dev.	271.3		140.6	136.3							

Remarks:

Tested By:

19-5063-F100-DLS-90-CTA
Panel Designation

Double LAP SHEAR DATA SHEET

PROJECT 3-036 TITLE **BOEING/AFRL CRADA - FUSEPLY EVAL.** DATE *01/04/2021 & 01/05/2021*

ADHEREND: Cycom®5320-1/IM7 12K 145/33, Batch 303732611, Rolls 0001, 0002, and 0003, Date manufactured 11/14/2018
Parent Panel: [90,0,90,0,45,-45]2s
Strap Config:[+45,-45,0,90,0,90]s

SURFACE PREP: Fuseply®100 Batch 101, Rolls 0001, 0012, and 0013, Date manufactured 11/14/2018

ADHESIVE: Name FM309-1M
Source
Weight 0.080 psf
Carrier
Batch # Batch 134 Roll 0001, Date manufactured 5/4/2018

DRY CYCLE:
MOISTURE COND:

BONDING CYCLE:
1) Autoclave cured, full vacuum
2) Temp. to 250 ± 10°F at a max free-air. Ramp Rate of 3° F/min
3) Hold temp. at 250 ± 10°F for 120min ±5 min. full vacuum
4) Temp. up to 350 ± 10°F at 0.5 to 1°F per minute .
5) Hold temp. at 350 ± 10°F for 120 min ± 5 min,

Lab Conditions: 73.7 °F 18.8 % R/H
Notes: ASTM D3528, Type B specimen configuration with modification to overlap length
Soak Specimen for 10 ± 3 minutes @ -65 ± 5°F

Specimen ID	Width [in.]	Overlap Length [in.]				Average Bondline Thickness [in.]				Date	Time	Test	Peak		Shear Strength (F_{s1})	Shear Strength (F_{s2})	Failure Mode				Failure Mode (2nd Lap)		
		Lap 1	Lap 2	Lap 3	Lap 4	Lap 1	Lap 2	Lap 3	Lap 4	Tested	Tested	Temp	Load [lbs]	Failure Site	[psi]	[psi]	%Coh	%Lam	% Int.	Type	%Coh	%Lam	% Int.
1-CTA-1	1.001	1.4156	1.58396	1.37031	1.61628	0.00996	0.00819	0.01109	0.01321	1/4/2021	1505	-65.0	5177.5	*	*	*	0.0	100.0	0.0	2	0.0	100.0	0
2-CTA-2	0.999	1.43068	1.5773	1.40489	1.59663	0.0084	0.00788	0.00846	0.00787	1/4/2021	1607	-65.0	4263.5	3	1505.8	1519.7	0.0	100.0	0.0	1	x	x	x
3-CTA-3	1.000	1.50021	1.48824	1.49576	1.46501	0.00866	0.00798	0.00851	0.00824	1/5/2021	0946	-65.0	4981.1	*	*	*	0.0	100.0	0.0	2	0.0	100.0	0
4-CTA-4	1.001	1.52175	1.5176	1.4767	1.52998	0.00697	0.00775	0.00816	0.00854	1/5/2021	1052	-65.0	4338	2	1422.0	1427.8	0.0	100.0	0.0	1	x	x	x
1-CTA-5	0.999	1.44339	1.53289	1.41477	1.53627	0.0091	0.00846	0.01481	0.01081	1/5/2021	1158	-65.0	4619.3	1	1617.8	1601.8	0.0	100.0	0.0	1	x	x	x
2-SP-2	1.002	1.41477	1.59195	1.40552	1.59998	0.00865	0.00808	0.00947	0.00779	1/5/2021	1401	-65.0	3768.8	3	1334.3	1338.7	0.0	100.0	0.0	1	x	x	x
Avg:	1.000	1.454	1.549	1.4280	1.5574	0.0086	0.00806	0.01008	0.00941				4524.7		1470.0	1472.0							
												Std. Dev.	513.4		120.9	113.8							

Remarks: *Both sraps broke away upon specimen failure.

Tested By:

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- Failure Analysis/Accident Investigation
  - Structural
  - Electronic
  - Chemical

- Consultations on
  - Materials/Process Specifications
  - Physical and Mechanical Metallurgy
  - Materials and Component Failure Analysis
  - Electronics and Packaging
  - Bonded Repair of Metals/Composites
  - Nonmetallic Materials
  - Welding, Joining, and Adhesive Bonding

- Nondestructive Inspection

- Electrostatic Discharge (ESD) Testing, Materials Qualification and Specifications

- Composites Supportability